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Interrelationships of Peak Expiratory Flow Rate With Physical and Cognitive Function in the Elderly: MacArthur Foundation Studies of Aging

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Background. Peak expiratory flow rate (PEFR) is correlated with several measures of health in the elderly, including physical and cognitive function. It is unclear, however, whether these relationships persist among the non-frail.

Methods. The Community-based Studies of the MacArthur Foundation Research Network on Successful Aging included measures of PEFR using a mini-Wright peak flow meter on a sample of 1,354 subjects selected from those aged 70–79 in three population samples. Subjects were chosen on the basis of simple measures of physical and cognitive function (high = 1192; medium = 80; low = 82), and were given a series of more detailed tests.

Results. Residual PEFR, adjusted for age, sex, height, weight, and smoking, was highly correlated ($p < .001$) with several physical performance measures, including number of steps in a tandem walk, number of seconds in a single leg stand, times to turn in a circle, write one's name, and walk 10 feet at a fast pace, foot-tapping (time per tap), and hand grip strength. The strongest association was evident for a combination of six physical function items. Residual PEFR was also correlated with cognitive performance, including tests of similarities, naming, spatial recognition, memory, and figure drawing. The strongest association was present for a combined measure. These associations persisted in analyses restricted to those in the "high" function group as well as with no history of previous myocardial infarction, stroke, or cancer. Residual PEFR also exhibited a strong independent association with urinary norepinephrine, as measured in 12-hour overnight urine specimens. This relation did not appear to be mediated by smoking or medication use.

Conclusions. These results suggest that PEFR is a sensitive measure of physical and cognitive function in both frail and non-frail elderly.

PEAK expiratory flow rate (PEFR) is a strong and independent predictor of total and cardiovascular mortality among the elderly (1), and is correlated with smoking and respiratory symptoms as well as socioeconomic status, self-assessed state of heath, measures of functional ability, and brief tests of cognitive function (2). These relationships have been reported from selected populations as well as in a community-dwelling population of elders in East Boston, Massachusetts. In the latter study (1,2), the instruments used to assess functional ability and cognitive function were brief and designed to detect those at lower levels of function, or the frail elderly. They were not sensitive enough to distinguish between levels of functioning among the unimpaired. It is thus unclear whether the relationships of PEFR with functional ability can be seen among the non-frail elderly, especially those exhibiting higher levels of physical and cognitive function, or whether there is a threshold effect of poor function and PEFR.

These issues were addressed in data from the MacArthur Foundation Research Network on Successful Aging's multisite study of community-dwelling elderly (3). Detailed physical performance and cognitive function tests were conducted on samples selected from the general population with relatively high levels of functioning as well as with medium and low levels of functioning. The instruments used were sensitive to the whole range of performance of physical and cognitive function, and not just to impairment (3). The study was designed to examine the characteristics of the high-functioning group of "successful agers" and to follow them longitudinally to determine predictors of continued future success (4). The present analysis examines the relationship of PEFR with these detailed assessments of physical and cognitive performance among high-, medium-, and low-functioning groups.

METHODS

Subjects. — Subjects were selected from three large community samples of elderly people from the "Established Populations for Epidemiologic Studies of the Elderly" (or EPESE), funded by the National Institute on Aging (5). This large prospective study, initiated in 1982, included a baseline population survey of those aged 65 and over with follow-up conducted by telephone or in-home interviews. A subsample of subjects eligible for the MacArthur Study of Successful Aging was selected at the time of the 1988 interviews in East Boston, Massachusetts; New Haven, Connecticut; and Durham, North Carolina.

The selection criteria have been described in detail previously (3). The sample was restricted to those aged 70–79 at the time of the 1988 interviews. Groups with high, medium, and low functional ability were defined. All subjects in the high status group were eligible, and smaller numbers of subjects were sampled from the medium and low groups. The functional status groups were defined on the basis of performance on simple tests of physical and cognitive performance that had been included in the population survey. The criteria were chosen so as to divide the study population roughly into thirds. In terms of physical performance, the high-performance group included those who had no disability on the 7-item Katz ADL scale (6) and at most one disability on the combined 8 items of the Rosow-Breslau (7) and Nagi (8) scales; they were able to hold a semi-tandem balance for at least 10 seconds (9) and were able to stand up from a seated position five times within 20 seconds (10). In terms of cognitive function the high performance group was defined as those who scored six or more correct on the 9-item Pfeiffer mental status scale (11) and remembered three or more of six elements of a story on a test of delayed recall (12). These criteria defined the upper third of those aged 70–79 in terms of both physical and cognitive function.

The low-performance group was defined as those who had at least one Katz disability, two or more disabilities on the Rosow-Breslau scale, or three or more disabilities on the Nagi scale, or scored less than six correct on the 9-item Pfeiffer scale. The medium performance group was defined as those whose scores fell between those of the high and low groups. A total of 1,192 subjects were selected and enrolled across all three sites in the high status group. Samples of size 82 and 80 were selected from each of the low and medium status groups, respectively, and were age- and sex-matched to the high status group, for a total sample size of 1,354. Of these, 88% were from the "successful aging" group defined by high performance.

Measures. — Subjects were asked to complete the MacArthur battery of measures in addition to the standard EPESE interview. The former was a 90-minute interview which included detailed measures of physical and cognitive function, including several physical performance tests as well as psychosocial and biomedical assessments. All testing was done in the subjects' homes by trained interviewers. The interview included three measurements of PEFR with a mini-Wright peak flow meter (Armstrong Industries, North Brook, IL), a small hand-held device that provides a crude measure of lung function. The subject was asked to blow as hard and fast as possible into the instrument while in a standing position.

The measures of physical and cognitive function were designed to assess and score subjects across a wide range of functional levels, as opposed to determining impairment; they have been described previously (3,13). The physical function measurements included assessments of balance, gait, and upper body strength. Subjects were asked to do a tandem stand, with one foot in front of and touching the other for 10 seconds, with eyes open and, if successful, with eyes closed. They were asked to do a tandem walk with one foot in front of the other and touching for up to 10 steps, and were asked to stand on one leg for up to 10 seconds. Performance times were measured on a variety of tests. These included foot-tapping (switching between 2-inch circles one foot apart) as time per tap over a maximum of 10 taps, time to turn in a circle, to sign their name, to stand up from a chair five times, and to walk 10 feet at a fast pace. Three measurements of handgrip strength (maximum kg pressed) were taken in the dominant arm using a dynamometer. A summary measure of physical performance on six activities was computed. To do this, the performance times for foot-tapping, signature, the chair stands, walking 10 feet, the sum of times for the tandem stand with eyes open and the leg stand, and the maximum handgrip strength were each grouped into quartiles with scores 1–4. The quartile scores for all six measures were then added to get a summary physical score with a range of 4 to 24.

Subjects were also questioned on their level of physical activity, including both light and strenuous work around the house and yard, and in employment and leisure activities. The total number of strenuous activities reported was computed and ranged from 0–15. Subjects were asked to assess their own state of health, both overall and in relation to their peers.

Subjects underwent extensive cognitive function assessment (13) with a neuropsychological battery of tests assessing various cognitive domains, including language, memory, conceptualization, and visuospatial ability. A test of similarities was taken from the revised Wechsler Adult Intelligence Scale (14) and was scored 0–16. Subjects were asked to explain how two different concrete objects were similar to one another, such as an orange and a banana. A test of confrontation naming asked subjects to name objects in 18 drawings, including both common and less common items, such as a broom and accordion (15). Spatial recognition was tested with the Delayed Recognition Span Test (16). Circular disks were added to a board while the board was hidden from view, and the subject was asked to identify each new disk. This was scored 0–17. Delayed memory was tested by incidental delayed recall of the 18 objects from the naming test and was scored 0–18. A total memory score was computed as the sum of scores on the spatial recognition and delayed memory test. Figure copying was used to assess spatial ability. In this test, subjects were asked to copy a series of geometric figures (17). These were scored according to a standardized system, with a total score ranging from 0–20. Finally, a total cognitive score was computed, which was the sum of all individual test scores and which ranged from 0–89.

Several measures of systolic and diastolic blood pressure were taken, both in a seated and a standing position, and pulse over 15 seconds was measured. The waist/hip ratio was assessed, measuring the hips at both the iliac crest and maximal buttocks level. Self-reported medical history was obtained from the most recent EPESE interview.

Subjects also supplied blood (80%) and overnight urine (85%) specimens. Blood samples, collected at a separate visit at least a day later, were tested for total and high-density lipoprotein (HDL) cholesterol, dehydroepiandrosterone sulfate (DHEAS), and serum glutamic oxalacetic transaminase (SGOT). Overnight urine specimens collected over a 12-hour period the evening of the interview were assayed for cortisol, epinephrine, norepinephrine, dopamine, and creatinine. All these measures, except the last, were adjusted for creatinine level.

Completeness of the urine specimen was a criterion for inclusion in the analysis. This was evaluated according to both urine volume and, in most cases, creatinine clearance. Specimens were judged to be complete if the volume was ⩾400 mL and creatinine clearance was 520 mL/min, or if the volume was 300–400 mL and a creatinine clearance ⩾40 mL/min (n = 874). An additional 104 subjects had a urine volume ⩾400 mL, but no blood sample, and thus no information on creatinine clearance. Among subjects with a urine volume ⩾400 mL and a blood specimen, 98% were judged complete according to the creatinine clearance. Thus, specimens for these 104 subjects were highly likely to be complete, and were included in the analyses. Mean levels of urine values were very similar to those judged complete.

Data analysis. — The observed PEFR was the maximum of three measures, and the expected value was obtained by adjustment for age, sex, height, and weight. These expected values were obtained from a linear regression among asymptomatic never-smokers in the baseline East Boston survey conducted in 1982–83 (1). A residual PEFR was defined as the observed minus the expected PEFR. These residuals represent values of PEFR adjusted for age, sex, height, and weight, and are deviations from those expected among asymptomatic never-smokers. Expected peak flow rate was calculated as: 444.42 + 373.41 sex(male) −5.57 age(years) −3.61 (Sex × Age) + 0.30 weight(pounds) + 3.45 height (inches).

Separate linear regression analyses were used to examine the association between residual PEFR and each predictor variable, adjusting for age, sex, race (Black vs other), site, and smoking, including years of smoking. Individual performance tasks were dichotomized (1 = able, 0 = unable to do), and the logarithms of performance times were taken. Logarithms were also used for the urinary excretion variables, which exhibited a skewed distribution. For the dichotomous explanatory variables, the regression coefficient (b) reflects the adjusted mean difference between groups in L/min; for the others, b reflects the L/min per unit difference in the explanatory variable. For the log-transformed variables, which are approximately normally distributed, the coefficients are expressed per standard deviation (*SD*) unit.

The total group of subjects from all three performance levels and those in the high status group with no reported history of myocardial infarction (MI), stroke, or cancer were analyzed separately. In addition, as a further control for smoking, analyses were repeated among never-smokers in the high status group with no prior history of MI, stroke, or cancer. Stepwise regression analyses were run in all three groups separately to determine the strongest independent predictors of residual PEFR.

RESULTS

Measures of PEFR were available for 1,338 subjects including 598 men and 740 women across all three sites, and residual PEFR, a function of age, sex, height, and weight, could be calculated for 1,228 subjects. The mean PEFR in this sample was 375 L/min out of a range of 0–800. In linear regression analyses adjusting for age, sex, and smoking, the mean residual PEFR was lower in Blacks than Whites (b = −16.6 L/min, p = .04). There were also differences across site, with both Durham and New Haven exhibiting lower levels than East Boston (b = −15.4 L/min, p = .04 for Durham; b = −12.1 L/min, p = .10 for New Haven) independent of race. Smoking was a strong predictor of residual PEFR, with mean levels that were 64.8 L/min lower in current smokers ($p < .001$) and 15.0 L/min lower in ex-smokers (p = .02) than in never-smokers.

We examined the relationship of residual PEFR with several physical performance measures after controlling for age, sex, smoking, race, and site. These included the ability to do the tandem stand with eyes opened and eyes closed, the tandem walk, and leg stand. The ability to do each of these, except the tandem stand with eyes closed, was highly associated ($p < .01$) with residual PEFR (Table 1A). For example, those who could do the tandem stand with eyes open had levels of PEFR that were 18.1 L/min higher than those who could not. The analysis was repeated among subjects in the high status group with no reported history of MI, stroke, or cancer. The relationships with the performance variables persisted in this group, but at somewhat diminished levels of significance. When this high status group was restricted to never-smokers (n = 373 with PEFR measures), the size of the effects remained similar, but the significance levels became borderline (p = .03 for tandem stand with eyes open and leg stand; p = .08 for the tandem walk, data not shown).

This positive association was also evident when we examined performance times on a variety of tests. These included foot-tapping as time per tap over a maximum of ten taps, time to turn in a circle, sign one's name, to stand up from a chair five times, and to walk 10 feet at a fast pace. PEFR was very strongly associated with the log of performance time for all tests (data not shown). The effect sizes ranged from a decrease in PEFR of 12 L/min for chair stands to a decrease of 24 L/min for the fast walk and 23 L/min for foot-tapping per *SD* unit increase in log performance time. Among the high status group, all remained significant but with smaller effect sizes, and among never-smokers all except time to turn in a circle remained significant.

Residual PEFR was also associated with several summary measures of health and functional ability (Table 1B). For handgrip strength (the maximum of three measures), PEFR increased by 3.0 L/min per kg pressed (or by 32.1 L/min per *SD* of max grip). Mean PEFR increased by 5.1 L/min for every strenuous activity reported (medium 5, interquartile range = 5), and by 8.8 L/min per unit on the summary physical score on six activities (median = 15, interquartile range = 5). This last measure was approximately normally distributed, and the effect per *SD* unit was an increase in PEFR of 34.4 L/min. The measures remained strongly associated among the high status group only, and except for

Table 1. Regressions of Residual PEFR on Physical and Cognition Function Measures Controlling for Age, Sex, Race, Site, and Smoking

Variable	Total Sample (N = 1161)*			High Status Group With No MI, Stroke or CA (n = 753)*		
	b	SE	p-value	b	SE	p-value
A. Dichotomous performance variables						
Tandem stand ≥ 10 secs (eyes open)	18.1	6.2	.004	14.5	7.6	.056
Tandem stand ≥ 10 secs (eyes closed)	0.3	9.8	.972	−9.8	10.9	.368
Tandem walk ≥ 10 steps	26.8	7.4	<.001	22.8	8.6	.008
Leg stand ≥ 10 secs	23.4	5.9	<.001	21.8	7.1	.002
B. Summary measures of health and physical function						
Hand grip strength (max Kg)						
Max of 3	3.02	0.41	<.001	2.59	0.49	<.001
Mean of 3	3.19	0.42	<.001	2.79	0.51	<.001
Number of strenuous activities (range 0–15)	5.13	1.00	<.001	3.44	1.24	.006
Summary physical score (range 4–24)	8.83	0.82	<.001	7.42	1.01	<.001
Self-rated health (1 = exc, 2 = good, 3 = fair/poor)	−20.58	3.87	<.001	−16.45	4.89	<.001
Self-rated health compared to others of same age (1 = exc, 2 = good, 3 = fair/poor)	−17.19	3.99	<.001	−14.31	5.01	.004
C. Summary cognitive function measures						
Memory (range 0–35)	5.42	0.61	<.001	3.88	0.76	<.001
Total cognitive score (range 0–89)	2.59	0.27	<.001	1.68	0.34	<.001

*Number with PEFR measurements and data on all adjustment variables.

number of strenuous activities, among the never-smokers also. PEFR was related to self-assessed state of health both overall and in relation to others their own age, with a decrease of 20.6 or 17.2 L/min, respectively, per category of declining health. Since few in this sample reported poor health, particularly in the high status group, self-assessed state of health is not a sensitive marker. Among never-smokers, the relation was not significant. Among the total group, PEFR was associated strongly with all of these summary measures ($p < .001$), and the relationships remained significant in men and women separately. The strongest relationship was exhibited with the summary physical score of six activities. Adjustment for socioeconomic status, including education and income, had very little impact on the findings.

The relationships of PEFR with the neuropsychological tests were also examined. These tests were intended to describe cognitive function rather than impairment. Of these tests, only the scores on the confrontation naming and figure copying were skewed to the high end of the distribution. The others, which included tests of similarities, spatial recognition, memory, and the total cognitive score, were centered near the middle of the range. Level of PEFR was associated with all of the cognitive measures ($p < .001$), even among the high status group only (data not shown). The strongest associations were found with the total cognitive score and the memory score (Table 1C), which both had approximately normal distributions with means of 52 and 15, respectively. When expressed per SD unit, the increase in PEFR was 27.7 L/min for the total score and 24.8 L/min for the memory score. Among never-smokers, all except figure drawing remained significant.

Physical and cognitive performance were correlated (r = .30, $p < .001$ between the summary physical score of six activities and the cognitive score). To further explore these interrelationships, we stratified by tertile of total cognitive score and examined the relationship of PEFR with physical function within strata. PEFR was significantly associated with both the summary physical score and handgrip strength ($p < .0001$) in all three tertiles. The regression coefficients exhibited no trend across tertiles and were similar in magnitude to the overall effects (Table 1B). Because poor cognitive function could interfere with ability to follow directions on the test of PEFR, we also considered interviewer opinion of understanding and compliance with the lung test. These were rated excellent, good, fair, or poor, and were strongly associated with total cognitive score, summary physical score, and mean handgrip strength as well as PEFR itself. Among those rated as having an excellent understanding of and compliance with the lung test (n = 812), PEFR remained significantly associated with both summary physical score and handgrip strength as well as with total cognitive score (b = 2.02, $p < .0001$) for total cognitive score.

We also explored the relationship of residual PEFR with other physical measurements including those obtained from the blood and urine specimens. Even though the residual measure is partially adjusted for height and weight, we found a highly significant association with waist/hip ratio, particularly with hips measured at the maximal buttocks level (b = −144.1, $p < .001$). Among those in the high status group, this relation was also evident (p = .04). Residual PEFR was not correlated with body mass index. No relationship was seen with any of the blood pressure measurements, including sitting, standing, or mean arterial blood pressure. PEFR was also not related to the variables obtained from analyses of the blood samples, although HDL cholesterol exhibited a slight association which disappeared after further adjustment for smoking and alcohol use.

When we examined the relation of PEFR to the urinary excretion variables, an unexpected relation emerged. Residual PEFR was inversely related to the natural logarithm (ln) of norepinephrine (b = −9.8 per SD unit, p = .004) after controlling for age, sex, race, site, and smoking in the total sample (Table 2). The association remained among the high status group only and among high status never-smokers. When the sample was restricted to the subgroup with blood measures of creatinine clearance, the beta coefficients were very similar. Little change in this relationship occurred after further control for alcohol use or when those taking medications that could potentially affect norepinephrine level were excluded from the analysis.

Finally, all of the variables considered above were entered into a stepwise regression model, which included terms for age, sex, race, site, and smoking. Those variables which entered the model at the .05 level are presented in Table 3 in order of entry. As noted previously, among the total group the strongest correlate of residual PEFR was the sum of six physical performance activities, followed by total cognitive score, another summary measure. Ln norepinephrine was the third variable to enter the model, followed by self-rated health, score on tandem and leg stands, number of strenuous activities, waist/hip ratio measured at the maximum buttocks level, and score on the memory tests. Ln norepinephrine remained highly significant with waist/hip ratio, a measure of obesity, in the model. As evidenced by the stepwise model, all of these measures were independently associated with PEFR.

Similar results were evident among the high status group overall as well as the subgroup of high status never-smokers. The overall physical performance measure and a cognitive measure, either total cognitive score or score on the memory or naming test, were always strong predictors. Ln norepinephrine also entered the stepwise model in all three groups, as did number of strenuous activities.

Discussion

PEFR, as measured by the mini-Wright peak flow meter, is highly correlated with measures of physical and cognitive

Table 2. Regressions of Residual PEFR on Urinary Excretion Variables Controlling for Age, Sex, Race, Site, and Smoking Among Subjects With Urine Samples Judged Complete

	Total Sample (N = 839)			High Status Group With No MI, Stroke or CA (n = 535)			High Status Never-Smokers With No MI, Stroke or CA (n = 272)		
Variable (per *SD* unit)	*b*	*SE*	*p*-value	*b*	*SE*	*p*-value	*b*	*SE*	*p*-value
Ln creatinine (g/l)	1.0	3.7	.790	1.5	4.6	.737	7.3	6.0	.219
Ln cortisol*	2.9	3.4	.396	1.4	4.2	.741	−2.3	5.5	.674
Ln norepinephrine*	−9.8	3.4	.004	−12.8	4.2	.002	−12.4	5.4	.021
Ln epinephrine*	−3.0	3.6	.399	−2.0	4.3	.635	−4.1	5.6	.462
Ln dopamine*	−5.0	3.4	.144	−4.6	4.2	.273	−5.8	5.6	.297
Urine volume (100 cc units)	4.3	3.3	.195	6.4	4.1	.117	−0.2	5.4	.972

*Ln microgram per gram creatinine.

Table 3. Stepwise Regression Analysis of Residual PEFR Controlling for Age, Sex, Race, Site, and Smoking Among Those With Urine Samples Judged Complete

Variables (range)	*b*	*SE*	*p*-value
Total sample (N = 749)			
Summary physical score (4–24)	7.27	1.10	<.001
Total cognitive score (0–89)	0.98	0.49	.048
Ln norepinephrine*	−10.40	3.32	.002
Self-rated heath (1–3)**	−9.54	4.58	.038
Tandem stand + leg stand ≥20 secs (0–1)	−19.43	7.38	.009
Number of strenuous activities (0–15)	2.49	1.17	.034
Waist/hip (max buttocks) ratio	−107.51	48.93	.028
Memory score (0–35)	2.16	1.05	.040
High status group with no MI, stroke or CA (n = 505)			
Summary physical score (4–24)	5.27	1.48	<.001
Memory score (0–35)	3.01	0.87	<.001
Ln norepinephrine*	−12.46	3.98	.002
Number of strenuous activities (0–15)	3.29	1.46	.025
Foot-taps (log time per tap)*	−11.23	5.22	.032
High status never-smokers with no MI, stroke or CA (n = 254)			
Summary physical score (4–24)	5.64	1.54	<.001
Naming score (0–18)	8.38	2.81	.003
Number of strenuous activities (0–15)	4.63	2.03	.024
Ln norepinephrine*	−11.59	5.10	.024

*per *SD* unit.
**1 = excellent; 2 = good; 3 = fair/poor.

function among the elderly. The physical function measures included balance and strength (the tandem stands and walk, and leg stand), gait (10-foot walk), and upper body strength (hand grip strength) and dexterity (signature). PEFR was correlated with most of these individual measures, except for the tandem stand with eyes closed, which perhaps relies most on balance. The strongest association was observed for the summary physical score, a composite score that reflected performance on six measures, followed by hand grip strength. PEFR had previously been found to be correlated with self-reported assessment of functional ability (2), including the Katz scale of activities of daily living (8) and the Rosow-Breslau (9) and Nagi (10) scales. These latter measures were primarily designed to measure impairment, however, and the relationship with PEFR could have been due to an association with impairment or a threshold in the relationship of physical function and PEFR. The physical performance testing in the present study was designed to array subjects across a range of ability, and was a more sensitive indicator of ability among the unimpaired (3). In the high status group, representing those in the upper third of physical and cognitive functioning, scores on the testing still exhibited much variability, reflecting heterogeneity of performance even among this group (3). PEFR remained correlated with almost all measures of performance in this group, indicating that the associations with function are not confined to the low end of the spectrum. The relations remained among never-smokers, indicating that they were not mediated by smoking. Education and income also did not alter the basic findings.

Regarding cognitive function, PEFR was strongly related to all of the individual tests considered both in the entire cohort and among the high status group. Again, the strongest association was with the total cognitive score, a composite measure that was a summary of scores from the other tests. While these associations may be partly related to the subject's ability to understand and perform the test of PEFR, they remained significant among those the interviewer considered to have an excellent understanding of and compliance with the lung test. Furthermore, PEFR was independently associated with summary measures of both physical and cognitive performance in the stepwise regressions, despite their interrelations.

An inverse relation of PEFR with norepinephrine was found consistently, both overall and in the high status group, and even among the subgroup of never-smokers in the high status group. Indeed, the beta coefficient was larger in the high status group than in the total group (Table 2) and was not altered by further adjustment for alcohol use or waist/hip ratio, a measure of obesity. The association with norepinephrine remained in the stepwise models with the physical and cognitive performance variables, and thus appeared to be independent of both physical and cognitive function.

This relationship of PEFR with norepinephrine, while unanticipated, may be related to chronic obstructive lung disease (COPD). Available data suggest that the autonomic nervous system is involved in the pathogenesis of obstructive airway disease (18). Patients with COPD exhibit enhanced sympathetic nervous activity and have been found to have elevated levels of plasma norepinephrine (19). The lack of a clear association between PEFR and norepinephrine among those in East Boston exhibiting no respiratory symptoms is consistent with this hypothesis, although these data are sparse. Because this study includes healthy, high-functioning elderly, the relation may not be limited to those with disease, but may hold across a range of pulmonary function levels. This association may also be related to the ability to fully relax the muscles of the diaphragm, thus enabling a larger lung volume. Norepinephrine level is known to be related to tension in smooth muscle. Contraction in these muscles in the lung could cause restriction of the air pathways, contributing to lower PEFR. These potential mechanisms deserve exploration in other studies.

In general, the stepwise regressions indicate that PEFR is highly related to summary measures of both physical and cognitive performance. It may thus serve as an important overall indicator of functional ability, which is relatively easy and inexpensive to measure. PEFR is also strongly related to hand grip strength, and was found to be associated with forced vital capacity in the Framingham study (20). The latter two measures have been implicated as biomarkers of overall heath and aging. Hand grip strength as a marker has the disadvantage of being affected by arthritis. How PEFR compares to forced vital capacity as a biomarker is unknown. Because PEFR is strongly affected by subject effort, as well as lung function, it may be the ability to expend that effort, or overall vitality, that is being measured. Thus PEFR could be a more sensitive measure of health and ability to function both physically and cognitively among the elderly. It remains to be established whether, and if so, how well PEFR will predict future successful aging.

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