Behavioral Interventions in Asthma

Breathing Training

THOMAS RITZ
University of Hamburg

WALTON T. ROTH
Stanford University and VA Palo Alto Health Care System

Breathing exercises are frequently recommended as an adjunctive treatment for asthma. A review of the current literature found little that is systematic documenting the benefits of these techniques in asthma patients. The physiological rationale of abdominal breathing in asthma is not clear, and adverse effects have been reported in chronic obstructive states. Theoretical analysis and empirical observations suggest positive effects of pursed-lip breathing and nasal breathing but clinical evidence is lacking. Modification of breathing patterns alone does not yield any significant benefit. There is limited evidence that inspiratory muscle training and hypoventilation training can help reduce medication consumption, in particular ß-adrenergic inhaler use. Breathing exercises do not seem to have any substantial effect on parameters of basal lung function. Additional research is needed on the psychological and physiological mechanisms of individual breathing techniques in asthma, differential effects in subgroups of asthma patients, and the generalization of training effects on daily life.

Keywords: *asthma; breathing training; abdominal breathing; inspiratory muscle training; pursed-lip breathing; breathing pattern; hypoventilation; nasal breathing*

Elements of breathing training are often integral parts of relaxation exercises and biofeedback protocols (for reviews see Ritz, 2001; Ritz, Dahme, & Roth, in press). Due to the voluntary control over breathing

AUTHORS' NOTE: Preparation of this manuscript was partly supported by the German Research Society (Deutsche Forschungsgemeinschaft, Project Ri 957/2-1). Correspondence concerning this article should be addressed to Thomas Ritz, Ph.D., Psychological Institute III, University of Hamburg, Von-Melle-Park 5, D-20146 Hamburg, Germany; e-mail: Thomas.ritz@uni-hamburg.de.

BEHAVIOR MODIFICATION, Vol. 27 No. 5, October 2003 710-730
DOI: 10.1177/0145445503256323

and the multiple influences of breathing on autonomic nervous system function, breathing techniques seem to offer a promising avenue to behavioral control of psychophysiological states and organ functions (Ley, 1999). Breathing training has a long tradition as an intervention or rehabilitation technique for various disorders such as panic-agoraphobia (Meuret, Wilhelm, Ritz, & Roth, 2003), chronic obstructive respiratory disease (Lacasse, Guyatt & Goldstein, 1997), and bronchial asthma (Ernst, 2000; Holloway & Ram, 2000). However, as these reviews have documented, there is a surprising lack of well-controlled research supporting the usefulness of breathing training.

Breathing training procedures typically comprise a number of teaching and exercise elements such as modification of breathing pattern, use of abdominal versus thoracic compartments, training of inspiratory muscles, nasal versus mouth breathing, and pursed-lip breathing. Whereas some of these techniques (such as abdominal breathing) are common to training methods for various diseases or disorders, others (such as pursed-lip breathing) have been used more specifically in chronic pulmonary diseases. In some studies, the multiplicity of breathing training elements makes it impossible to discern the effects of individual components (e.g., Asher, Douglas, Airy, Andrews, & Trenholme, 1990). However, knowing their contributions would be of importance because breathing training elements are sometimes taught individually and are adopted by behavioral self-management and biofeedback training programs. It would be advantageous to focus future research efforts on the more promising elements of breathing training, and training methods could be made more efficient by limiting them to elements that are effective. More comprehensive breathing training interventions are often embedded in pulmonary rehabilitation of patients with severe asthma or chronic obstructive pulmonary disease (COPD) (Sutton, Pavia, Bateman, & Clarke, 1982), where additional elements such as techniques for expectoration of mucus are included. This review is focused on the available evidence from controlled studies in asthma and the validity of the psychophysiological rationale behind individual breathing techniques in their application to asthmatic patients.

METHOD

We used the search engines of Medline and PsychInfo to retrieve studies of breathing training in asthma. Keywords were *asthma* combined with *breathing training*, *breathing exercise*, *abdominal breathing*, *pursed-lips*, *inspiratory muscle training*, *respiratory muscle training*, *Buteyko*, *nasal breathing*, and *nose breathing*. In addition, reference lists of the retrieved articles were searched for further published material. Due to the small number of retrieved references, studies involving asthmatic patients of all ages were included.

Effect sizes were calculated as raw g and then corrected for small-sample bias to obtain d (Hedges & Olkin, 1985). Where means and standard deviations were available, d was calculated as the difference between the within-individual effect sizes of treatment and control groups ($d_{treatment} – d_{control}$). In that case, the within-individual g for measurements before (M_1) and after (M_2) intervention in treatment or control groups were calculated as $(M_2 – M_1)/SD$, where $SD = (sd_1^2 + sd_2^2) – 2 \cdot r \cdot sd_1 \cdot sd_2$ (Bortz, 1985). The correlation between M_1 and M_2 was estimated with $r = .50$ for indices of spirometry and self-report variables (symptoms, medication use, quality of life questionnaires), which all had time lags of several weeks in the relevant studies. In some cases, means were estimated by the median and SDs by range/square root(N), where N is the sample size.

Before averaging across studies, effect size estimates were weighted by their respective *df*s.

RESULTS AND DISCUSSION OF STUDIES

ABDOMINAL BREATHING

Abdominal breathing is stressed by many breathing training methods or relaxation techniques. It is also frequently recommended for asthma (Fried, 1993) and included as an integral part of physical therapy of severe asthma (e.g., Asher et al., 1990). In general, training in abdominal breathing should help reduce the work load of the accessory muscles and thereby reduce hyperinflation and breathlessness, which are typical features of acute and chronic airway obstruction

(Gibson, 1996). Surprisingly, only one controlled study of abdominal breathing training involving asthmatic patients has been reported. Girodo, Ekstrand, and Metivier (1992) trained a group of patients in the use of respiratory muscles over the course of 16 weeks to facilitate an abdominal breathing pattern, and they compared this group to physical exercise and waiting list control groups. No evidence of manipulation success was reported. Only self-report outcome measures were collected. Patients in the abdominal breathing group showed substantial reductions in diary entries of attack intensity and medication use, and they showed an increase in physical activities in their leisure time. These outcome measures returned to pretreatment values at an 8-week follow-up. The study suffered from a considerable attrition rate: 30% in the abdominal breathing group and 48% in the physical exercise group.

Instructions to breathe abdominally are also included in some biofeedback training methods, such as respiratory sinus arrhythmia biofeedback (Lehrer et al., 1997), and more prominently in the incentive spirometry and thoracic muscle EMG biofeedback of Peper and Tibbets (1992). However, abdominal breathing is combined with other training elements in these studies and the available evidence from controlled interventions is only preliminary (Ritz, Dahme, & Roth, in press), precluding adequate evaluation of its effects.

The potential physiological benefits of abdominal breathing in asthma are far from clear. For example, it has been suspected that distribution of air in the lungs and gas exchange would be improved, but this has not consistently shown for obstructive airway disease (Hughes, 1979; Sackner, Silva, Banks, Watson, & Smoak, 1974). Depending on the degree and chronicity of obstruction, adverse effects could also occur. Vitacca, Clini, Bianchi, and Ambrosino (1998) found that abdominal breathing training in severe COPD patients indeed improved gas exchange but these benefits were overweighed by less mechanically efficient breathing, asynchrony in thoracic-abdominal motion, and breathlessness. Similar adverse effects were reported by Gosselink, Wagenaar, Rijswijk, Sargeant, and Decramer (1995). In addition, the instruction to adopt a "deep" abdominal breathing pattern could lead to increases in minute ventilation with airway drying and/or cooling and hypocapnia, both factors promoting asthmatic symptoms (Herxheimer, 1946; Solway, 1997). More basic and controlled studies that include monitoring of ventilation are needed for a more definitive conclusion about effects of abdominal breathing in asthma.

PURSED-LIP BREATHING

Pursed-lip breathing is a technique often used in conjunction with abdominal breathing for patients with severe asthma or chronic obstruction. Patients are instructed to exhale slowly and steadily through pursed lips. The buildup of positive expiratory pressure keeps the airway passages open and helps prevent end-expiratory collapse (Barach, 1973). Although the technique is common in clinical settings and sometimes is practiced intuitively by obstructed patients, no controlled research is available that documents its benefit for asthma patients. The technique has been included in specific biofeedback and breathing exercises (e.g., Lehrer et al., 1997; Peper & Tibbetts, 1992), but no indication of its value as a sole component is available. A determination of the benefits of pursed-lip breathing needs to take into account asthma severity as a potential moderator variable. There has been some debate about the potential benefits of the technique; some authors have even suggested that detrimental effects could occur: The excessive buildup of pulmonary pressure could collapse the small airways with more air trapping (see Zadai, 1990). However, recent research in patients with COPD suggests that benefits of the technique prevail. Pursed-lip breathing improves gas exchange (Tiep, Burns, Kao, Madison, & Herrera, 1986) and reduces respiration rate when no additional instructions on altering breathing patterns are given (Breslin, 1992). Breslin also suggested an increased recruitment of accessory muscles of ventilation, while diaphragmatic recruitment was reduced during inspiration and increased during expiration. Although this pattern of muscle recruitment is usually associated with an increase in dyspnea, Breslin interpreted it as preventing diaphragmatic fatigue and improving accessory muscle function through a reduction in functional residual capacity. These findings encourage investigation of mechanisms of pursed-lip breathing, particularly in patients in various states of reversible airway obstruction. An additional benefit of slow, controlled exhalation for asthma patients could be a reduction of heat loss and airway cooling and/or drying.

INSPIRATORY MUSCLE TRAINING

It is generally recognized that inspiratory muscle function is involved in the development of dyspnea (American Thoracic Society, 1999). In patients with COPD, there is good evidence that inspiratory muscle training can help reduce dyspnea, improve strength and endurance of the muscles, and thus increase patients' capacity for physical activity and quality of life. However, benefits of this training are less clearly documented in asthma patients. Weiner, Azgad, Ganam, and Weiner (1992) trained a group of patients with moderate to severe asthma, using a threshold inspiratory muscle trainer. Patients trained for 6 months, five times a week, with gradually increasing resistance to their inspiratory airflow. Compared to a group using a sham device, patients in the intervention group successfully increased their muscle strength and endurance. They found significant reductions in symptoms, medication consumption, health care utilization, and absence from school or work as well as small improvements in lung function (see Table 1). Although these results are encouraging, they might have been influenced by the fact, reported by the authors, that most control group patients gradually became aware that they were using a placebo device. More general concerns could also be raised against this type of training in asthma. First, underperformance of the respiratory muscles, the main rationale for inspiratory muscle training, is present in patients with COPD but rarely in patients with asthma, even in acute states of obstruction (Stell, Polkey, Rees, Green & Moxham, 2001). Second, a central problem for asthma self-management is the poor perception of airflow obstruction in a number of patients, which can lead to severe, life-threatening states (Barnes, 1994). Training that aims to reduce sensations of dyspnea by enhancing respiratory muscle function would, in fact, be contraindicated in these patients. The authors addressed this problem in a more recent study in which they restricted their sample to "asthma overperceivers" who were defined indirectly by an overuse of ß-bronchodilators for their mild asthma and more directly by higher dyspnea scores during breathing against resistive loads (Weiner, Berar-Yanay, Davidovich, Magadle, & Weiner, 2000). After a 3-month training with the threshold inspiratory muscle trainer, the intervention group had reduced their ß-bronchodilator consumption and their sensitivity to resistive loads. Unfortunately, no other outcome measures were reported. Thus, inspiratory muscle training can lower medication consumption with a moderate to high overall effect size (Table 2). In clearly defined subgroups of asthma, a reduction in dyspnea to obstruction could indeed be beneficial. However, given the facts that the training is demanding in terms of time and patient motivation and that effects on the perception of obstruction can have a negative impact, the criteria for patient selection should be strict.

MODIFICATION OF BREATHING PATTERN

Important aims of breathing techniques in asthma could be adoption of slower breathing, prolonged expiration, or reduction in overall ventilation. Less overall ventilation could help reduce the risk of airway cooling and/or drying, which is thought to underlie certain asthma symptoms, particularly those induced by physical activity and exercise. Slowing of respiration can also reduce flow rates and thus reduce symptom development through irritant receptor stimulation (Hida et al., 1984). Singh (1987) tested the effects of reducing breathing frequency and adopting an inspiratory to expiratory time ratio of 1:2, two elements of a common yoga breathing technique (pranayama). Patients were instructed to train twice a day at home using a specially designed device with adjustable apertures and one-way valves that slowed expiration. The results suggested overall improvement in lung function and noctural wheezing in a group of 12 patients from a placebo phase to a 2-week training phase. However, the study was essentially uncontrolled in this within-subject design because the placebo phase always preceded the training phase. In a second controlled study, Singh, Wisniewski, Britton, and Tattersfield (1990) trained 18 patients with mild asthma for 2 weeks with the same device and an additional 2 weeks with a placebo device (see Table 1). This time, the order of training and placebo phases was randomized across patients. Effects on peak flow, symptom and medication dia-

TABLE 1

Overview of Controlled Studies on Inspiratory Muscle Training, Modifying Breathing Patterns, and Raising PCO_2

Study	*Treatment* (n), *Duration*	*Control* (n)	*Age Group*	*Random Allocation*	*Manipulation Check*	*Outcome Measure*	*Treatment vs. Control*[a]
Weiner et al. (1992)	Inspiratory muscle training with threshold resistance trainer (15), 6 months, 5 sessions/week, 30 minutes	Placebo device (15)	A	Not reported	Yes	FEV_1	S
						FVC	S
						Symptoms daytime	S
						Symptoms nighttime	S
						Cough	S
						Health care use	S
						Bronchodilator use	S
						Work or school absence	S
Weiner et al. (2000)	Inspiratory muscle training with threshold resistance trainer (11), 3 months, 5 sessions/week, 30 minutes	Placebo device (11)	A	Yes	Yes	Dyspnea for resistance breathing	S
						Bronchodilator use	S
Singh et al. (1990)	Modification of I:E ratio 1:2 with exercise device (18), 2 weeks, home training: twice daily, 15 minutes	Placebo device[b]	A	NA	No	FEV_1	N
						PEF	N
						Symptoms	N
						Bronchodilator use	N
						Histamine test	S
Ceugniet et al. (1994)	Modification of I:E ratio 1:3 (9), 2 sessions, 20 to 30 minutes	Modification of I:E ratio 1:1 (9); No instruction (6)	C	Yes	unsystematic observations	FEV_1[c]	N
						FVC[c]	N
						HR[c]	N
						Running distance[c]	N

(continued)

TABLE 1 (continued)

Study	*Treatment* (n), *Duration*	*Control* (n)	*Age Group*	*Random Allocation*	*Manipulation Check*	*Outcome Measure*	*Treatment vs. Control*[a]
Ceugniet et al. (1996)	Reduction in breathing frequency by 40% during exercise (9), 9 sessions, 45 minutes	No instruction (7); noncontingent feedback (9)	C	Yes	Yes	Pulmonary gas exchange[c]	S
						Dyspnea[c]	N
Bowler et al. (1998)	Hypoventilation training, (Buteyko method) (19), 7 days, 60 to 90 minutes, home training 3 months, additional sessions as needed	Asthma education, relaxation, abdominal breathing (20)	C, A	Yes	Yes	PEF	N
						FEV_1	N
						Bronchodilator use	S
						Corticosteroid use	N
						Quality of life	N
Opat et al. (2000)	Hypoventilation training, (Buteyko method) (13), training video 4 weeks, twice daily, 20 minutes	Placebo video (15)	A	Yes	No	PEF	N
						Symptoms	N
						Bronchodilator use	S
						Corticosteroid use	N
						Quality of life	S

NOTE: A = adults; C = children and adolescents; FEV_1 = forced expiratory volume in the first s; FVC = forced vital capacity; PEF = peak expiratory flow; HR = heart rate.
a. Significance as reported by authors: S = significant; N = nonsignificant.
b. Within-individual design.
c. Outcome for exercise test.

TABLE 2
Effect Size Estimates for Replicated Outcome Variables of Controlled Breathing Training Studies

Breathing Training	*Outcome Measure*	*Number of Studies*	*Treatment* n	*Weighted* d: *Treatment vs. Control* d	*Weighted* d: *95% CI of* d	*Range of Unweighted* d
Inspiratory muscle training	Bronchodilator use	2	26	0.84	0.26 – 1.42	0.55-1.09
Breathing pattern modification	FEV_1	2	27	–0.18	–0.72 – 0.36	–0.65-0.04
	Symptoms	2	27	–0.25	–0.80 – 0.30	–0.64-0.07
Modification of PCO_2	PEF	2	32	0.02	–0.46 – 0.50	–0.17-0.24
	Bronchodilator use	2	32	1.34	0.80 – 1.88	0.89-2.22
	Corticosteroid use	2	32	0.57	0.08 – 1.06	0.50-0.66
	Quality of life	2	32	0.57	0.08 – 1.06	0.43-0.78

NOTE: *d* = effect size corrected for small-sample bias; FEV_1 = forced expiratory volume in the first s; PEF = peak expiratory flow; CI = confidence interval.

ries, and laboratory spirometry were not statistically significant between training and placebo phases, although mean changes favored the training. Only hyperreactivity to histamine provocation was significantly reduced following the breathing training phase. In both studies, the lack of home training monitoring and problems with the validity of paper-and-pencil diary techniques might have introduced biases. It is also unclear to what extent the training was different from respiratory muscle training or pursed-lip breathing because the device introduced a resistance to airflow. The possible influence on gas exchange and risk of hypocapnia are additional critical issues because patients were instructed to breathe at their full vital capacity for the 15-minute training sessions. Deep inspiration alone can have adverse effects in asthma patients, producing bronchoconstriction (Gayrard, Orehek, Grimaud, & Charpin, 1975) and increasing nonspecific airway sensitivity (Orehek, Gayrard, Grimaud, & Charpin, 1975).

The potential of voluntary modification of breathing patterns to reduce exercise-induced asthma in children was studied by Ceugniet, Cauchefer, and Gallego (1994). Patients were trained using visual feedback from a spirometer to adopt one of two types of breathing patterns: either an identical duration for inspiratory and expiratory phase (I:E = 1:1) or expiratory phase three times longer than inspiratory phase (I:E = 1:3). The latter pattern was thought to reduce the amount of water and heat exchange in the airways and consequently to limit typical post-exercise bronchoconstriction. Three groups of patients were formed: two intervention groups, one with each of the two breathing pattern instructions, and a control group with no instructions. Patients then performed an exercise test (6 minutes, running) in which they were to breathe according to their previous instructions. Compared to an identical running test before breathing training, spirometric pulmonary function tests showed no advantage for any group over another. All three groups showed typical exercise-induced airway obstruction, with slightly less obstruction on the second day. A limitation of the study is the absence of verification of manipulation success: Experimenters observed rather than recorded ventilation to ascertain that patients followed the breathing instructions. The feasibility and validity of this approach during the running test can be questioned. As an explanation for the lack of group differences, the authors suggest that changes in timing of the breathing pattern may have been compensated by changes in tidal volume of breathing to achieve comparable levels of minute ventilation. Volume measures were not included in the measurement protocol. Indeed, in an experiment with asthma patients, variations in the inspiratory-expiratory ratio during cold air hyperpnea (which can partly simulate airway cooling during exercise-induced asthma) did not change the degree of bronchoconstriction when minute ventilation was kept at a constant level, although respiratory heat exchange may have been affected (Ingenito et al., 1990).

In a second asthma study, the authors tested the effects on pulmonary gas exchange and dyspnea of a more comprehensive, 9-session breathing training with the goal of lowering respiration rate (Ceugniet, Cauchefer, & Gallego, 1996). In the given exercise protocol, the prescribed reductions in rate amounted to a 40% reduction in ventilation. Compared to a spontaneous breathing group, the training group showed reductions in arterial oxygen saturation and increases in end-tidal carbon dioxide levels during cycle ergometry testing. Dyspnea levels were not different between groups, and none of the patients in either group seemed to have developed exercise-induced asthma. Based on their findings, the authors advise against the general use of breathing rate reduction in asthma because of the risk of hypercarbia and hypoxia when tidal volume increases cannot compensate sufficiently for increased exercise demands.

In conclusion, the current evidence suggests that modifications of breathing frequency or inspiratory-expiratory ratio alone are unlikely to lead to greater improvements in clinical status, exercise-induced asthma, or asthmatic symptoms. Average effect sizes in Table 2 for outcome variables measured at least by two studies are low. Future studies should closely monitor gas exchange to be sure that patients do not become too hypocapnic or hypercapnic with particular maneuvers.

MODIFICATION OF CO_2 LEVELS

The potentially detrimental effects of hypocapnic overbreathing have long been recognized (Fried, 1993). In addition, hypocapnia as a risk factor for asthma has been discussed for some time (Herxheimer, 1946). Hypocapnia leads to an increase in respiratory resistance (van den Elshout, van Herwaarden, & Folgering, 1991), and lower PCO_2 in asthma patients is associated with hyperresponsiveness of the airways (Osborne, O'Connor, Lewis, Kanabar, & Gardner, 2000). Recently, the Russian physician Konstantin Buteyko has advocated a breathing training method that aims at increasing PCO_2 levels by teaching patients to hypoventilate (Stalmatski, 1999). Patients are instructed to breathe slower and shallower, breathe through their noses, and hold their breath at regular intervals. To this can be added the radical measure of taping the mouth shut at night to enforce nose breathing.

Two clinical trials have studied the efficacy of this method (see Table 1). Bowler, Green, and Mitchell (1998) trained a mixed group of adolescent and adult asthma patients for 1 week and encouraged them to continue with the exercises at home for the following weeks. A second group received a control intervention that included asthma education, relaxation, and abdominal breathing. At the final assessment after 3 months, the breathing training group compared to the control group showed lower minute ventilation, less ß-bronchodilator use, and a trend toward better quality of life. PCO_2 levels in both groups remained unchanged and below healthy control values. Similarly, spirometry did not detect any changes or group differences in lung function. Results for daily symptom ratings were not reported. Although carefully designed in many respects, more attention was given to individual patients in the intervention group, because those who had difficulties with the techniques received multiple contact calls and extra teaching. The failure of PCO_2 levels to increase in intervention patients suggests another mechanism for the observed changes than that of the original therapeutic rationale.

In a second trial of the efficacy of the Buteyko breathing method, adult asthma patients watched an informational and instructional video of the method, including a 20-minute self-guided training segment. These patient were instructed to replay and follow the 20-minute segment twice daily for 4 weeks (Opat, Cohen, Bailey, & Abramson, 2000). A control group initially saw a nature video and then was instructed to watch a 20-minute segment of it twice daily for 4 weeks. Following the intervention, the breathing training group showed a significant reduction in ß-bronchodilator use and an improvement in quality of life, which the control group did not show. Daily symptoms from paper-and-pencil diaries showed a trend toward decreases favoring the intervention group, whereas lung function measurements by peak flow showed no changes or group differences. This study did not include PCO_2 measurement although PCO_2 was the target of the treatment.[1]

Thus, although both clinical trials demonstrated improvements in the intervention groups, the mechanisms of change are uncertain. Whereas reduction of hypocapnia is an appealing physiological rationale and deserves to be tested, neither study provided evidence for the mechanism presumed to be at work. Also, the rationale of raising PCO_2 levels is not universally accepted (Al-Delaimy, Hay, Gain, Jones, & Crane, 2001; Walters & Johns, 2001). More basic research is needed to understand effects of hypoventilation on the airways in patients with asthma. On the positive side, mechanisms such as avoidance of airway drying and/or cooling, avoidance of bronchoconstriction by lung inflation, and reduction of airway irritation by higher flow rates could all contribute to the benefits of hypoventilation on asthma. In addition, hyperventilation due to anxiety states, often presumed to be a mediator of asthma exacerbations (e.g., Knapp, 1989), might be successfully reduced by this intervention. On the negative side, hypoventilation could increase the danger of hypoxia in severe asthmatic conditions and in patients with COPD. In addition, discontinuing anti-inflammatory drug treatment could lead to life-threatening worsening of asthma beyond the control of hypoventilation exercises (Weiner & Burdon, 1999). Anecdotal accounts of the Buteyko breathing method also mention increases in dyspnea, particularly in the beginning of training. Even mild hypoventilation can produce an increase in perceived breathlessness in healthy individuals during physical activity (Harty & Adams, 1994). Whether such an effect is sustained or whether breathing discomfort habituates should be subjects of further investigation.

NASAL BREATHING

Breathing through the nose rather than the mouth can result in greater efficiency of breathing and gas exchange, and it is known to improve inspired air by humidification, warming, and filtration for pollutants and allergens (Bjermer, 1999). These advantages are particularly important in asthma. Experimental studies have demonstrated that patients with exercise-induced asthma experience fewer symptoms following a 6-minute run when breathing through the nose (Mangla & Menon, 1981). In addition, air pollutants such as sulfur dioxide have a smaller impact on the asthmatic airways during exercise when the patient breathes with the mouth occluded (Kirkpatrick, Sheppard, Nadel, & Boushey, 1982). Although nasal irritation has been shown to increase airway resistance, this reflex action does not seem to be operative when greater amounts of cold air are inhaled via the nose (McLane et al., 2000). There is no systematic evidence on breathing training focused on nasal breathing only. One study suggests that a mechanical dilator of the nasal passages during the night can reduce noctural asthma symptoms (Petruson & Theman, 1996). It is unclear whether asthmatic patients face particular difficulties with training in nose breathing. Perceived breathlessness and complications such as rhinitis often lead asthma patients to switch to oral or oronasal breathing (Kirkpatrick et al., 1982). These breathing routes are preferred by patients with acute asthma, who also use them more than healthy individuals when spontaneous breathing is disturbed by devices such as face masks (Kairaitis, Garlick, Wheatley, & Amis, 1999). Given the convincing physiological rationale and experimental results, more research on nasal breathing training is clearly indicated.

BREATHING TRAINING COMBINED WITH OTHER INTERVENTIONS

Breathing training elements are sometimes embedded in physical therapy programs or yoga training. Information regarding breathing techniques alone can not be derived from such interventions. One controlled study combined breathing training (abdominal breathing, thoracic mobility exercises) with techniques for clearing secretions traditionally used in physical therapy of asthma (Asher et al., 1990). A group of 19 children was compared to a placebo group of 19 children receiving emotional support. No differences were found in lung function, attack frequency, and days in hospital at the end of the intervention. A number of studies have investigated the effects of yoga breathing on asthma. Typically, yoga combines posture change, mental concentration, muscle relaxation, and cleansing practices with breathing techniques. Controlled studies of yoga focus on different elements (Nagarathna & Nagendra, 1985; Vedanthan et al., 1998). Results have been mixed and methodologies have been less than optimal (see Bradley, 1985; Ritz, 2001).

PRELIMINARY INFORMATION ON EFFECT SIZES

We calculated mean effect sizes of comparable outcome variables for three types of breathing training that had more than one controlled study available (Table 2). As can be seen, due to a lack of replication the evidence available is quite limited. Effect sizes for changes in lung function are mostly negligible. Moderate to high effect sizes were obtained for medication use as an outcome variable in inspiratory muscle training and hypoventilation training by the Buteyko method. The latter technique also showed moderate effects on quality of life. However, the small number of studies and patients for individual breathing techniques reduces one's confidence in the generalizability of the effect size to new patient samples. A calculation of effect size across all types of training would not be meaningful because of the diversity of their rationales and presumed mechanisms.

CONCLUSIONS

Considering the long tradition and generally assumed usefulness of breathing control techniques in asthma, it is surprising how little is really known about their effectiveness. The limited evidence available suggests that at least some techniques such as inspiratory muscle training or hypoventilation exercises can be beneficial in reducing medication consumption. However, this measure may less reflect an improvement in the disease than encouragement to use bronchodilators less or to report less use. Trials of the Buteyko breathing method could be particularly susceptible to the influence of social desirability, and would profit from electronic monitoring of inhaler use. Basic lung function measurements have generally not shown improvement with breathing training, although rationales for increasing PCO_2 imply at least limited improvements in mechanical lung function parameters. It remains to be seen whether more sensitive measurement techniques than spirometry will yield evidence for such changes. In any case, the current lack of spirometric evidence of improvement suggests that breathing training will not be able to add much to modern pharmacotherapy in improving basal lung function. However, such training may have a more important role in controlling asthma in terms of reducing variability of lung function across the day, reducing reactivity of the airways to a variety of trigger factors, and reducing airway inflammation. Indicators of these factors may be the more promising outcome measures in this type of research.

The current state of the literature leaves many important issues unresolved. More basic research is needed on psychophysiological effects of specific breathing techniques in asthma (e.g., abdominal breathing). A number of techniques such as pursed-lip breathing and nasal breathing have never been evaluated alone in controlled studies, although their rationale is convincing and they are frequently recommended in clinical practice. No information is available on breathing training in subgroups of patients such as adults versus children or patients with asthma of differing severity. Another issue not yet addressed is whether training will generalize to everyday life with its diverse settings, challenges, asthma triggers (e.g., strong emotions, physical activities, allergen and pollutant exposure, weather conditions), and asthma symptoms (e.g., shortness of breath, wheezing, congestion, cough). Follow-up monitoring to study the stability of manipulation success and long-term effects of training methods is clearly needed. Because success in achieving training goals cannot be assumed solely on the basis of improvements recorded in the laboratory situation where the patients can devote their attention to breathing as they were taught, additional evidence from ambulatory recording outside the laboratory could be helpful. Finally, a psychophysiological perspective on learning processes in the modification of breathing behavior (Ley, 1999) is needed to establish realistic goals and expectations for outcomes of breathing training.

NOTE

1. During the publication process of this paper, another controlled trial was reported comparing the Buteyko hypoventilation training with a breathing pattern modification training (inspiratory to expiratory time ratio 1:2, device of Singh et al., 1990) and a control group with placebo breathing pattern modification (sham device) (Copper et al., 2003). Only bronchodilator use and symptoms were reduced in the hypoventilation group compared to the other groups and no effects were found in nonspecific hyperreactivity (methacholine), FEV_1, asthma exacerbations, corticosteroid use, or general and asthma-specific quality of life. Again, the study did not include PCO_2 measurements as evidence of manipulation success. Thus, a valid test of the main physiological rationale of the Buteyko method may not have taken place.

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Thomas Ritz, PhD, is a senior research scholar at the Psychological Institute III, University of Hamburg, Germany. He has done extensive research on the psychophysiology of respiration and mechanical lung function, behavioral medicine of asthma. In recent years he has collaborated with teams at the University of Hamburg, Germany, the University of London, UK, and Stanford University, United States, funded by the German Academic Exchange Service (DAAD), the German Research Society (DFG), and the NIH. He is recipient of the Distinguished Scientific Award for an Early Career Contribution to Psychophysiology from the Society for Psychophysiological Research (SPR) and is currently serving as President of the International Society for the Advancement of Respiratory Psychophysiology (ISARP).

Walton T. Roth, MD, is a professor of psychiatry and behavioral sciences at the Stanford University School of Medicine and Chief of the Psychiatric Consultation Service, Veterans Administration Palo Alto Health Care System. He has published more than 100 scientific articles on clinical psychophysiology.