Heart Rate Variability Biofeedback*

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

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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 reported1 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 studies5–8 finding that the decline...
levels out after approximately age 40 years. Interventions that affect HRV also show greater effects in younger than older adults, including orthostatic effects, sleep, and aerobic exercise. Women tend to have higher levels of HRV than men, although this difference disappears during and after the fifth decade of life. 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 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 (UMD-NJ)—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 FEV1 increase ≥ 12%); a positive methacholine inhalation challenge test; or a documented recent difference disappears during and after the fifth number. Below we report a complementary analysis of our previously reported data exploring the age effects on HRV biofeedback in asthma and, consequently, the implications for use of HRV biofeedback in the treatment of asthma.

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**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, based on NHLBI guidelines for asthma treatment.

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 were explained elsewhere in detail. 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

<table>
<thead>
<tr>
<th>Pretreatment Values</th>
<th>Full Protocol</th>
<th>HRV Biofeedback Alone</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Younger Age</td>
<td>Older Age</td>
</tr>
<tr>
<td></td>
<td>(&lt; 40 yr)</td>
<td>(&gt; 40 yr)</td>
</tr>
<tr>
<td>Female/male gender, No.</td>
<td>6/2</td>
<td>8/3</td>
</tr>
<tr>
<td>Age, yr</td>
<td>27.55 ± 6.30</td>
<td>47.50 ± 6.55</td>
</tr>
<tr>
<td>Height, inches</td>
<td>67.00 ± 6.14</td>
<td>66.50 ± 4.41</td>
</tr>
<tr>
<td>Weight, lb</td>
<td>163.75 ± 52.02</td>
<td>169.36 ± 44.83</td>
</tr>
<tr>
<td>Medication step†</td>
<td>8.03 ± 2.14</td>
<td>8.35 ± 1.70</td>
</tr>
<tr>
<td>Log R-R interval</td>
<td>6.72 ± 0.20</td>
<td>6.73 ± 0.16</td>
</tr>
<tr>
<td>Log LF plus HF HRV</td>
<td>6.95 ± 1.12</td>
<td>6.33 ± 0.81</td>
</tr>
<tr>
<td>Log LF HRV</td>
<td>5.64 ± 0.84</td>
<td>5.60 ± 0.87</td>
</tr>
<tr>
<td>Log baroreflex gain</td>
<td>1.86 ± 0.40</td>
<td>1.65 ± 0.79</td>
</tr>
<tr>
<td>Log 6-Hz oscillation resistance</td>
<td>0.73 ± 0.35</td>
<td>0.84 ± 0.45</td>
</tr>
<tr>
<td>Log oscillation resistance frequency dependence</td>
<td>-0.26 ± 0.60</td>
<td>-0.08 ± 0.79</td>
</tr>
<tr>
<td>Log oscillation resonant frequency</td>
<td>2.85 ± 0.44</td>
<td>2.91 ± 0.31</td>
</tr>
</tbody>
</table>

*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. 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.
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 α = 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. 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.

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
patients, consistent with previous studies\textsuperscript{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

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{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 \( \alpha \) baroreflex gain = \( \alpha \) 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 \( \geq 0.8 \). HRVB = HRV biofeedback alone; RSA = respiratory sinus arrhythmia. See Table 2 for expansion of abbreviations.}
\end{figure}
breathe at approximately 0.1 Hz,\textsuperscript{13–15} as they did in the present experiment. Hayano et al\textsuperscript{16} have shown that gas exchange efficiency is maximized when respiratory sinus arrhythmia occurs in phase with respiration. Vaschillo et al\textsuperscript{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,\textsuperscript{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\textsuperscript{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.

Figure 3. Mean HRV and baroreflex gain.
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