Influence of Body Position on Breathing and Its Implications for the Evaluation and Treatment of Speech and Voice Disorders

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Summary: This paper examines how breathing differs in the upright and supine body positions. Passive and active forces and associated chest wall motions are described for resting tidal breathing and speech breathing performed in the two positions. Clinical implications are offered regarding evaluation and treatment of breathing behavior in clients with speech and voice disorders. Key Words: Body position—Breathing—Speech—Voice.

Breathing is critical to normal speech and voice production. Therefore, it is not surprising that the evaluation and treatment of breathing behavior is considered to be an important component of the clinical process when dealing with clients with speech and voice disorders. However, evaluating and treating breathing behavior is a complex task, in part because breathing is influenced by so many different variables, one of which is body position. Although there is a substantial body of scientific literature on how body position affects breathing (1-9), including speech breathing (10-12), little of the existing knowledge has made it into the clinical literature. Without this knowledge, the clinician is at a disadvantage when faced with the challenge of solving speech breathing problems.

The purpose of this paper is to provide the clinician with a set of fundamental principles to serve as a guide for clinical practice, with an emphasis on the influence of body position on breathing. These principles are illustrated using the upright and supine body positions because these are the most common body positions used in clinical treatments aimed at changing breathing behavior. Presented first is a simplified description of the structure of the breathing apparatus and its function during performance of various activities, including relaxing, resting tidal breathing, and conversational speech breathing in the two body positions of interest. This is followed by a discussion of how this information relates to clinical applications.

THE BREATHING APPARATUS

The breathing apparatus provides driving pressure to downstream structures for the production of normal speech and voice. It can accomplish its task in a variety of ways, even when viewed within a fixed gravitational context. However, if body position changes, and correspondingly the gravitational context changes, so do the inherent recoil forces and mechanical relationships among the various muscles, cartilages, tendons, and connective tissues that make up the breathing apparatus. Thus, for each body position assumed, a different muscular solution is required.

The breathing apparatus is made up of the pulmonary system, consisting of the lungs and airways, and the chest wall system, consisting of the rib cage, abdomen, and diaphragm. The pulmonary
system is a "passive" system in that it contains no skeletal muscle. By contrast, the chest wall system contains numerous skeletal muscles that can inspire or expire the pulmonary system and can change the shape of the torso. Specifically, the rib cage contains both inspiratory and expiratory muscles, the abdomen contains only expiratory muscles, and the diaphragm is an inspiratory muscle. Between the abdominal wall and the diaphragm are housed the abdominal contents.

Relaxing

Figure 1 depicts a relaxed and motionless breathing apparatus in both the upright and supine body positions (Fig. 1a and b, respectively). In the upright body position, such as that assumed during standing or sitting, gravity acts to expire the rib cage by pulling down on it. By contrast, gravity acts to inspire the diaphragm and abdomen by pulling the abdominal contents footward (1), causing the abdomen to distend outward and the diaphragm to flatten. This inspiratory action on the diaphragm-abdomen enlarges the pulmonary system so that there is a substantial amount of air in the lungs and airways at the resting lung volume (i.e., functional residual capacity, FRC). When the breathing apparatus is relaxed at FRC, its recoil forces are in equilibrium. At lung volumes larger than FRC, the net recoil force is expiratory, whereas at lung volumes smaller than FRC, the net recoil force is inspiratory (2).

FIG. 1. The breathing apparatus during relaxation of the chest wall muscles in the upright (a) and supine (b) body positions. The dashed lines in (b) represent the configuration of the upright apparatus and are included for the purpose of comparison to the supine configuration. [Adapted with permission from Prentice-Hall (13).]

Within the abdominal contents, there is a hydrostatic pressure gradient, just as there is in a column of water. The gradient is vertical in the upright body position so that pressure increases in the footward direction.

The effects of gravity on the breathing apparatus are different in the supine body position. In this position, gravity operates in the expiratory direction on the rib cage and abdomen and drives the abdominal contents and diaphragm headward (1). That is, gravity expires the entire breathing apparatus. This means that, at rest, the supine breathing apparatus is relatively small, and the pulmonary system contains a smaller amount of air than it did when in an upright position (2). As was the case in upright, the net recoil force is expiratory at lung volumes larger than FRC and inspiratory at lung volumes smaller than FRC. In this position, the hydrostatic pressure gradient within the abdominal contents is such that pressure is lowest near the anterior abdominal wall and highest near the back.

Resting Tidal Breathing

Given that the mechanical state of the breathing apparatus changes with body position, it is not surprising that the muscular mechanism used in performing various breathing activities also changes with body position. Depicted in Fig. 2 are the muscular mechanisms involved in resting tidal breathing in the upright and supine body positions. In the up-

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1 This can be demonstrated by performing the following simple exercise. Inspire a moderate amount of air, close your larynx, and relax your breathing muscles. The force on your breathing apparatus should feel like a "squeezing" force (i.e., expiratory). Next, expire a moderate amount of air below your resting lung volume level, close your larynx, and relax your breathing muscles. Now, the force on your breathing apparatus should feel like a "sucking" force (i.e., inspiratory).
Breathing

**FIG. 2.** Muscular actions of the rib cage, abdomen, and diaphragm during resting tidal breathing—including inspiration (a) and expiration (b) in the upright body position and inspiration (c) and expiration (d) in the supine body position. Arrows indicate the direction of the muscular pressures applied. [Adapted with permission from Prentice-Hall (13).]

right position, inspiration is accomplished primarily with the diaphragm, as indicated by the arrow in the figure (Fig. 2a). The rib cage muscles also are active, but probably do not function as prime movers (3). Rather, they probably serve to stiffen the rib cage so that it is not pulled inward when pleural pressure drops with inspiratory efforts of the diaphragm. Expiration is driven by the recoil force provided by the breathing apparatus (Fig. 2b). However, this does not mean that the breathing apparatus is completely relaxed. Rather, as shown by the arrow, the abdominal muscles are active (4,8,12,14-20). In fact, they remain active throughout the entire breathing cycle and displace the abdominal wall inward from its relaxed position to counteract the distending force of gravity on the abdomen and its contents. The further footward one moves along the wall of the abdomen, the more active are the abdominal muscles (12,14,20). This reflects the need to counteract the higher pressure in the lower part of the abdomen resulting from the hydrostatic pressure gradient within the abdominal contents. Thus, the abdomen plays a prominent role in upright resting tidal breathing. Nevertheless, the abdomen is almost always overlooked in textbook descriptions of breathing function.

Why is the abdomen active during upright resting tidal breathing? The answer is related to the way in which the abdomen and diaphragm are mechanically linked. When the abdomen is distended, such as when the abdominal muscles are quiescent, the diaphragm assumes a somewhat flat configuration and its fibers are relatively short. By contrast, when the abdomen is displaced inward, the diaphragm is displaced headward. This improves the function of the diaphragm by placing it on a more advantageous portion of its length–tension characteristic (4,5,11,21). Thus, the abdomen, by being displaced inward, serves to "tune" the diaphragm mechanically.

The muscular mechanism used in resting tidal breathing changes when the breathing apparatus assumes the supine body position (see lower portion of Fig. 2). Inspiration is driven by the diaphragm (as indicated by the arrow in Fig. 2c) and expiration is driven by recoil force alone. The major difference between upright and supine resting tidal breathing is that the abdomen is not active in the supine position. It need not be active in this position because gravity performs the function that the abdomen performs in an upright position. That is, gravity mechanically tunes the diaphragm by expiring the abdomen, thus driving the diaphragm headward. Because the abdomen is passive, it is highly compliant and easily moved by contraction of the diaphragm. This is why the motions of the abdomen are noticeably large during supine resting tidal breathing (6), particularly when contrasted with those during upright resting tidal breathing.

**Conversational Speech Breathing**

The muscular mechanism used during conversational speech breathing is illustrated in Fig. 3. Beginning with the upright body position, the inspiratory phase of the speech breathing cycle is accomplished primarily by the diaphragm (Fig. 4a). The expiratory phase of the cycle, which is the speaking phase of the cycle, is accomplished by a combination of rib cage and abdominal muscular pressures, with the latter predominating (Fig. 3b) (11). The abdomen is very active throughout the upright speech breathing cycle, more so than it is during resting tidal breathing. The abdomen is maintained in an inwardly displaced position and moves little. Lung volume displacement during both inspiration and expiration is reflected primarily in motion of the rib cage (10,11,17–19,22,23). In fact, it is common for
Speaking

Inspiration  Expiration

(a)  (b)

(c)  (d)

FIG. 3. Muscular actions of the rib cage, abdomen, and diaphragm during conversational speech breathing—including inspiration (a) and expiration (b) in the upright body position and inspiration (c) and expiration (d) in the supine body position. Arrows indicate the direction of the muscular pressures applied. [Adapted with permission from Prentice-Hall (13).]

the abdomen to remain fixed and for only the rib cage to move when rapid volume expenditures are required, such as during the production of /h/. This appears to be an effective strategy because the rib cage covers a larger proportion of the pulmonary system (up to three-quarters) than does the diaphragm-abdomen unit. Thus, the rib cage does not have to move as far as the abdomen to effect the same change in lung volume.

Clearly, the abdominal muscles serve important functions for both phases of the upright speech breathing cycle. During the inspiratory phase, the abdomen mechanically tunes the diaphragm by defending its length and providing a relatively firm base against which it can contract (11,12). Tuning of the diaphragm is critical to meeting the communicative demand that inspirations be rapid and minimally interruptive to ongoing speech. One way to appreciate how important the abdomen is to inspiratory efforts during upright speech breathing is to observe someone whose abdomen is paralyzed. The paralyzed abdomen will be distended, the diaphragm flattened, and the inspirations abnormally slow (24).

The active role of the abdomen also is critical to the expiratory (speaking) phase of the cycle. To begin, when the abdominal muscles are maintained in an active state, the abdomen can serve as a stable base against which the rib cage can contract to raise pulmonary pressure. If the abdomen were not active, contraction of rib cage muscles would force the abdomen outward so that much of the rib cage muscular effort would be "wasted." Another consequence of displacing the abdomen inward is that the rib cage is enlarged through the raising of abdominal pressure. Abdominal pressure enlarges the rib cage via two potential mechanisms (5,11,21,25-27). First, abdominal pressure acts directly on the inner surface of the lower rib cage through the zone of apposition (i.e., the region where the diaphragm overlaps with the lower portion of the rib cage) to expand the rib cage circumferentially. That is, as abdominal pressure increases, it forces the rib cage upward and outward in the inspiratory direction. Second, as abdominal pressure increases, it forces the central tendon to be displaced rostrally, which, in turn causes the costal fibers of the diaphragm to pull the rib cage upward and outward in the inspiratory direction. This mechanical linkage between the abdomen and rib cage is a passive feature of the breathing apparatus, as can be illustrated by the fact that manual compression of the abdomen of a cadaver will expand the rib cage (28). The advantage of an expanded rib cage for speaking is that the rib cage muscles are elongated and their capacity for generating rapid pressure change is improved. An expanded rib cage also is advantageous for classical singing, in which the demands for rapid and precise
dominal muscles are usually quiescent. During su-
and the expiratory phase of the cycle is driven by
atory phase of the cycle is driven by the diaphragm
breathing in the supine body position. The inspira-
mechanism used during conversational speech
performance (29,30).

In fact, classical singers have been shown to em-
ploy very large inward displacements of the abdo-
minal muscles during loud speaking (11,12).

The lower portion of Fig. 3 depicts the muscular
mechanism used during conversational speech
breathing in the supine body position. The inspira-
tory phase of the cycle is driven by the diaphragm
and the expiratory phase of the cycle is driven by
the rib cage (Fig. 3c and d, respectively). The ab-
dominal muscles are usually quiescent. During su-
pine speech breathing, the motions of the abdomen
are a consequence of the actions of the diaphragm
(during inspiration) and rib cage (during speaking).
Nevertheless, there are occasions when the abdo-
men becomes active, such as during loud speaking
or when speaking at low lung volumes (11,12).

CLINICAL IMPLICATIONS

As is clear from the foregoing discussion, the be-
behavior of the breathing apparatus differs substan-
tially depending on body position (supine or up-
right) and performance activity (resting tidal breath-
ing or speech breathing). Thus, it follows that
approaches used in clinical evaluation and treat-
ment should be sensitive to these differences. How-
ever, some clinical practices do not take these dif-
ferences into account. Consider, for example, what
is perhaps one of the most commonly used ap-
proaches for modifying breathing behavior in cli-
ents with hyperfunctional voice disorders. This ap-
proach involves first placing the client in the supine
body position. This is done to relax the client and
facilitate emergence of what is sometimes referred
to as the most ‘‘natural’’ breathing pattern. This
pattern is said to be characterized by relatively
large abdominal motion and little or no rib cage mo-
tion. The client is asked to attempt to the rise and fall
of the abdomen while breathing quietly, and then to
practice vocalizing using the same large abdominal
motion. Next, the client is brought to an upright
seated or standing position and instructed to main-
tain the same breathing pattern. The goal is that the
client eventually will carry over the so-called natu-
ral breathing pattern from the supine body position
to everyday speaking activities performed in the up-
right body position.

This treatment approach includes three major
steps relevant to the present discussion: (a) resting
 tidal breathing in the supine body position, (b)
speech breathing in the supine body position, and
(c) speech breathing in the upright body position.

As illustrated in Fig. 4, moving from one step to the
next involves a change in breathing activity in one
case and a change in body position in the other
case. What are the consequences of these changes
on the breathing apparatus and its performance? To
begin, the change from the resting tidal breathing to
speech breathing involves a significant change in
the behavioral goal. While both resting tidal breath-
ing and speech breathing have as a goal the ex-
change of oxygen and carbon dioxide for the pur-
pose of ventilation, only speech breathing includes
the additional goal of communicating a spoken mes-
gage. Unsurprisingly, these important goal-related
differences are accompanied by differences in the
neural mechanisms used to control these two
breathing activities (31).

The change in body position from supine speech
breathing to upright speech breathing dramatically
alters the mechanical characteristics of the breath-
ing apparatus. This is caused by several interacting
factors, including those related to gravitational ef-
teffects on the inherent recoil forces of the apparatus
and the geometrical relationships of its muscles.
Some of these factors have been discussed in this
paper. Along with these mechanical changes come
alterations in the sensory function of the breathing
apparatus (6). That is, the relative strength of the
sensory messages used in the neural control of
breathing changes with body position.2 The conse-
quences of all these changes in breathing activity
and body position are that the muscular mechanism
used to accomplish the respective behavioral goal
also must change. And, in fact, muscular mecha-
nism has been shown to change substantially across
breathing activity and body position.

Figure 5 provides a summary of the muscular
mechanisms used during supine resting tidal breath-
ing, supine conversational speech breathing, and
upright conversational speech breathing. As illus-
trated in the figure, supine resting tidal breathing
involves only efforts of the diaphragm (−DI) for
inspiration (recoil force drives expiration), whereas
supine speech breathing involves efforts of the dia-
phragm (−DI) for inspiration and efforts of the rib

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2 One clinical example of how body position can have a major
influence on sensorimotor function for speech breathing is found
in subjects with motor neuron disease (32). Although such sub-
jects may report relatively normal sensation and demonstrate
relatively normal speech breathing behavior when in the upright
body position, they often become dyspneic and exhibit abnormal
speech breathing movements when in the supine position.

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In summary, breathing activity and body position have a profound influence on breathing behavior. Thus, both breathing activity and body position should be taken into account in any quest to understand the mechanism underlying breathing behavior, in any effort to evaluate the nature of speech breathing function and its functional potential, and in any attempts to modify behavior for the purpose of alleviating breathing-based speech and voice disorders. A rational approach to understanding, evaluating, and treating breathing behavior should be conducted within the context of the breathing activity of interest—usually breathing for speaking (or for singing)—and within the body position of interest—usually upright. Any approach that is based on these simple principles will have a greater potential for success than those that are not.

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REFERENCES


3. De Troyer A, Loring S. Action of the respiratory muscles. In:

Additional text:

using nonspeech activities to modify speech-related behavior has been criticized by others (34,35). A second reason to question the efficacy of using supine resting tidal breathing as a model for upright speech breathing relates to the problem of generalizing across body positions. If this novel breathing pattern were substituted for the one that is typically used during upright speech breathing, this could result in replacing a biomechanically efficient pattern for one that is probably much less efficient in the upright position.3

A similar argument has been put forth with respect to the "belly out" method of breathing for singing (36).

There are certain circumstances in which body position may not be important. For example, body position is probably irrelevant in a nearly gravity-free environment, such as that found in outer space. As another example, body position may not have much influence on breathing in a very small person, such as a baby, because the abdominal mass is small (37).

There are other reasons to doubt the efficacy of using this type of approach in the treatment of clients with speech and voice disorders. One reason relates to the problem of attempting to carry over learning from a nonspeech breathing activity to a speech breathing activity. The general concept of

FIG. 5. Summary of the muscular mechanisms involved in supine resting tidal breathing, supine conversational speech breathing, and upright conversational speech breathing. Inspiratory muscular pressure exerted by the diaphragm (DI) is represented by a minus sign (−) and expiratory muscular pressure exerted by the abdomen (AB) and rib cage (RC) is represented by a plus sign (+). Inspiratory and expiratory phases of breathing cycles are illustrated in tracings of lung volume change (expressed in percentage vital capacity, %VC). Functional residual capacity (FRC) is indicated with a dashed line.

SUPINE BREATHING
SUPINE SPEAKING
UPRIGHT SPEAKING

The general concept of

Additional text:


