Heart Rate Variability Biofeedback: Effects of Age on Heart Rate Variability, Baroreflex Gain, and Asthma

Paul Lehrer, Evgeny Vaschillo, Shou-En Lu, Dwain Eckberg, Bronya Vaschillo, Anthony Scardella and Robert Habib

Chest 2006;129;278-284
DOI: 10.1378/chest.129.2.278

Heart Rate Variability Biofeedback*

Effects of Age on Heart Rate Variability, Baroreflex Gain, and Asthma

Paul Lehrer, PhD; Evgeny Vaschillo, PhD; Shou-En Lu, PhD; Dwain Eckberg, MD; Bronya Vaschillo, MD; Anthony Scardella, MD; and Robert Habib, PhD

Objectives: **To present additional analysis of data from a previously published study showing that biofeedback training to increase heart rate variability (HRV) can be an effective component in asthma treatment. HRV and intervention-related changes in HRV are negatively correlated with age. Here we assess the effects of age on biofeedback effects for asthma.**

Design: **Ten sessions of HRV biofeedback were administered to 45 adults with asthma. Medication was prescribed by blinded physicians according to National Heart, Lung, and Blood Institute criteria. Medication needs were reassessed biweekly.**

Results: **Decreases in need for controller medication were independent of age. There were larger acute decreases in forced oscillation frequency dependence in the older group but larger increases in HRV variables in the younger group. Differences between age groups were smaller among subjects trained in pursed-lips abdominal breathing as well as biofeedback, than among those receiving only biofeedback.**

Conclusions: **Age-related attenuation of biofeedback effects on cardiovascular variability does not diminish the usefulness of the method for treating asthma among older patients. Additional training in pursed-lips abdominal breathing obliterates the effects of age on HRV changes during biofeedback.** ***(CHEST 2006; 129:278–284)***

Key words: age; asthma; breathing exercises; heart rate variability; psychology

Abbreviations: HF = high frequency; HRV = heart rate variability; LF = low frequency; NHLBI = National Heart, Lung, and Blood Institute; NS = not significant; UMDNJ = University of Medicine and Dentistry, New Jersey

Heart rate variability (HRV) biofeedback can easily be used to teach people to increase the amplitude of HRV. We have previously reported[1] that HRV biofeedback in healthy subjects also results in significantly increased baroreflex gain, both acutely and chronically.

Recently in *CHEST* (August 2004),[2] we reported that 10 weeks of training in HRV biofeedback produces clinically significant improvement in asthma. Patients receiving this training showed decreases in respiratory resistance and asthma symptoms, while receiving a lower dose of "controller medications" (inhaled steroids, sometimes along with a long-acting β-adrenergic stimulant or a leukotriene inhibitor). Medication was controlled using a strict titration schedule derived from National Heart, Lung, and Blood Institute (NHLBI) guidelines.[3]

It is known that HRV is negatively correlated with age,[4] with most studies[5–8] finding that the decline

*From UMDNJ–Robert Wood Johnson Medical School (Drs. Lehrer and Scardella), Piscataway and New Brunswick, NJ; Rutgers, The State University of New Jersey (Drs. E. Vaschillo and B. Vaschillo), Piscataway, NJ; UMDNJ-School of Public Health (Dr. Lu), Piscataway, NJ; Virginia Commonwealth University (Dr. Eckberg), Medical College of Virginia, Richmond, VA; and Mercy Children's Hospital (Dr. Habib), Toledo, OH.

This work was supported by grant R01 HL58805 from the NHBLI, National Institutes of Health.

This research was performed at UMDNJ–Robert Wood Johnson Medical School, Piscataway and New Brunswick, NJ.

Manuscript received February 16, 2005; revision accepted June 23, 2005.

Correspondence to: Paul Lehrer, PhD, Department of Psychiatry, UMDNJ–Robert Wood Johnson Medical School, 671 Hoes Lane, Piscataway, NJ 08854; e-mail: lehrer@umdnj.edu

levels out after approximately age 40 years. Interventions that affect HRV also show greater effects in younger than older adults, including orthostatic effects,[9] sleep,[10] and aerobic exercise.[11] Women tend to have higher levels of HRV than men, although this difference disappears during and after the fifth decade of life.[6,7]

There are no previous data showing how age affects biofeedback response, either for asthma or the cardiovascular system, or whether the two kinds of effects are related. Below we report a complementary analysis of our previously reported data[2] exploring the age effects on HRV biofeedback in asthma and, consequently, the implications for use of HRV biofeedback in the treatment of asthma.

Materials and Methods

Subjects

This research was approved by the Institutional Review Board of the University of Medicine and Dentistry, New Jersey (UMDNJ)–Robert Wood Johnson Medical School. Inclusion criteria were as follows: age 18 to 65 years, history of asthma symptoms and, within the past year, either a positive bronchodilator test result (postbronchodilator FEV_1 increase $\geq 12\%$); a positive methacholine inhalation challenge test; or a documented recent history (within the past year) of clinical improvement and FEV_1 increase $\geq 12\%$ following instigation of inhaled steroid therapy among individuals with a protracted history of asthma. Exclusion criteria were as follows: a disorder that would impede performing the biofeedback procedures (*eg*, abnormal cardiac rhythm); a negative methacholine challenge test result; an abnormal diffusing capacity (tested among all subjects > 55 years old or with > 20 pack years of smoking); or current practice of any relaxation, biofeedback, or breathing technique. Number and characteristics of subjects are summarized in Table 1.

Instrumentation and Software

Instrumentation and physiologic measurement procedures are detailed in our previous report.[2] We assessed heart rate and HRV from the ECG, baroreflex gain derived from cross-spectral analysis of beat-to-beat heart rate and BP within the low-frequency (LF) [0.05 to 0.15 Hz] range, and three parameters derived from forced oscillation pneumography: resistance at 6 Hz, frequency dependence of resistance, and resonant frequency of the airways.

Procedure

Before randomization, we stabilized subjects on the lowest possible dose of controller medication that eliminated asthma symptoms and maintained normal pulmonary function. The asthma physicians were blinded to experimental condition. They titrated medications up or down according to symptoms and pulmonary function, according to the protocol described in our previous report,[2] based on NHLBI guidelines for asthma treatment.[3]

Physiologic data were collected during 4 of 10 treatment sessions in the biofeedback condition, and in 4 equivalently spaced sessions in the control group. Data were collected during four 5-min periods: (1) a pretraining rest period (task A), in which subjects were asked to relax as deeply as possible with eyes open, and to try not to move, so as not to disturb the measuring equipment; (2) the first 5 min of biofeedback training (task B); (3) the last 5 min of an approximately 30-min biofeedback training period (task C); and (4) a posttraining rest period (task D), with the same instructions as for the pretest rest period. For control subjects, instructions for tasks B and C were identical to those in tasks A and D.

Procedures for HRV biofeedback training are explained elsewhere in detail.[9,12] Subjects were randomly classified among four treatment groups, of which two groups, reported here, received HRV biofeedback. One of these groups received a "full protocol," which also included training in pursed-lips abdominal breathing beginning in the second training session. The second group received HRV biofeedback alone.

Subjects were paid $100 for each of the four testing sessions but were not paid for biofeedback sessions or medical evalua-

Table 1—*Subject Characteristics in Each Group

	Full Protocol		HRV Biofeedback Alone	
Pretreatment Values	Younger Age (< 40 yr)	Older Age (> 40 yr)	Younger Age (< 40 yr)	Older Age (> 40 yr)
Female/male gender, No.	6/2	8/3	7/3	5/2
Age, yr	27.55 ± 6.30	47.50 ± 6.55	28.07 ± 5.62	50.44 ± 3.23
Height, inches	67.00 ± 6.14	66.50 ± 4.41	65.45 ± 4.10	66.29 ± 2.81
Weight, lb	163.75 ± 52.02	169.36 ± 44.83	147.50 ± 29.29	183.57 ± 33.92
Medication step†	8.03 ± 2.14	8.35 ± 1.70	6.40 ± 2.39	8.5 ± 2.87
Log R-R interval	6.72 ± 0.20	6.73 ± 0.16	6.75 ± 0.17	6.76 ± 0.11
Log LF plus HF HRV	6.95 ± 1.12	6.33 ± 0.81	7.80 ± 1.56	6.79 ± 0.77
Log LF HRV	5.64 ± 0.84	5.60 ± 0.87	6.75 ± 1.72	5.93 ± 1.32
Log baroreflex gain	1.86 ± 0.40	1.65 ± 0.79	2.35 ± 0.45	1.56 ± 0.61
Log 6-Hz oscillation resistance	0.73 ± 0.35	0.84 ± 0.45	0.81 ± 0.28	1.17 ± 0.45
Log oscillation resistance frequency dependence	− 0.26 ± 0.60	− 0.08 ± 0.79	− 0.70 ± 1.97	0.59 ± 0.82
Log oscillation resonant frequency	2.85 ± 0.44	2.91 ± 0.31	2.87 ± 0.27	3.12 ± 0.44

*Data are presented as mean ± SD unless otherwise indicated. LF is 0.05 to 0.15 Hz. For cardiac and forced oscillation measures, "pretest" is the initial 5-min rest period in the first treatment session. For other measures, it is the level taken before the first session.

†Medication level is from a 13-step protocol described elsewhere.[3] Levels 1 to 2 are appropriate for mild intermittent asthma, 3 to 5 for mild persistent asthma, 6 to 8 for moderate asthma, and 9 to 13 for severe asthma. Medication levels are based on NHLBI criteria.[4]

Table 2—*Significance of Changes in Outcome Variables

Variables	Age < 40 yr			Age ≥ 40 yr			Age < 40 yr vs Age ≥ 40 yr			
	Estimated ΔM	SE	p Value	Estimated ΔM	SE	p Value	Difference	SE	t Test	p Value
Medication level										
FP (A10 − A1)	− 2.250	0.432	0.000	− 3.050	0.540	0.000	0.800	0.692	1.157	NS
HRV (A10 − A1)	− 2.500	0.386	0.000	− 1.643	0.646	0.008	− 0.857	0.752	− 1.139	NS
Log HF plus LF HRV										
FP (BC − AD)	1.639	0.277	0.000	1.654	0.230	0.000	− 0.015	0.360	− 0.042	0.967
HRV (BC − AD	2.073	0.242	0.000	1.194	0.287	0.000	0.879	0.376	2.340	0.020
FP (A10 − A1)	0.495	0.510	0.334	− 0.104	0.429	0.809	0.599	0.667	0.899	0.371
HRV (A10 − A1)	− 0.208	0.432	0.632	− 0.087	0.512	0.865	− 0.121	0.670	− 0.180	0.858
Log LF HRV										
FP (BC − AD)	3.114	0.375	0.000	2.761	0.319	0.000	0.353	0.492	0.718	0.473
HRV (BC − AD)	3.489	0.332	0.000	2.220	0.397	0.000	1.270	0.517	2.456	0.015
FP (A10 − A1)	0.722	0.542	0.186	0.057	0.459	0.901	0.665	0.710	0.936	0.352
HRV (A10 − A1)	− 0.322	0.469	0.494	− 0.349	0.560	0.535	0.027	0.730	0.037	0.971
Log α LF baroreflex gain										
FP (BC − AD)	0.604	0.121	0.000	0.219	0.101	0.030	0.385	0.157	2.448	0.015
HRV (BC − AD)	0.590	0.107	0.000	0.371	0.126	0.003	0.218	0.165	1.325	0.186
FP (A10 − A1)	0.289	0.211	0.175	− 0.155	0.182	0.397	0.444	0.279	1.591	0.115
HRV (A10 − A1)	− 0.061	0.189	0.750	− 0.139	0.226	0.539	0.079	0.295	0.267	0.790
Log forced oscillation resistance at 6 Hz										
FP (BC − AD)	− 0.170	0.096	0.077	− 0.032	0.082	0.696	− 0.138	0.126	− 1.096	0.274
HRV (BC − AD)	0.016	0.086	0.855	− 0.188	0.102	0.067	0.203	0.134	1.524	0.128
FP (A10 − A1)	− 0.225	0.159	0.160	− 0.140	0.136	0.304	− 0.085	0.209	− 0.407	0.685
HRV (A10 − A1)	− 0.149	0.142	0.296	− 0.264	0.170	0.125	0.114	0.222	0.514	0.608
Log forced oscillation resonant Frequency										
FP (BC − AD)	− 0.128	0.090	0.158	0.003	0.077	0.968	− 0.131	0.119	− 1.103	0.271
HRV (BC − AD)	0.024	0.081	0.767	− 0.350	0.096	0.000	0.374	0.126	2.972	0.003
FP (A10 − A1)	− 0.192	0.142	0.179	− 0.040	0.121	0.743	− 0.152	0.187	− 0.816	0.416
HRV (A10 − A1)	− 0.212	0.127	0.098	− 0.205	0.152	0.180	− 0.007	0.198	− 0.036	0.971
Log forced oscillation Frequency dependence										
FP (BC − AD)	− 0.520	0.266	0.051	− 0.409	0.228	0.074	− 0.111	0.350	− 0.317	0.751
HRV (BC − AD)	0.025	0.238	0.917	− 1.049	0.286	0.000	1.074	0.372	2.889	0.004
FP (A10 − A1)	− 0.585	0.393	0.140	− 0.475	0.335	0.160	− 0.110	0.517	− 0.214	0.831
HRV (A10 − A1)	− 0.344	0.347	0.325	− 0.820	0.420	0.054	0.476	0.545	0.873	0.385

*A10 − A1 = differences between the 5-min pretraining rest periods in the last vs the first training sessions; BC − AD = difference between the mean of the 5-min biofeedback periods at the beginning and end of each session vs the mean of the 5-min rest periods before and after each session. ΔM = difference between comparison means; FP = full protocol, including HRV biofeedback and training in pursed-lips abdominal breathing.

tions. We only analyzed data from subjects who completed the 10-session biofeedback protocol.

Statistical Analysis

The statistical analysis was done using a mixed-effect model analysis, with unstructured variance-covariance structure, to compare the short-term and long-term within-treatment effects between the age groups, with age treated as a dichotomous variable (> 40 years vs < 40 years). For age as a continuous variable, we used a heterogeneous first-order autoregressive analysis. The model included two repeated measures (sessions, times within sessions [task A = presession rest period, task B = first 5 min of biofeedback, task C = last 5 min of biofeedback, task D = postsession rest period]), treatment conditions (full protocol, HRV alone), and age classes (age < 40 years vs ≥ 40 years). Weight and height were additional covariates included in the model because they correlate strongly with pulmonary function and HRV parameters. Because data were skewed, we applied a log transformation to the cardiovascular and forced oscillation data. Bonferroni criteria were used but only between different physiologic systems, because cardiovascular measures were all related to each other, as were forced oscillation measures. We thus set $\alpha = 0.018$ as the criterion for statistical significance. We repeated the mixed-models analysis using age as a continuous variable.

Results

In order to normalize data, log transformations were used for all physiologic variables.

Pretest Differences Between Groups

We used the mixed-models analysis main effect for age to examine the effects of age on physiologic

variables, across all treatment conditions. With age treated, respectively, as a dichotomous (> 40 years or < 40 years) and continuous variable, values among older subjects were lower than among younger subjects, thus indicating poorer cardiovascular regulation, for LF HRV ($p < 0.002$, $p < 0.0001$), high-frequency (HF) HRV ($p < 0.002$, $p < 0.0001$), SD of normal R-R intervals (p = not significant [NS], $p < 0.011$), coefficient of variation in R-R intervals (p = NS, $p < 0.0085$), and cross-spectral α LF baroreflex gain ($p < 0.0001$, $p < 0.0001$). Values were higher for forced oscillation measures, indicating poorer pulmonary function, for frequency dependence ($p < 0.006$, $p < 0.009$) and resonant frequency of the lung ($p < 0.01$, p = NS). With the exception of resonant frequency, the significance of differences was greater when examining age as a continuous variable than as a dichotomous variable, indicating that age continues to affect these physiologic variables past age 40 years. There were no age differences in forced oscillation resistance at 6 Hz.

Age Differences in Effects of Biofeedback

Changes in asthma severity, as measured by medication consumption (the primary outcome variable), improved in both age groups but did not differ between them. Based on our 13-step protocol, medication dropped from an average of that prescribed for moderate asthma to that prescribed for mild persistent asthma (Table 2, Fig 1): a clinically significant improvement, as previously reported.[2] This result was maintained after adjusted for age as both a dichotomous and continuous variable. There were no differences between age groups in medication changes.

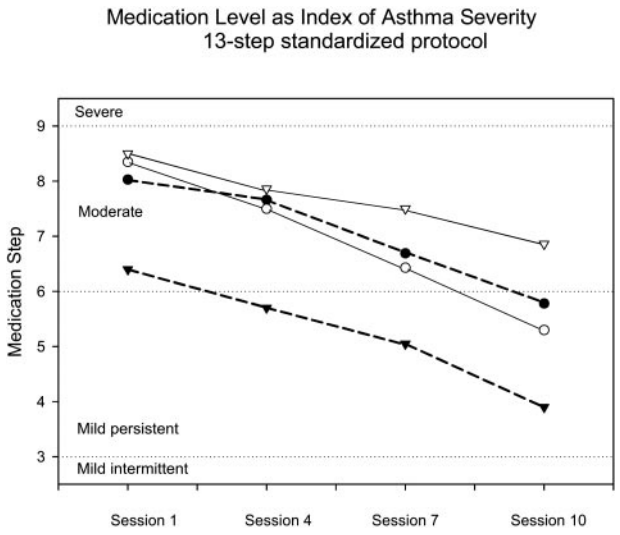

FIGURE 1. Medication level as index of asthma severity: 13-step standardized protocol.

Total HRV was quantified as the sum of LF and HF HRV. Using age as a continuous variable, there was a negative relationship between age and acute change from rest to biofeedback periods ($p < 0.006$) for subjects receiving HRV biofeedback alone, but this was not significant among subjects receiving the full protocol, nor was it significant in either treatment group with age treated as a dichotomous variable. The significance of these findings was not affected when the analyses were adjusted for age differences in tidal volume and respiration rate. The negative relationship between age and increase in baroreflex gain during biofeedback was significant in both treatment groups with age treated as a continuous variable ($p < 0.0001$ for the full protocol, and $p < 0.006$ for the group receiving biofeedback alone) but was significant only in the full protocol ($p < 0.015$) with age treated dichotomously. The significance levels of these findings were not affected by controlling for tidal volume and respiration rate.

In contrast to the cardiovascular effects, there was a tendency toward acute improvement (decrease) in oscillation resonant frequency dependence only among older subjects receiving HRV biofeedback alone, with significant differences between groups. The change was significantly greater in the older than younger groups ($p < 0.003$) and there was a significant relationship between age as a continuous variable and biofeedback-induced decreases in resonant frequency ($p < 0.0001$). A decrease in frequency dependence also occurred only in the older group but in both treatment conditions (Table 2, Fig 2). The decrease was significantly greater in older than younger subjects ($p < 0.004$) but only among subjects receiving HRV biofeedback alone. This effect also was significant ($p < 0.001$) with age treated as a continuous variable. This relationship was also significant in the HRV biofeedback group for oscillation 6-Hz resistance. The significance of the forced oscillation effects were, as the cardiovascular effects, unaffected by adjusting for tidal volume and respiration rate.

Chronically there were significant decreases in oscillation 6-Hz resistance and airway resonant frequency only in the younger group but only among those receiving HRV biofeedback alone. However, age groups did not differ significantly in these changes, and there were no significant chronic age effects when age was examined as a continuous variable.

DISCUSSION

Biofeedback effects on cardiovascular measures were smaller among older than among younger

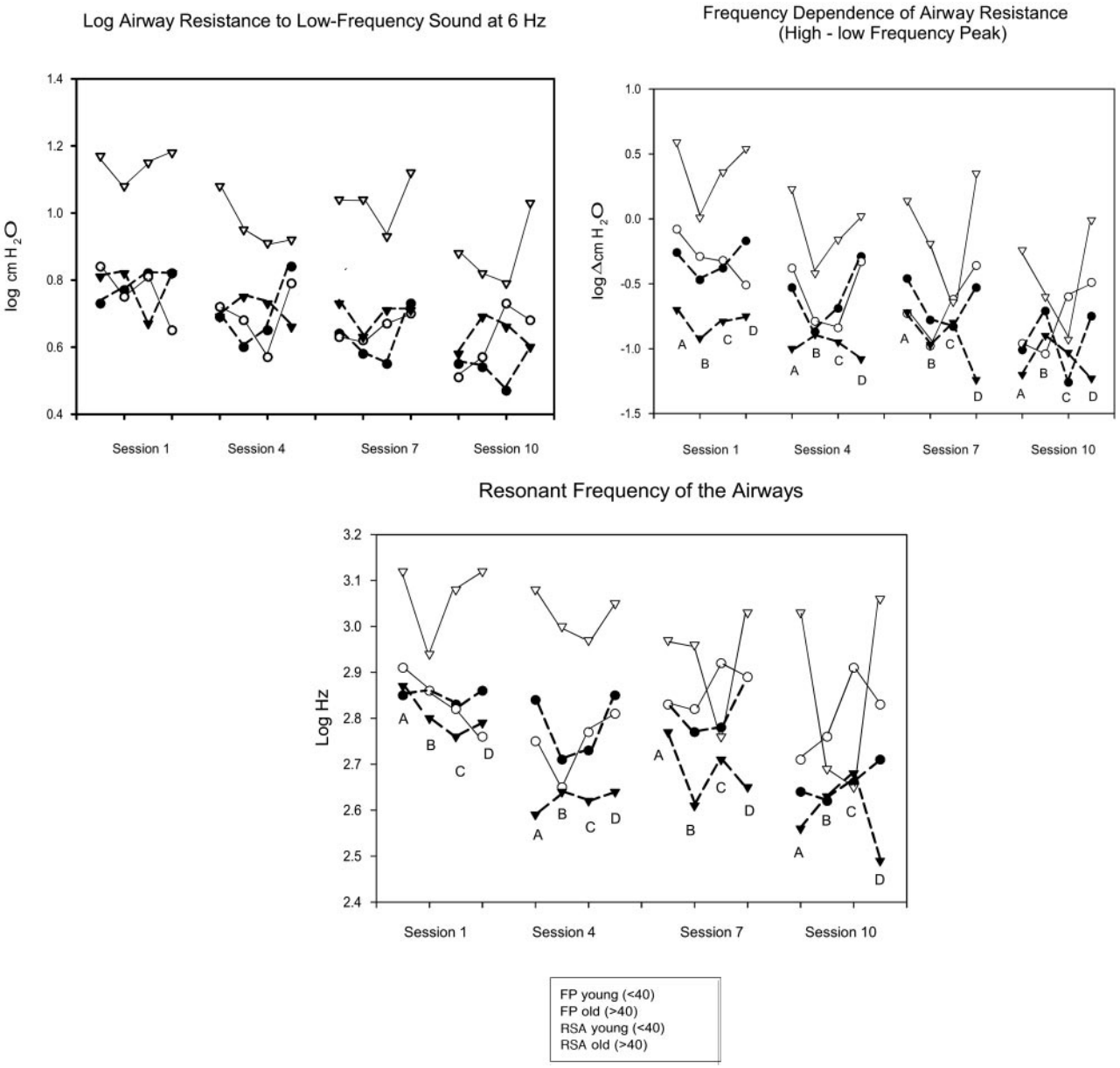

FIGURE 2. Respiratory function from forced oscillation pneumography. Task A = 5-min presession rest period; task B = first 5 min of biofeedback; task C = last 5 min of biofeedback; task D = 5-min postsession rest period. "Biofeed-rest" represents the average across sessions of the mean of the first and last 5-min periods of biofeedback (tasks B and C) minus the mean of the pretest and posttest rest periods (tasks A and D)."S10–1 Pre-rest" represents the difference between values in the 5-min presession rest period (task A) in the last training session (session 10) and those in the first session. Log LF α baroreflex gain = α LF baroreflex gain (milliseconds per millimeter of mercury) is the cross-spectral baroreflex gain within the LF range, where coherence between heart rate and BP oscillations is ≥ 0.8. HRVB = HRV biofeedback alone; RSA = respiratory sinus arrhythmia. See Table 2 for expansion of abbreviations.

patients, consistent with previous studies[6,7,9–11] of conditions and methods that generally increase HRV. However, age did not appear to decrease the effects of HRV biofeedback on asthma severity, as measured by medication level or oscillation pneumography measures (Fig 2). Indeed, the effects appeared to be slightly greater among older subjects, for reasons not understood.

These results indicate that HRV biofeedback is as effective for asthma among older adults as among younger people, despite the attenuated effects on HRV and baroreflex gain (Fig 3). This pattern of results gives further evidence that the effects on asthma may not be mediated by autonomic changes. Other possibilities include the effects of improved gas exchange efficiency that occurs when people

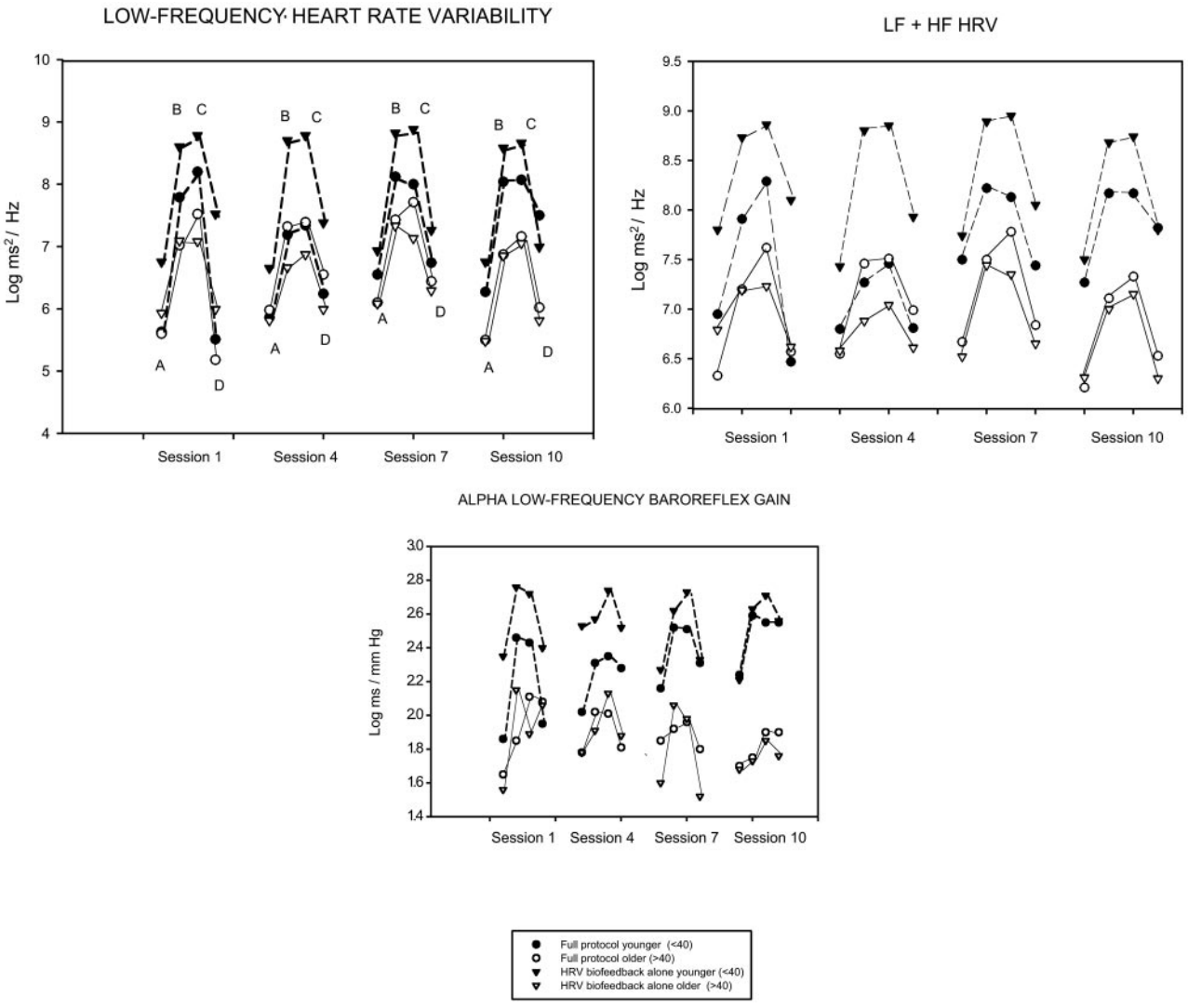

FIGURE 3. Mean HRV and baroreflex gain.

breathe at approximately 0.1 Hz,[13–15] as they did in the present experiment. Hayano et al [16] have shown that gas exchange efficiency is maximized when respiratory sinus arrhythmia occurs in phase with respiration. Vaschillo et al[17] have shown that a zero-degree phase relationship between breathing and variations in heart rate occurs only when people breathe at a rate of approximately 0.1 Hz. Also the amplitude of respiratory sinus arrhythmia is maximized at this respiration rate,[15,18] which also may contribute to gas exchange efficiency. Other possibilities include changes in inflammatory activity, and possible mechanical effects on pulmonary function of practicing slow deep breathing.

It is notable that age differences in both cardiovascular and pulmonary variables were greater among the group receiving HRV biofeedback alone than among those receiving the full protocol, which included training in pursed-lips abdominal breathing. Although the treatment effects did not differ on any variable, the combined procedure obliterated the effects of age, for reasons that are not known. Our previous report[2] also showed a nonsignificant tendency for fewer asthma exacerbations in subjects receiving the full protocol. We therefore suggest that the full protocol be used in clinical application, although biofeedback alone, without training in pursed-lips abdominal breathing, also had significant physiologic and clinical effects; and, for older subjects, the acute improvements in respiratory resistance were greater without training in pursed-lips abdominal breathing. Understanding the additive effects of biofeedback over pursed-lips abdominal breathing alone requires further investigation.

Acknowledgment: The authors thank Tom Kuusela, PhD, University of Turku, Finland, for providing WinCPRS software (Absolute Aliens Oy; Turku, Finland) for analysis of HRV and baroreflex data; and to Mahmood Siddique, DO, for designing the index of asthma severity and for assistance in recruitment and medical treatment of asthma patients.

References

1 Lehrer PM, Vaschillo E, Vaschillo B, et al. Heart rate variability biofeedback increases baroreflex gain and peak expiratory flow. Psychosom Med 2003; 65:796–805
2 Lehrer P, Vaschillo E, Vaschillo B, et al. Biofeedback treatment for asthma. Chest 2004; 126:352–361
3 National Heart Lung and Blood Institute. National Asthma Education and Prevention Program expert panel report: guidelines for the diagnosis and management of asthma; update on selected topics–2002. Washington, DC: U.S. Department of Health and Human Services, 2002
4 Agelink MW, Malessa R, Baumann B, et al. Standardized tests of heart rate variability: normal ranges obtained from 309 healthy humans, and effects of age, gender, and heart rate. Clin Autonom Res 2001; 11:99–108
5 Liao D, Barnes RW, Chambless LE, et al. Age, race, and sex differences in autonomic cardiac function measured by spectral analysis of heart rate variability: the ARIC study. Am J Cardiol 1995; 76:906–912
6 Antelmi I, de Paula RS, Shinzato AR, et al. Influence of age, gender, body mass index, and functional capacity on heart rate variability in a cohort of subjects without heart disease. Am J Cardiol 2004; 93:381–385
7 Shannon DC, Carley DW, Benson H. Aging of modulation of heart rate. Am J Physiol 1987; 22 874–877
8 Korkushkio OV, Shatilo VB, Plachinda YI, et al. Autonomic control of cardiac chronotropic in man as a function of age: assessment by power spectral analysis of heart rate variability. J Auton Nerv Syst 1991; 32:191–198
9 Srinivasan K, Sucharita S, Vaz M. Effect of standing on short term heart rate variability across age. Clin Physiol Funct Imaging 2002; 22:404–408
10 Yeragani VK, Sobolewski E, Kay J, et al. Effect of age on long-term heart rate variability. Cardiovasc Res 1997; 35: 35–42
11 Hautala AJ, Makikallio TH, Kiviniemi A, et al. Cardiovascular autonomic function correlates with the response to aerobic training in healthy sedentary subjects. Am J Physiol Heart Circ Physiol 2003; 285:H1747–H1752
12 Lehrer PM, Vaschillo E, Vaschillo B. Resonant frequency biofeedback training to increase cardiac variability: rationale and manual for training. Appl Psychophyisol Biofeed 2000; 25:177–191
13 Bernardi L, Gabutti A, Porta C, et al. Slow breathing reduces chemoreflex response to hypoxia and hypercapnia, and increases baroreflex sensitivity. J Hypertens 2001; 19:2221–2229
14 Bernardi L, Passino C, Wilmerding V, et al. Breathing patterns and cardiovascular autonomic modulation during hypoxia induced by simulated altitude. J Hypertens 2001; 19:947–958
15 Giardino ND, Glenny RW, Borson S, et al. Respiratory sinus arrhythmia is associated with efficiency of pulmonary gas exchange in healthy humans Am J Physiol Heart Circ Physiol 2003; 284:H1585–H1591
16 Hayano J, Yasuma F, Okada A, et al. Respiratory sinus arrhythmia: phenomenon improving pulmonary gas exchange and circulatory efficiency. Circulation 1996; 94:842–847
17 Vaschillo E, Vaschillo B, Lehrer P. Heartbeat synchronizes with respiratory rhythm only under specific circumstances. Chest 2004; 126:1385–1386
18 Vaschillo E, Lehrer P, Rishe N, et al. Heart rate variability biofeedback as a method for assessing baroreflex function: a preliminary study of resonance in the cardiovascular system. Appl Psychophysiol Biofeedback 2002; 27:1–27