Whole-Body Breathing

A Systems Perspective on Respiratory Retraining

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HISTORY

This chapter describes a breathing method that has been developed over the past 50 years in Europe. It includes elements of direct respiratory retraining, as well as indirect approaches to modify respiration by way of its connections to the whole body. It is combined with a systems perspective by taking mental and physical tension states into account.

One of the roots of the method is the work of voice teachers in Germany and the Netherlands. Gerard Meyer imported the techniques of audible inhalation through the lips, developed by the German laryngologist Ulrich (1928) into the Netherlands. The main focus was to achieve an optimal inhalation at high speed and well distributed along the whole of the trunk. It implied full relaxation of exhalatory tension and contraction, which could remain after previous exhalatory effort, in singing a phrase. Inhaling through pursed lips was meant to open the throat and allow a full column of air to flow in. It was combined with body movements, such as swinging a leg, flexing the spine, or moving the head forward and back, to facilitate coordination through the whole body.

Although the purpose was to increase voice production among students of singing, it appeared that breathing and vocal problems responded well. One of Meyer's pupils, Bram Balfoort, was a voice teacher as well as a therapist. He had a private practice and worked in an academic hospital, where he successfully treated lung patients with "relaxed breathing therapy" from the early 1950s to the late 1970s. At the end of his career, he started treating patients with hyperventilation syndrome and was one of the first to have success. He found that many had the tendency for high exhalatory residual tension, which led to difficulty inhaling and a sense of dyspnea. Another of the pupils of Gerard Meyer developed a method for treatment of stuttering based on the breathing techniques in the same time period.

I cooperated with Balfoort for several years. This resulted in a popular book (Balfoort & Dixhoorn, 1979) and further development of the techniques. By applying them in the context of cardiac rehabilitation and studying the effects of various procedures using biofeedback, I shifted the emphasis from breathing technique to a wider perspective of relaxation, body awareness, and tension regulation. An initial treatment protocol was the basis of a clinical trial of breathing therapy in the early 1980s on patients who had experienced a myocardial infarction. Clear benefits appeared from adding relaxation to exercise training (Dixhoorn & Duivenvoorden, 1989; Dixhoorn, Duivenvoorden, Staal, & Pool, 1989). This outcome had far-reaching effects on cardiac rehabilitation practice in the Netherlands. Now most hospitals conduct a cardiac rehabilitation program that includes relaxation therapy using the present method.

I applied the concepts of Edmund Jacobson (see McGuigan & Lehrer, Chapter 4, this volume) to systematically reduce residual, unnecessary muscle tension and effort associated with breathing. This was supplemented by elements from the dynamic system of Feldenkrais (Feldenkrais, 1972), who defined effort as muscle tension that is in excess relative to its function in moving the bony structure of the body. As a result, I developed a model for breathing patterns in relation to skeletal movement, particularly the spinal column. Instructions were designed that influence breathing movement throughout the body, from the head to the feet, in a way that is accessible to everyone. Finally, a systems perspective was applied. Breathing was seen in continuous interaction with mental and physical tension states. The main function of therapy is the self-regulation of tension. The method has been described in a manual (Dixhoorn, 1998a) that became the basis of a 3-year part-time education in breathing therapy for professionals, who apply it to a wide range of problems.

THEORETICAL FOUNDATIONS

Basics of Respiration

Respiration is a rhythmic contraction and expansion of the body, as a result of which air flows in and out of the lungs. It can be represented as a curve, going up as the air flows in with inhalation and down as the air flows out with exhalation (Figure 12.1). Normal inhalation time is about 40% of total cycle length, and exhalation is about 60%. There are slight pauses or breath holds at the end of inhalation (about 3–5%) and at the end of exhalation (5–10%), when the flow reverses. However, there is great variation in the timing of respiration. Total cycle length determines the rate of respiration per minute, or cycles per minute (CPM), which also shows great variation, and can be anywhere between very low frequencies of 3–6 CPM and higher frequencies of 16–24 CPM, or even higher. The amount of air that flows in and out of the lungs is another variable that determines

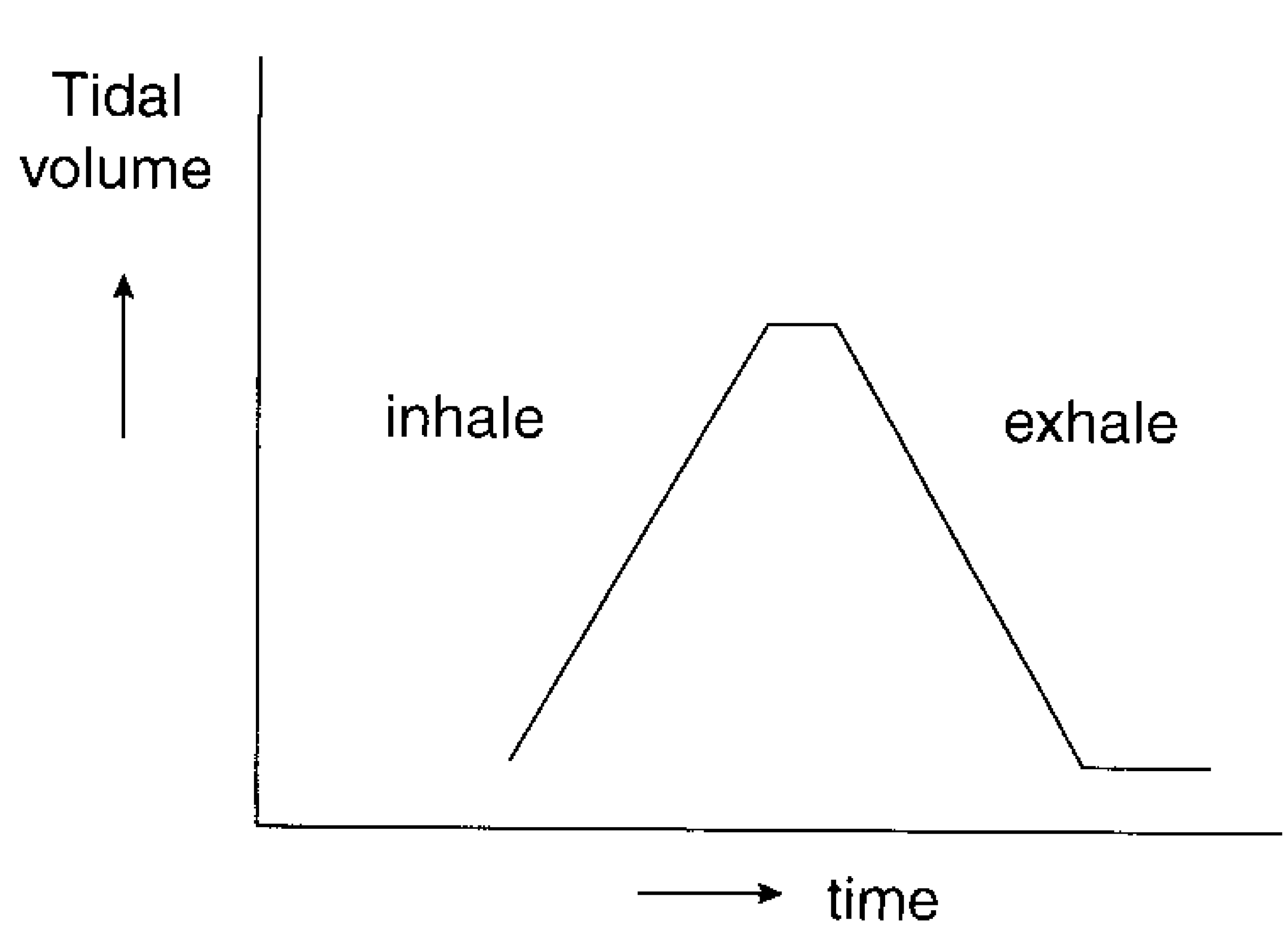

FIGURE 12.1. Respiration curve.

breathing pattern. It is called tidal volume, V_t, and varies greatly as well. In resting situations it is normally between 0.3–0.5 liters. The minute volume (MV) is the total amount of air that passes in and out of the lungs per minute. It is the product of V_t and CPM.

The action of air passing in and out of the lungs is called *ventilation*. The outside air that comes in supplies fresh oxygen, and the air that is expelled from the lungs contains carbon dioxide (CO_2). Both gases are essential for (aerobic) metabolism, which provides the energy that the living system requires. Oxygen combines with nutrient substances to produce energy and leaves water and CO_2 as waste products. Thus the metabolism in living tissues produces CO_2, which is passed to venous blood and carried to the lungs. In the small air sacs, or *alveoli*, the blood capillaries allow diffusion of the gases between the blood and the air. The high concentration of CO_2 in the blood creates diffusion to the alveoli, which contain the outside air with much lower concentration of CO_2. At the end of expiration, the concentration of CO_2 in the expired air almost equals the venous concentration. This end-tidal CO_2 ranges between 37 and 43 mm Hg. Carbon dioxide is important for many reasons, including its determination of the acidity of the blood, or pH. The pH is vital for homeostasis and needs to be regulated within a strictly delimited range. When CO_2 drops, the blood becomes less acidic; when CO_2 rises, the blood becomes more acidic.

By contrast, oxygen concentration is higher in inspired air than in venous blood, and oxygen diffuses in the alveoli into the capillary blood vessels. The oxygenated blood circulates back into the heart and from there throughout the body. Almost all of the oxygen is bound to hemoglobin molecules in the blood, which carry and store it. A small percentage is dissolved in the blood and has sufficient pressure to allow it to pass to the tissues that need it. Under normal conditions the hemoglobin in arterial blood is almost 100% saturated with oxygen. When the pressure of the dissolved oxygen (pO_2) drops, the saturation decreases slowly but leaves sufficient oxygen in storage. However, when the acidity of the blood decreases because of low CO_2 levels, oxygen is bound here tightly to the hemoglobin and passes less easily to the tissues. This is called the *Bohr effect* (Lumb, 2000).

Normally, minute ventilation is regulated automatically on the basis of the requirements for gas exchange. When the body becomes more active and requires more energy, metabolism increases, more oxygen is required, and more CO_2 is produced. Mostly on the basis of CO_2 levels, the body increases ventilation. Hypoventilation can occur when the lungs function insufficiently because of lung disease—for instance, chronic obstructive pulmonary disease (COPD). In that situation, oxygen levels can drop (hypoxemia), CO_2 levels rise, and the need for ventilation cannot be met, which results in dyspnea or the sense of air hunger or laborious breathing. In patients who are prone to hypoxemia, it is recommended therefore to increase physical effort in exercise training only on the basis of regular measurement of the pO_2 in the blood. This can be done quite easily by way of an oximeter through thin skin, for instance, of an earlobe (Tiep, Burns, Kao, Madison, & Herrera, 1986). By contrast, hyperventilation occurs when ventilation is too large for the metabolic requirements of the moment. As a result, CO_2 pressure drops, resulting in hypocapnia, and the blood becomes less acid. Although the pO_2 may rise in acute hyperventilation, after some time the pH increases, which causes the oxygen to be bound tighter to the hemoglobin, which results, paradoxically, in less tissue oxygenation. Thus hyperventilation is primarily characterized by hypocapnia. Hypocapnia can be measured by capnography of the expired air, either exhaled through a mouthpiece or sampled from a tube in the nostrils. It may also be measured transcutaneously, but that is less accurate. Hypocapnia can lead to many complaints (see Table 12.2 later in the chapter), but it does not cause dyspnea. When there is no physical cause for hyperventilation, the excess ventilation is thought to be a problem of tension, anxiety, or faulty breathing.

The same ventilation can be achieved through many combinations of CPM and V_t: Many small breaths per minute move the same amount of air in and out of the lungs as a few large breaths. Although mechanical constraints limit the number of possible combinations without extra work in breathing, the remaining range is large. So far, no optimal breathing pattern has been established. The actual choice of V_t and CPM, made in the breathing regulatory centers in the brain, depends much on the state of the organism as a whole and reflects its condition.

The effect of ventilation is that outside air, which is high in oxygen and low in CO_2, comes into contact with capillary venous blood, which is low in oxygen and high in CO_2, so that diffusion occurs. An important factor, therefore, is the space between the opening for air (mouth and nose) and the lung alveoli. It is called "dead air space" because the air passes through it without actual diffusion. It consists of the throat, trachea, and bronchi. The size depends on the structure of the body, but it averages about 0.15 L. It can be enlarged by breathing through a tube, which decreases effective ventilation. When the tube is so large that the volume of the dead-air space equals tidal volume, there is no effective ventilation: No outside fresh air comes into the lung alveoli. Similarly, high-frequency breathing with very small breaths leads to very little effective ventilation, because the size of V_t approaches dead-air space. Its main use is to cool the body by the flow of air: inhaling cool outside air, which is heated inside the body and flows outside by exhalation. By contrast, when the body becomes more active and metabolism increases, ventilation increases first by an increase of V_t (Wientjes, 1993). The deeper breaths lead directly to more effective ventilation because the dead-air space becomes a smaller part of tidal volume.

The combination of time and volume results in flow: The amount of air that flows in during inhalation time represents inhalatory force or drive. When more air is inhaled in a shorter time, the inhalatory drive is high. This may occur when the person is dyspneic, for instance, if COPD is present, or when a novice diver breathes through a gas mask for the first time under water. It may lead to a breathing pattern of "gasping," that is, making great effort to inhale air.

The contraction and expansion of the body is performed by the respiratory muscles, which change the volume of the trunk. When the volume of the trunk increases, the interior pressure decreases relative to the atmospheric pressure. When the airways are open, the air flows inside the lungs. However, the movement of expansion is made in the trunk as a whole, reaching from the first rib to the pelvic floor. Under resting conditions, about two-thirds of the volume changes are achieved by the diaphragm. This is a double dome-like muscle that separates the chest from the abdominal cavity. When it contracts, it increases the size of the chest cavity in three directions. It moves downward, pressing on the abdominal cavity, and it lifts the lower ribs, which elevate sideways and in anterior direction (Kapandji, 1974). Other respiratory muscles include the intercostal muscles, some of which elevate the ribs for inhalation while others bring them down for exhalation. The scalene muscles elevate the upper ribs toward the neck. The abdominal muscles compress the abdominal cavity and help the diaphragm to move upward for exhalation. The pelvic floor muscles resist the downward pressure of the diaphragm and help with exhalation.

A Systems Perspective

Breathing is dependent on many factors, both physical and mental, that influence its rate, depth, and shape. Within psychophysiology, respiratory measures function mainly as dependent variables, reflecting the state of the individual. Within *applied* psychophysiology, however, respiration also functions as an independent variable, a potential influence on one's state. Breathing is the only vital function that is open to conscious awareness and modification (Ley, 1994). The individual may voluntary modify breathing patterns in order to change mental or physical tension states. A study by Umezawa found that such modification was the most popular maneuver for managing stress (Umezawa, 2001). Thus there is a double relationship between breathing and the state of the system, represented in Figure 12.2, which makes matters rather complicated. The arrows that lead from respiration toward physical or mental tension state represent the regulatory role of breathing; the arrows that lead toward respiration represent its role as indicator. The distinction is important to avoid confusion, but it tends to be overlooked. For instance, breathing may respond to relaxation of the system, indicated by longer exhalation pauses or participation of the abdomen in breathing movement. These characteristics are then taken as a guide for regulation by practicing exhalation pauses or abdominal breathing. It does not follow however, that the system automatically relaxes when these characteristics are imitated. Voluntary breath modification in a high-tension state may give a sense of control but may also disturb respiration even more. This explains why some individuals do not respond favorably to simple breathing advice or instruction. The model further shows that measuring breathing to estimate the individual's state (indicator role) can be complicated by voluntary changes in breathing or control of breathing by the individual who is aware that breathing is being measured. Focusing attention on breathing may modify it. It is, therefore, not easy to measure "spontaneous" breathing. Conversely, any breathing maneuver involves both respiratory changes and changes in mental and physical state. Thus, although its effects may be attributed to respiration, they also may be caused by concomitant changes in the entire body system that affect both respiration and the outcome parameter.

Paced breathing, for example, consists of modification of respiration rate but also involves focusing of attention and often a stabilization of posture, which have widespread effects as well. It is therefore important in studies of breathing therapies that respiratory measures be included to see whether breathing actually changes, although even in such cases the effects may also be attributed to other factors. For instance, Meuret, Wilhelm, and Roth (2005) studied the effect of six sessions of clear-cut breathing regulation, assisted by capnography feedback, for patients with panic disorder. Panic attacks decreased, and pCO_2 rose. These effects were correlated, leading to the conclusion that the anxiety decreased as a result of ventilation decrease. However, the sessions equally taught the participants to focus their minds and sit still for an extended period of time, which may have resulted in a relaxation response that led to lower anxiety and reduced ventilation (Benson, Beary, & Carol, 1974). Alternatively, participants in the study may have

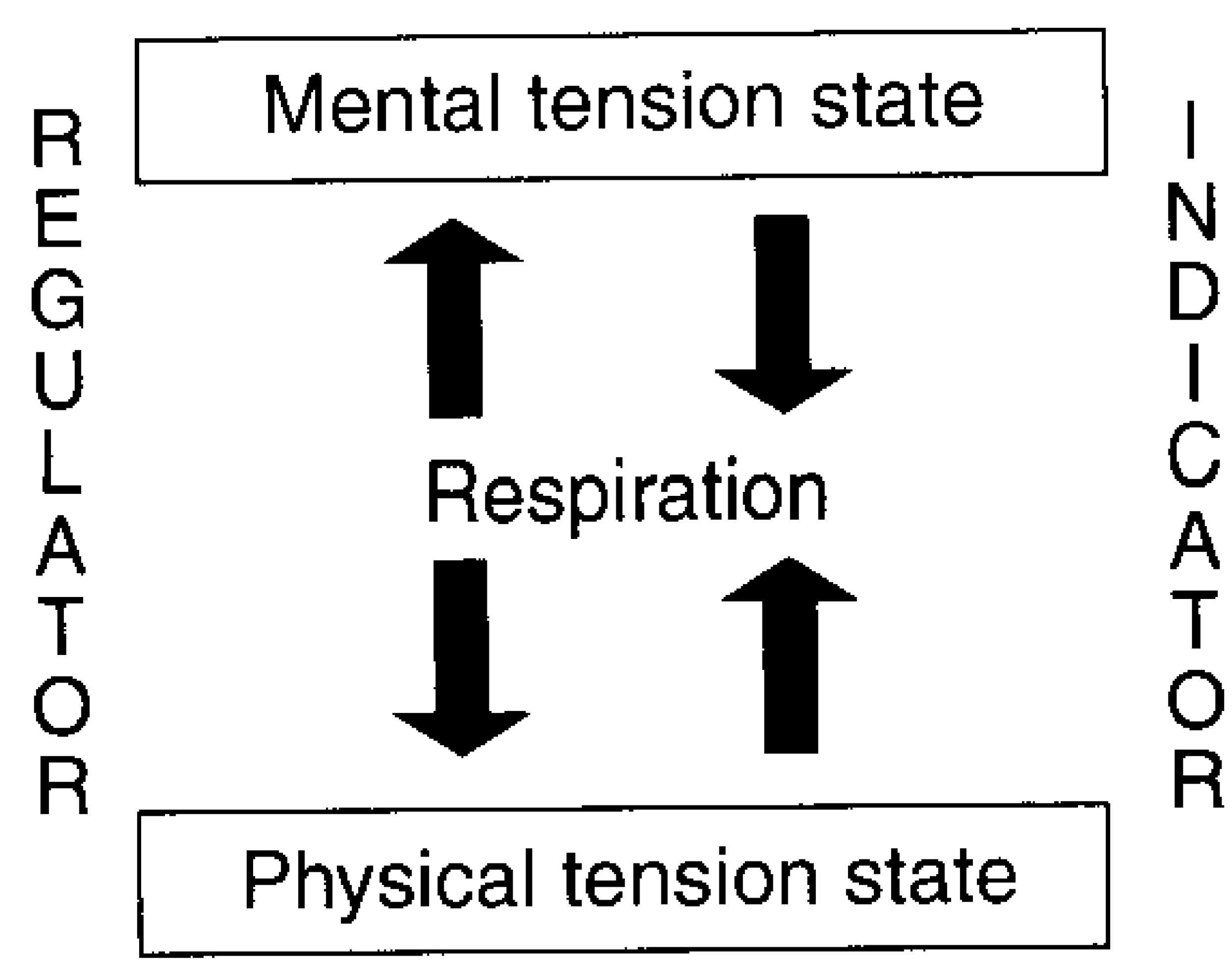

FIGURE 12.2. Model of double relationship between respiration and individual system.

concluded from the sessions that their anxiety attacks were not due to an impending catastrophic event but simply related to breathing. This process of cognitive reattribution of their attacks to an innocent and controllable factor may have reduced their anxiety and, as a result, reduced ventilation. The researcher who wants to disentangle these factors must measure all of them. For clinical practice, it is recommended that the complexity of the interrelationships be taken as a starting point.

This model represents a systems view of respiration. It underlines the complexity of breathing instruction, which always includes both mental and physical components and effects. One consequence of the model is that breathing instruction consists of two parts—one in which breathing is consciously modified or regulated and one in which this regulation is consciously stopped. This is comparable to Jacobson's procedure of consciously tensing a muscle in order to learn to consciously stop muscle tension. One cannot ask the participant to stop breathing, but it is possible to stop a conscious regulatory practice. The purpose is to observe how the system responds to the regulation and whether there is a durable and stable effect on breathing after regulation has stopped. The instruction that regulates breathing is more like an invitation to the system to respond favorably than a dominant influence. To underline this, it is important to teach a specific skill to practice, but it is equally important to have the participant stop practicing.

Another consequence of the model is that breathing instruction may consist of instructions for posture, body movement, or attention, not even mentioning breathing explicitly, but influencing it indirectly. The list of practical strategies shows this clearly (see the "Instructions" in the Treatment Manual later in this chapter). A good example is an intervention that helps lung cancer patients deal with dyspnea (Bredin et al., 1999) of which direct respiratory regulation is only a part. Once breathing has changed, this may spontaneously draw the attention of the patient, or the patient may be asked to pay attention to it. In scientific studies the complexity is often overlooked or ignored to reduce the treatment to a reproducible protocol. However, the model specifies that such a reduction may be costly when the context of an instruction is as important as the instruction itself. For instance, many participants, particularly novice ones, have trouble performing a breathing instruction and use too much effort initially. This may lead to an overshoot and production of opposite effects. Such effects probably occur less often when sufficient attention is paid to the physical and mental tension state. For instance, Choliz (1995) reported on a highly effective breathing instruction for insomnia, in which underventilation gradually led to a state of drowsiness. He simply described the respiratory protocol without mentioning any strategy to make the system accept the instruction and facilitate a favorable response. The protocol was replicated (Hout & Kroeze, 1995) and led, in many participants, to *hyper*ventilation! On the basis of this, the treatment and its supposed mechanism were rejected.

A further consequence of the systems view is that it is very difficult to define "good" and "bad" or "functional" and "dysfunctional" breathing. A particular breathing pattern may look irregular or effortful but actually result from a specific factor within the system to which breathing responds. A good example is the breathing pattern of patients with COPD whose lungs are hyperinflated and whose diaphragms are maximally active. Their breathing is clearly upper thoracic and effortful, involving auxiliary respiratory muscles, and they are often told or taught to breathe more abdominally. In that condition, however, upper thoracic breathing may be a functional way of elevating the chest to inhale air, and "abdominal" breathing may not be functional at all and may even worsen their already insufficient ventilation (Cahalin, Braga, Matsuo, & Hernandez, 2002;

Gosselink, Wagenaar, Rijswijk, Sargeant, & Decramer, 1995). However, upper thoracic breathing may also be a dysfunctional exaggeration of a functional adaptation. The sense of dyspnea, for instance, leads to a quick inhalation (Noseda, Carpiaux, Schmerber, Valente, & Yernault, 1994), which may result in insufficient time for adequate distribution of inhalation and thus to excess ventilatory effort. It is difficult, therefore, to differentiate between functional and dysfunctional breathing. A good way is to observe whether instructions that aim to reduce unnecessary effort in breathing are successful in changing the breathing pattern and whether the sense of dyspnea responds to that (Dixhoorn, 1997b; Thomas, McKinley, Freeman, & Foy, 2001). It is important to include time for the response to occur after instruction. When a particular breathing pattern changes and remains visibly less effortful after instruction, the pattern was probably dysfunctional to some extent. This formulation refers to the first consequence of the model: that breathing instruction entails that regulation is also stopped. If that condition is not fulfilled, the observed change in breathing pattern may be simply the result of conscious practice while being monitored or observed.

Definitions of Breathing

Breathing instruction and the sense of laborious breathing, or dyspnea, can be viewed from various perspectives, depending on the definition of breathing. The most common definition of breathing refers to the *passage of air* that serves for *lung function and ventilation*. Breathing is measured by way of lung function parameters such as rate, inhalation time, exhalation time, pauses, tidal volume, minute volume, flow (duty cycle), O_2 saturation, and end-tidal CO_2. The mechanics by which the air is moved in and out of the lungs are of secondary importance, because they hardly influence lung function. Dyspnea is a common complaint in lung disease, and the medical point of view is to objectify its basis in lung function. This is partly successful. Also, lung function does not account for the function of air passage in communication. Without air movement, there is no voice or sound, and the person cannot smell. The regulation of air passage to ensure speech and communication is highly complex and represents a different process from ventilation (Conrad, Thalacker, & Schonle, 1983). The behavioral demands contingent on communication mostly overrule the ventilatory requirements (Phillipson, McClean, Sullivan, & Zamel, 1978). Thus air passage has an important expressive function that is often neglected. The implication is that breathing difficulties may signify difficulties in social interaction and experience rather than ventilatory problems.

A second definition refers to the *rhythmic expansion and contraction* of the body. This breathing motion serves, of course, to bring the air in and out of the lungs, but it has other functions as well. Breathing is a central pump, or oscillator, in the body that moves various organs and the fluids; for example, it acts to move venous blood, lymph fluid, and the cerebrospinal fluid. In addition to these hydraulic effects throughout the body, there is a clear oscillatory relationship with heart rate and heart rate variability that affects the autonomic nervous system (see Lehrer, Chapter 10, this volume). Next, the mechanical properties of volume changes have a dynamic of their own. The coordination of breathing movement determines, to a large extent, the effort of the pump and the sense of dyspnea but also affects movement and posture. The components of the breathing apparatus play a role in posture, weight bearing, walking, and lifting objects, as well as in moving air in and out of the lungs. The qualities that apply here have to do with smoothness of movement, fluency, effortlessness, and coordination throughout the whole system, from head to feet.

A third definition of breathing refers to its role in *self-perception*. Like any movement, breathing is a sensory motor activity that serves to provide important feedback to the conscious individual about his or her state. The sense of freedom of movement or restriction in space, the sense of tension or relaxation within oneself, the sense of safety or danger within the environment, all have much to do with the quality of internal feedback. Thus a person may feel free and at ease or restricted and even dyspneic because of changes in self-perception. An important aspect of breathing is, therefore, to what degree its sensation is accessible to conscious awareness without this awareness leading to disruption of the natural rhythm. For instance, patients with lung disease can be "non perceivers," which means that they do not notice changes in lung function (Noseda, Schmerber, Prigogine, & Yernault, 1993). This is a risk because it prevents them taking adequate measures in time, but it also appears that the response to medication is greater in "perceivers." Poor perceivers of respiratory sensations, for example, have more "near death" experiences from asthma (Kikuchi et al., 1994). In clinical practice it appears that many individuals have little awareness of the quality of breathing and lack this sort of feedback. The purpose of breathing therapy is to enhance this awareness by inducing a marked improvement in perceived quality. At the same time, overconsciousness needs to be avoided. Breathing is a natural and automatic function that does better without constant conscious attention. For that reason, the indirect strategies are extremely useful.

These three perspectives are complementary; they represent three ways of looking at dyspnea and breathing difficulties, and they lead to different measurements and treatment strategies. Ideally, breathing therapy should take all three into account. It is interesting what the result of a dysfunction is in the latter two viewpoints—when the quality of breathing movement is low and effortful but at the same time self-perception is also limited. What will a person with these characteristics report? Clearly, nothing special. Although internal tension may be high, it does not enter conscious awareness. This is a quite common situation and may explain why breathing instructions can be met with mixed feelings. An increased ease in breathing may feel pleasant, but the increased awareness of the tension is unpleasant. It all depends on which one dominates.

Strategies for Breathing Regulation

In this section strategies are described to modify breathing that are either direct or indirect, that often consist of combinations of breathing instruction with attentional and/or movement instruction, and that aim at either breath or tension regulation or both.

Timing

Counting breathing is a common procedure that consists of coupling attention to breathing. In Benson's Respiration One Method (Benson, 1993) breathing is counted '1, 1, 1,' and so on because the person may lose count, which gives rise to unrest. Breathing may also be counted from 1 to 10, or the inhalation and exhalation may be mentally followed with such words as *in*, *out*, *in*, *out*. Attention can also be coupled to breathing without counting; the instruction may be to mentally follow inhalation and exhalation. *Pacing breathing* is used mostly to slow down breathing and may consist of the instruction to breathe at fixed rates: "in, 2, 3, out, 2, 3," or "1, 2, 3, 4" during inhalation and "5, 6, 7, 8, 9" during exhalation. There may be protocols for this, gradually increasing length, and it may be prescribed in a directive fashion or may be more open and free. The rationale is mostly that slower breathing leads to relaxation or that it increases CO_2 and reduces hyperventilation or both. Sometimes a device is constructed that indicates by a tone of varying pitch how long to inhale and how long to exhale. Again, this may be a fixed preset rate, or the instruction may depend on the actual breathing rate of the individual, in which case the instrument contains a sensor to measure that rate (Schein et al., 2005). Sometimes the rate is subsequently adapted to breathing measured during sessions (Grossman, Swart, & Defares, 1985) to achieve a feasible lengthening.

Focusing on *exhalation pauses* is a good way to lengthen breathing, because pauses naturally appear under relaxation conditions (Umezawa, 1992). Instructions that can help achieve this state are "in, out, stop" or "pause" or "in, 2, 3, out, 2, 3, pause 2, 3." In the Buteyko method, these pauses are gradually lengthened to approach almost one minute (Bowler, Green, & Mitchell, 1998). During transcendental meditation they are observed to occur spontaneously for about 30 seconds, particularly during EEG changes (Badawi, Wallace, Orme-Johnson, & Rouzere, 1984). In hyperventilation treatment, the focus on exhalation pause serves to increase CO_2. By contrast, pacing may also be used to increase respiration rate and decrease depth. An example is to count "in, out, stop" at such a pace that it results in a ratio of respiration to heart rate of approximately 1:4. Such short and shallow breathing helps to break an overconscious pattern of slow breathing or to induce shallow breathing, which is useful when there is a persistent unproductive cough. The therapist should warn the client not to breathe deeply. This pattern fits a situation of high tension or challenge, for instance, during delivery of a child, but it is also useful to show that, during rest, reduced ventilation is sufficient.

Interestingly, short and shallow breathing during rest may lead to effortless breathing, whose movement is perceptible throughout the whole trunk. The reason is that a low volume requires little effort and leads to relaxation of respiratory muscles. Another variation is to pay attention to the *transitions* between inhalation and exhalation and exhalation and inhalation. The breathing cycle is divided into four parts: in, pause, out, pause. Attention is brought to the period when breathing reverses direction and stops for a brief moment. This is a natural control strategy that helps to focus and calm the mind and make breathing less hurried. It is useful when someone is dyspneic from lung disease, because it provides a small margin of control. It may be a starting point for gradually increasing the time period of the transitions.

Coupling to Movement

An indirect and natural way of pacing breathing is through *coupling to movement*. Any movement that has a periodicity similar to breathing tends to synchronize with it. Walking, cycling, or running tend to go easier when the rate of repetition has a whole number ratio to the rate of breathing. When coupling has occurred, slowing down the movement tends to slow down breathing. For example, walking slowly for some time may gradually lead to slower and deeper breathing. At the same time, inhibition of habitual speed leads to increased mental focus and attention, which, in turn, favors slower breathing. When the goal is too slow, however, the effort to do it creates unrest and distraction and thus quickens respiration.

Small, repetitive movements are easy to couple to breathing: rolling the hands or arms in and out, moving the head up and down, pressing the fingers together and relaxing them, flexing and extending the feet. Single tense–release cycles can also be coupled to breathing, as is done in the abbreviated version of progressive relaxation (see Chapter 5, this volume), in which tensing a muscle is coupled to inhaling. This is a natural combination, but in the present method it is reversed: tensing is coupled to exhaling (see "Instructions" section in Treatment Manual). This combination requires attention and, therefore, acts as a focus of attention. Movements that flex and extend the spine play a special role, because this tends to couple mechanically with inhaling and exhaling. When running, animals such as dogs and horses tend to inhale when the four legs are spread out and breathe out when the legs are together. Similarly, the yoga exercise series, "sun greeting," consists of an alternation of flexing the whole body (exhaling) and extending it (inhaling). On a smaller scale, in the sitting position, bending forward or sitting upright tends to extend the spine and couples with inhaling, whereas sitting backward in a slump tends to flex the spine and couples with exhaling (see "Instructions"). Using these combinations facilitates breathing instruction, but it may also be used with reverse coupling. The reason to *reverse coupling* is to break the habitual combination and thereby increase the flexibility and the area of breathing movement. For instance, sitting slumped or with head down helps the body to breathe in while the spine is flexed. Once this is possible, the movement to sit back and round the spine can be combined with inhalation and sitting upright with exhalation. This facilitates "width breathing," which may feel unfamiliar and strange. When someone gets the knack of it, however, the range of breathing movement increases, the diaphragmatic motion is stimulated (Cahalin et al., 2002), and dyspnea may decrease. Another option is to reverse the habitual combination of raising the shoulders while inhaling (see "Instructions"). These kinds of instructions may extend to ones in which movement and breathing are *uncoupled*. This increases flexibility of breathing. Also, breathing serves as an indicator of the effort involved in the movement. Thus, in Feldenkrais's method, a fully functional movement implies that it is carried out with undisturbed breathing. A simple example is rolling the head in the supine position, which tends to interfere with breathing until breathing has become more flexible and/or the rolling movement has become more effortless.

Air Passage

The *passage of air* is a good way to modify respiration, which is done naturally by patients with COPD who use *pursed-lips breathing* to lengthen exhalation when dyspnea occurs. The added resistance to the air by the lips helps to keep the airways open and postpones airway collapse, thus enhancing ventilation. Similarly, audible exhalation through the lips (see "Instructions") lengthens it; in this method, however, it is done with less force than in pursed-lips breathing and is combined with slow inhalation. After a longer exhalation, one tends to inhale hurriedly, and a fast inhalation tends to be an upper-thoracic movement with auxiliary breathing muscles, particularly when one has gotten out of breath. The resulting "gasping" inhalation confirms the sense of dyspnea. Gasping is prevented by the instruction to exhale gently and slowly. It results in generally larger tidal volumes and should be done a few times (5–6), after which normal nose breathing is resumed. This is to prevent hyperventilation.

Slow inhalation tends to improve the distribution of breathing movement, because all the components are allowed more time to become involved. It results in a larger volume, more involvement of the whole body, and less risk of hyperventilation, particularly when breathing though the nose. A good example is the idea of smelling a nice fragrance, such as a flower. The image of enjoying the inhalation of the air slowly into the body adds to this effect. It may be combined with imagery of the airways and of the air passing from the tip of the nose through the inside of the nose and throat, down into the lungs and chest, and even further down the body. By contrast, mouth breathing tends to result in shorter inhalation times.

Resistance training is a technique for strengthening the power of inhalatory muscles, such as the diaphragm. It can be done by breathing through a mouthpiece with a varying opening width, thus increasing the resistance and providing a training impulse to the muscles (Dekhuijzen, 1989). This is useful for patients with lung disease, but a recent study showed a good effect on exercise capacity and dyspnea in patients with heart failure (Laoutaris et al., 2004). A similar method of resistance training comes from voice training and is used by singers to open the upper airways. They breathe in through the lips, making a sound like "fff" from the lips, in order to increase resistance (Ulrich, 1928; Balfoort & Dixhoorn, 1979). This trains rapid and full inhalation, which is important for performance. Generally, inhaling through a mouthpiece tends to increase ventilation (Han et al., 1997). This effect counteracts the effect of breathing through a tube, which is used for hyperventilation complaints to increase dead-air space.

Distribution of Breathing

The shape or form of the volume changes with breathing can vary considerably, because the potential volume change in the trunk is much larger than is possible for the lungs. Thus the same ventilation can be achieved by different parts of the trunk, which ensures that ventilation can be maintained in very different postures. This leaves a large margin of flexibility and also allows conscious control and modification. Before practicing voluntary control of the location and form of breathing movement, however, it is important to realize that the areas of the body that are actively involved in breathing movement largely depend on posture, on mental state (focused or passive), on emotional or expressive state, and on physical tension state (energy and ventilation requirement, nervous tension). When a person is resting, mentally and physically, tidal volume is relatively low, primarily achieved by the diaphragmatic pump, and the muscles of the trunk are relatively relaxed. In this situation visible breathing is mainly costoabdominal: the lower ribs widen, and the abdomen expands with inhalation. The upper ribs and so-called auxiliary muscles, such as the scalenes, nevertheless also contract with each inhalation. This is necessary to prevent a slight collapse of the rib cage under the increased negative pressure inside that leads to the inflow of air (Decramer & Macklem, 1985). It is hardly visible, but its absence is not functional, and maintaining upper chest immobility should not be taken as a sign of functional breathing. When the activity and tension levels rise, volume increases and involves more movement of the rib cage, and the muscles around the abdomen may tighten a little. As a result, breathing becomes "higher." From this natural response, many strategies advocate that breathing remain "low" in the body while under stress or during greater activity.

Thus *abdominal breathing*, diaphragmatic breathing, and slow deep breathing are common practices, probably the most common (Gevirtz & Schwartz, 2005). This strategy is quite effective in remaining or becoming quiet and calm and in reducing stress (Peper & Tibbets, 1994; Czapszys, McBride, Ozawa, Gibney, & Peper, 2000). The person is taught to put the hands on the abdomen (or the therapist may do so) or to put a weight, such as a book (Lum, 1977), on the abdomen in the reclining position and make it move up and down with breathing. Lum reported 75% success among more than 1,000 patients with anxiety and hyperventilation (Lum, 1981). It is particularly useful in individuals who demonstrate an exaggerated response to the rise of tension, which is dysfunctional and dysponetic (Whatmore & Kohli, 1974) and which can be reduced in this way. This makes breathing a quick and easy tool for handling stress.

However, two points need to be considered. First, the effect of this strategy may not be due to breathing itself but to the concomitant shift in attention, which is directed to the center of the body. This is the area of the center of gravity, and, as such, it represents a neutral ground for attention, less threatening or challenging than the visual perspective in front or in one's mind. This reduces the mental tension state. Attention in the center also implies that body movement tends to become more functional and less effortful. This reduces the physical tension state. Thus breathing may simply be the tool to induce these shifts. A second point is that the emphasis on abdominal movement may lead to the mistaken notion that the (upper) chest should be immobile. As stated earlier, reducing exaggerated upper thoracic breathing does not imply that the upper ribs should not move at all. Functional inhalation requires the rib cage to change its shape as a whole (Parow, 1980; Bergsmann & Eder, 1977; Balfoort & Dixhoorn, 1979).

Functional upper chest movement is important for breathing and, in particular, for emotional freedom of expression, as well as for voice production. It is intimately linked to an adequate use of the upper back. In the best singers, the upper chest rises simultaneously, with a slight lengthening of the upper spine, thereby increasing the length of the scalene muscles and making their contraction more effective. The head is tilted slightly forward, relative to the neck, which moves slightly backward. Thus the head remains still. This pattern is evoked by the beginning of a yawn (Xu, Ikeda, & Komiyama, 1991), whereby the throat and vocal cords descend. This favors voice production. It is the basis for the instruction "looking up and down" (see "Instructions"). The opposite pattern is seen in a dyspneic person, whose head is tilted backward relative to the neck, increasing lordosis of the neck during inhalation. This moves the head frontally and up, which appears as a movement of gasping for air. Instructions that promote functional upper chest breathing are also important for neck problems.

Another aspect of location of breathing movement is the *pelvic floor.* This lower diaphragm is a natural antagonist of the middle respiratory diaphragm, and their functions support each other. When the respiratory diaphragm contracts during inhalation, the pelvic diaphragm relaxes, and vice versa. Adequate contraction of the pelvic floor is necessary to carry the weight of the internal organs and to counteract the force of breath holding when lifting or carrying a weight. Thus pelvic floor dysfunction tends to compromise breathing, as well as posture. The instruction "sitting, standing" aims to facilitate pelvic floor contraction when getting up because of its coupling to exhalation. This helps to prevent urine leakage in women who suffer from this problem. Another option is the Muslim prayer posture, in which relaxation of the pelvic floor during inhalation can be observed.

Focus of Attention

Providing a *single focus of attention* is the most common way to relax and reduce tension (Benson, 1993), and it also tends to quiet and regulate breathing. Its effect on breathing does not require a focus on respiration. For some, it is best not to focus on breathing directly, as that tends to disturb it and to cause overconsciousness and dysregulation. The object of attention may be breathing movement anywhere in the body, sound or sensation of air passage, or respiratory feedback signals, but also the sense of body weight in sitting, standing, or lying quietly or during movement, the sense of touch by the therapist or oneself, words that are repeated to oneself, or any visual or auditory focus. Another dimension of attention is active versus passive concentration. *Passive attention*, or *receptivity,* is a hallmark of relaxation (Smith, 1988) and can be seen as a prerequisite for self-regulation of tension (Peper, 1979). It is in particular present when the indicator role of breathing is emphasized. In an older study, Burrow (1941) found that during "cotention," which is like an unfocused gaze in the distance, respiration rate drops greatly. He associated this with a state of mind in which the individual is in more direct contact with the whole organic system of the body. In a more recent study, passive attention, or mindfulness, was found to be associated with a different pattern of EEG activity than was focused attention (Dunn, Hartigan, & Mikulas, 1999). Thus the very attitude of passivity and not being goal directed may induce a change, including a respiratory response.

An intriguing aspect is a relationship between the *object of attention* and *distribution of breathing*. Respiratory movement follows the direction and content of attention. For instance, Peper (1996) found that the image of standing on a hard concrete floor resulted in breathing that was shallower and higher in the body than the image of natural grass. Calling attention to the supporting ground for the body on the backside and also emphasizing the width of the body may help distribute an evenness of breathing in the body. In the instruction "circling knees," the repetitive movement of rolling over the sitting bones draws attention to the supporting ground in a passive way. Awareness of the width of the eyes and the distance between the outer corners of the eyes or of the corners of the mouth and slightly increasing their distance induces the beginning of a smile, as well as a sense of breathing very easily (Dixhoorn, 1998a). This relationship is also present in the influence of attention on the *direction of inhalation*. Although the diaphragm moves downward as it contracts, a common image of inhalation is a movement upward, as if drawing in the air from above. This is strengthened when experiencing dyspnea. By contrast, the image of inhalation as a downward movement helps to let the air flow in easily and reduces dyspnea.

Feedback Devices

Various measurements of respiration can be used as a source of biological or instrumental feedback. A detailed description is given by Gevirtz and Schwartz (2005). An obvious parameter is CO_2 feedback, using capnographic measurements (Doorn, Folgering, & Colla, 1982; Fried, 1984; Meuret, Wilhelm, & Roth, 2001; Terai & Umezawa, 2004). The patient may or may not receive instructions for breathing. The main purpose is for CO_2 to reach normal levels. CO_2 biofeedback is particularly useful when hypocapnia is present. Similarly, feedback of oxygen tension is useful when PO_2 is low (Tiep et al., 1986). Another parameter is feedback for respiration rate. In contrast to paced respiration, in which a specific frequency is given, respiration rate feedback does not impose a frequency but only provides feedback of actual respiration rate. It appears to have a soothing influence, and respiration rate gradually slows down (Zeier, 1984; Schein et al., 2005; Leuner, 1984). A more directive approach is to use measurement of muscle tension and to teach a specific way of breathing that does or does not involve these muscles (Reybrouck, Wertelaers, Bertrand, & Demedts, 1987; Johnston & Lee, 1976; Kotses et al., 1991; Peper & Tibbets, 1992; Tiep, 1995). In these approaches the breathing strategy is the prime intervention, and the feedback device serves as an aid for teaching it. Another intervention is to give feedback for tidal volume in order to make patients aware that they tend to hold their breath when under stress. This may or may not be accompanied by teaching strategies for inhaling more effectively (MacHose & Peper, 1991; Peper, Smith, & Waddell, 1987; Peper & Tibbets, 1992; Roland & Peper, 1987). An overview of biofeedback techniques for lung patients is given by Tiep (1995). Finally, a more recent form of biofeedback is resonance feedback, in which the parameter consists of heart rate variability that increases with slow breathing (Del Pozo, Gevirtz, Scher, & Guarneri, 2004; Lehrer et al., 2004; see also Chapter 10, this volume).

Whole-Body and Spinal Column Involvement

Given the many interdependencies of respiration that follow from the system's perspective, the method on the one hand seeks orientation in specifying attention and posture and on the other hand follows the skeletal structure of the body. A model was developed during the 1980s that specified the relationship of the spinal column, the core structure of the skeleton, to respiratory movement (Dixhoorn, 1997a). The spinal column connects the rib cage with the head and the pelvis. When it is extended, standing upright or in the supine position, respiration involves a minute wave-like motion in the spine, which is more like a preference for motion than an actual visible movement. It originates from the rib cage, which makes a rolling movement during respiration. Inhalation involves an upward rolling movement of the chest, which is accompanied by a preference for slight lumbar lordosis and flattening of the cervico–thoracic junction. The opposite preference is present during exhalation. Therefore, small movements, initiated from the legs, arms, or head, are able to influence respiration indirectly. This is the first pattern of interaction between spinal column and respiration. The coupling of inhalation to extension is called "length" breathing. It is complemented by the opposite pattern of "width" breathing. When the spinal column is flexed, for instance in a slightly slumped sitting posture, the connections of the first pattern are blocked. This is also the case when a person lies prone. In that situation, the rib cage cannot roll upward, and the cervico–thoracic junction cannot flatten during inhalation. Instead, the costoabdominal circumference expands and lumbar lordosis flattens during inhalation. Because of the emphasis on sideways expansion, it is called *width breathing*. Breathing in both directions, horizontally and vertically, allows the body to respond flexibly to various postures. Therefore, the degree to which both patterns can be utilized is an important indicator of functional breathing and serves as a parameter of the success of breathing therapy (Dixhoorn, 1997b).

These connections are the background for many instructions of the method. They also help to deal with the issue of attention and of conscious control of breathing in several ways. First, the perception of "whole body involvement" invites a more passive concentration than attention that is actively focused on one particular area or movement. The instruction starts with one area or movement and then invites the individual to notice connected movements all over the body. Second, the periphery (arms and legs) and the back are, for most individuals, not consciously related to breathing. Thus facilitation of breathing through the instructions happens unwittingly and does not elicit conscious control. Third, the skeletal connections promote a functional use of the muscles, which tends to lead to a greater ease of movement and of breathing. The patterns may not be fully habitual, and the instructions may feel strange at first, but they tend to remain present after the period of conscious practice. Thus the instructions tend to generalize and become part of automatic movement.

Flexibility and Variability

In the 1990s the Dutch branch of what later became the International Society for the Advancement of Respiratory Psychophysiology (ISARP) set up a series of meetings to discuss the criteria for what constitutes a proper breathing pattern. It was also a theme at the international meetings (Ley, Timmons, Kotses, Harver, & Wientjes, 1996). In the end, not a single characteristic could be validated to serve as such a criterion. This conclusion supported the assumption of this method that a key characteristic of functional breathing is its variability. The manual (Dixhoorn, 1998a) stated that, rather than working toward a particular pattern of breathing, the main goal is that breathing should be flexible and