Biofeedback
Volume 44, Issue 1, pp. 42–49
DOI: 10.5298/1081-5937-44.1.03

FEATURES

Abdominal SEMG Feedback for Diaphragmatic Breathing: A Methodological Note

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Keywords: surface electromyography, respiration, diaphragmatic breathing, pelvic floor pain

Diaphragmatic breathing from a developmental perspective is a whole-body process. During exhalation, the abdominal wall contracts, and during inhalation, the abdominal wall relaxes. This pattern is often absent in many clients who tend to lift their chest when they inhale and do not expand their abdomen. Even if their breathing includes some abdominal movement, in many cases only the upper abdomen above the belly button moves while the lower abdomen shows limited or no movement. This article describes factors that contribute to the lack of abdominal movement during breathing, as well as a methodology to record the surface electromyography (SEMG) activity from the lower abdominal muscles (external/internal abdominal oblique and transverse abdominis). Strategies are presented to teach clients how to engage the lower abdominal muscles to facilitate effortless breathing. For example, when the person exhales, the lower abdominal muscles contract to flatten the abdomen and push the diaphragm upward, and these muscle relax during inhalation to allow the diaphragm to descend. Lower abdominal SEMG recording can also be used as a surrogate indicator for SEMG activity from the pelvic floor. To enhance activation of the lower abdominal muscles during a breathing cycle, specific exercises are described. In summary, lower abdominal SEMG feedback is a useful strategy to facilitate complete abdominal involvement during breathing.

Background

When asking clients to demonstrate inhaling diaphragmatically, many lift their chest and do not expand their abdomen, even though they think their stomach/abdomen expanded. In other cases, during exhalation, their chest goes down and their abdomen goes out, a pattern known as paradoxical breathing. Even if their breathing includes abdominal movement, in many cases only the upper abdomen above the belly button moves while the lower abdomen shows limited or no movement.

Factors that contribute to the lack of abdominal movement during breathing include:

1. "Designer jean syndrome" (the modern girdle): The abdomen is constricted by a waist belt, tight pants, or slimming underwear (Peper & Tibbitts, 1994).
2. Self-image: The person tends to pull his or her abdomen inward in an attempt to look slim and attractive.
3. Defense reaction: The person unknowingly tenses the abdominal wall—a flexor response—in response to perceived threats (e.g., worry, external threat, loud noises, feeling unsafe). Defense reactions are commonly seen in clients with anxiety, panic, or phobias.
4. Learned disuse (Peper et al., 2015): The person covertly learned to inhibit any movement in the abdominal wall to protect themselves from experiencing pain because of
   a. Prior abdominal injury/surgery (e.g., hernia surgery, appendectomy, cesarean operation)
   b. Abdominal pain (e.g., irritable bowel syndrome, recurrent abdominal pain, ulcers, acid reflux)
   c. Pelvic floor pain (e.g., pelvic floor pain, pelvic girdle pain, vulvodynia, sexual abuse)
   d. Low back pain
5. Inability to engage abdominal muscles because of the lack of muscle tone.
   a. The abdominal wall relaxes as a biological signal of defenselessness. This is sometimes observed in clients who feel defeated, depressed, or hopeless. The person will predominantly breathe shallowly in their chest with episodic sighs.
   b. Age or a sedentary life. The person has limited abdominal muscle strength and has reduced activation of muscles around the trunk during movement.

Whether the lower abdominal muscles are engaged or not (either by chronic tightening or lack of muscle activation),

Adapted from Peper, E., Booiman, A.C., Lin, I-M., Harvey, R., Mitose, J. (2015) Abdominal SEMG feedback for diaphragmatic breathing: A methodological note. Poster presented at the 46th Annual Meeting of the Association for Applied Psychophysiology and Biofeedback, Austin, Texas, March 11–14, 2015.

the resultant breathing pattern tends to be shallow, rapid, irregular, and punctuated with sighs in their chest. Over time, participants may not able to activate or relax the lower abdominal muscles during the respiratory cycle.

Breathing from a developmental perspective is a whole-body process, and whole-body involvement in respiration can usually be observed in infants and young children. When a person feels safe, optimum breathing should be effortless (van Dixhoorn, 1998, 2007). During inhalation, the abdominal wall expands and the lower abdominal muscles—transverse abdominis and abdominal oblique—relax, which allows the diaphragm to move caudally to increase lung volume in the thorax. During exhalation, the transverse abdominis and abdominal oblique muscles tighten to pull the abdomen inward, flattening the abdomen so that the abdominal circumference decreases, which pushes the diaphragm cranially upward to reduce lung volume in the thorax (Booiman & Peper, 2013; Peper et al., 2015; Talasz, Kalchschmid, Kofler, & Lechleitner, 2012; Talasz, Kofler, Kalchschmid, Pretterklieber, & Lechleitner, 2010).

Diaphragmatic breathing is the intrinsic respiratory pattern of mammals, as illustrated by a dog standing on all fours. During exhalation, the abdomen wall contracts upward against gravity, and during inhalation, the abdominal wall relaxes, allowing the abdomen to drop down. Moreover, during early embryological development, the respiratory tract and the urinary system develop from the same tissue. This connection is still present during breathing. For example, when a person with normal functional breathing exhales through pursed lips while making a hissing sound (*pssssssss*), the muscles of the pelvic floor and lower abdomen will slightly tighten (Hodges, Sapsford, & Pengel, 2007; Sapsford et al., 2001; van Dixhoorn, 2007).[1] When people improve their breathing patterns, numerous disorders are ameliorated, such as chronic obstructive pulmonary disease (Cahalin, Braga, Matsuo, & Hernandez, 2002; Gosselink, Wagenaar, Rijswijk, Sargeant, & Decramer, 1995), asthma (Thomas et al., 2003), and pelvic floor disorders (Zivkovic et al., 2012).

Conventional recording of respiration with strain gauges placed around the waist records the expansion of the abdomen during inhalation or constriction during exhalation; however, it usually records the upper abdomen, and in many people, it does not reflect the movement of the lower abdominal wall.

Purpose

The purpose of this methodological note is to describe a methodology to record the surface electromyography (SEMG) activity from the lower abdominal muscles (external/internal abdominal oblique and transverse abdominis) to monitor and to teach engagement of these lower abdominal muscles to facilitate effortless, whole-body breathing. Using this methodology, the participants can once again learn how to activate the lower abdominal muscles to flatten the abdominal wall during exhalation, thereby pushing the diaphragm upward, and then, during inhalation, relax the muscles of the abdominal wall to expand the abdomen to allow the diaphragm to descend. The location of the muscles and electrode location are illustrated in Figure 1.

Lower Abdominal SEMG Electrode Placement

Electrode Placement Options

Narrow electrodes placement. The Triode electrode is placed about 1 cm to the midline from the spina iliaca anterior superior (SIAS), as shown in Figure 1. The participant is asked to loosen material around the waist (e.g., beltline) and fold the clothing down on the side where the electrode is placed, as shown in Figure 2. This works well with people who are slim and do not have much adipose tissue or tissue folds. The band-pass filter is usually set between 20 and 500 Hz as the electrocardiogram (EKG) artifact is minimal; however, if the EKG artifact is large, the band-pass filter is set between 100 and 200 Hz (Peper, Gibney, Tylova, Harvey, & Combatalade, 2008).

Wide electrodes placement. One single active electrode is placed 1 cm from the right SIAS, and the other active electrode is placed on the other side 1 cm inward from the left SIAS, as shown in Figure 1. The reference electrode is placed midway between the two active electrodes. The band-pass filter is set between 100 and 200 Hz to reduce the EKG artifact. This electrode placement works well with people having significant adipose tissue or tissue folds (Peper et al., 2008).

Observations

For healthy participants who breathe diaphragmatically, there was a close correspondence between breathing activity measured by respiratory strain gauges and the SEMG sensor placed on the lower abdominal wall during slow, effortless breathing.[2] The SEMG activity increases during

[1] For additional information about effortless breathing, see the comprehensive work on whole-body breathing by van Dixhoorn (1998, 2007).

[2] The detailed methodology for monitoring muscle activity with SEMG and respiration with strain gauges are described in the book *Biofeedback Mastery* (Peper et al., 2008). The physiological recordings for this methodological note were done with a Procomp Plus Infiniti system with Biograph Infinity 6.1 software (Thought Technology, Ltd) using MyoScan-Pro^{TM} sensors to record the SEMG.

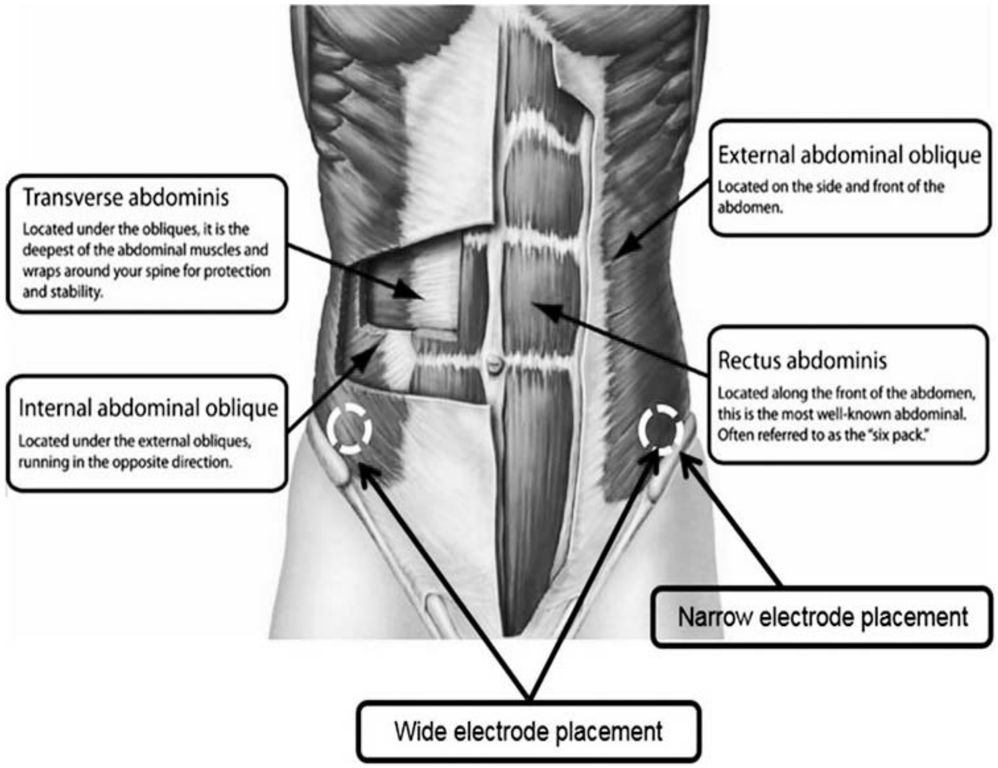

Figure 1. Approximate transverse and external abdominal oblique placement of surface electromyography (SEMG) sensors for detecting lower SEMG activity. From http://www.muscledudelife.com/wp-content/uploads/2014/12/abdominal-muscles-anatomy.jpg.

exhalation and decreases during inhalation, as shown in Figure 3.

The abdominal breathing pattern is often affected by the posture of the trunk. When the person sits collapsed with a posterior tilt of the pelvis, the lower abdomen muscles are more difficult to activate during exhalation as shown in Figure 4.

Challenges in Recording SEMG from the Lower Abdomen

- The participant has excessive adipose tissue under the abdominal wall, which reduces the SEMG signal recorded with narrow placement electrode. *Solution: Explore the use of wide placement electrodes.*
- Slouching posture of the client may increase tissue folds in that area and push the triode away from the muscle, thereby decreasing the signal amplitude. *Solution: Have the person sit erect.*
- Clients with little abdominal fat who have experienced weight fluctuations (e.g., significant weight loss or pregnancy) may have loose skin that moves away from the muscles, especially with a slouching posture, which will reduce the signal. *Solution: Use wide placement electrodes or let the person lie down on his or her back on a couch/floor.*
- Clothing may interfere with sensor placement and shift during position changes. *Solution: Have person wear clothing that allows electrodes to be discretely placed on the abdominal wall and discuss how clothing may restrict abdominal movement during breathing.*

The absence of lower abdominal muscle tension has been associated with a history of abdominal pain and pelvic floor

Figure 2. Placement of a triode electrode on the lower abdomen.

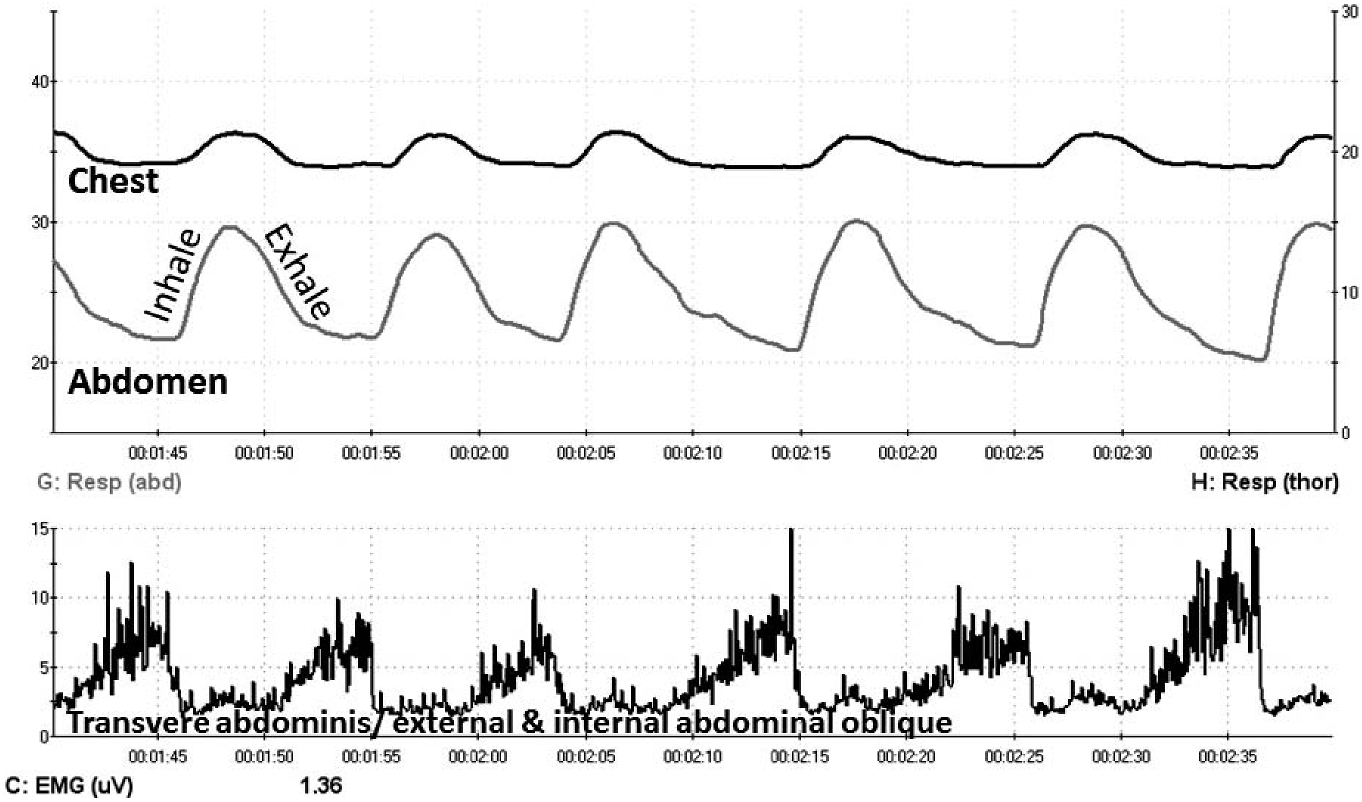

Figure 3. Correspondence between respiratory strain gauge changes and surface electromyography (SEMG) activity during breathing. When the person exhales, the lower abdominal SEMG activity increases, and when the person inhales, the SEMG decreases.

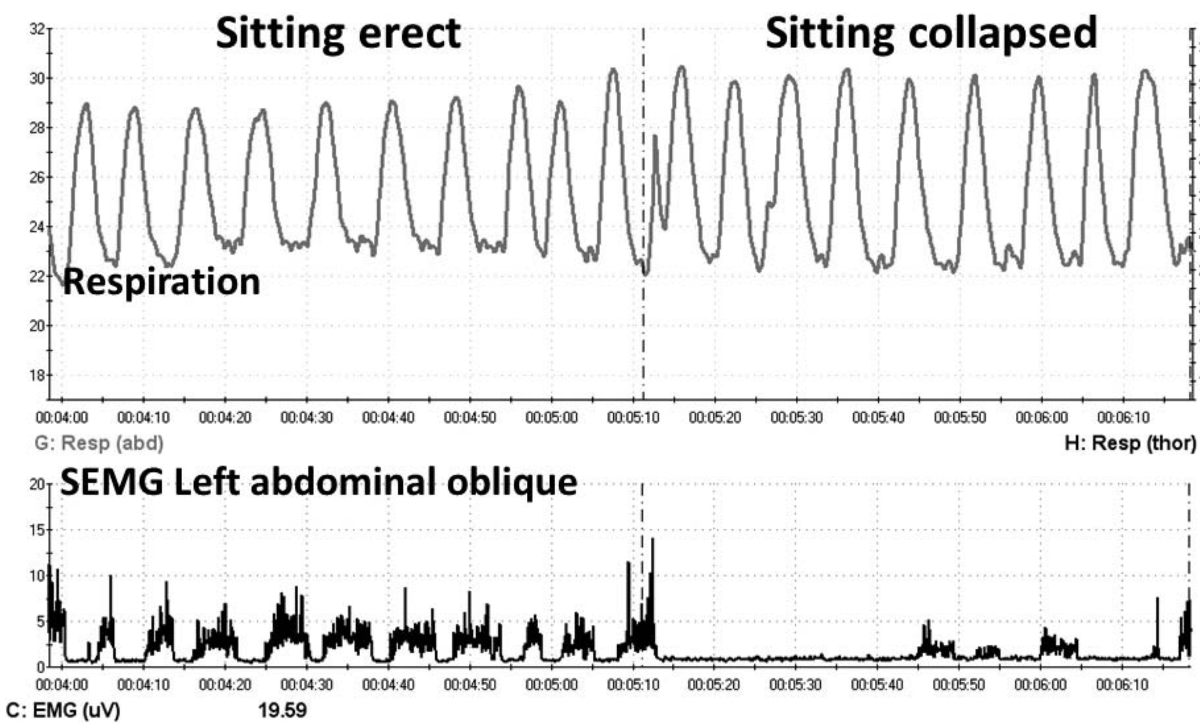

Figure 4. Effect of posture on abdominal surface electromyography recording.

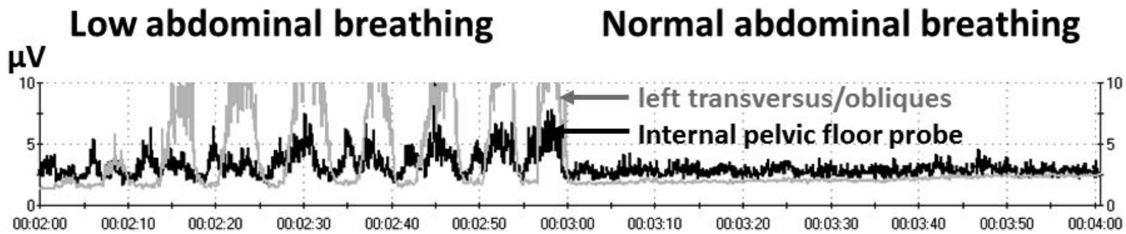

Figure 5. Comparison between low and normal abdominal breathing while recording surface electromyography (SEMG) from the transverse/obliques and an internally placed vaginal EMG probe.

discomfort in which the muscle activity is inhibited because of learned disuse (Gilbert & Chaitow, 2012; Haugstad et al., 2008; Haugstad, Kirste, Leganger, Haakonsen, & Haugstad, 2011). Low chronic abdominal muscle tension has been associated with the chronic triggering of the defense reaction (Haugstad et al., 2008). For many clients with this chronic low-tension pattern, especially those who are fearful and guarding, learning to relax the lower abdominal wall during inhalation as well as learning to increase slightly the tension of the abdominal wall muscles during exhalation is challenging. After mastering the skill, these individuals often report feeling more relaxed and safe.

The abdominal SEMG placement measures the low abdominal muscle function and may also be used as a surrogate indicator for SEMG activity from the pelvic floor, as measured by an internal probe shown in Figure 5.

For clients with pelvic floor pain such as vulvodynia or those with sexual abuse history, using lower abdominal SEMG recording may be a noninvasive and less threatening approach to teaching lower abdomen and pelvic floor relaxation (Peper et al., 2015). It may avoid retraumatizing that could occur when placing sensors in the vagina or anus.

The benefits of learning slower lower abdominal breathing include facilitating circulation and lymph fluid and venous blood return in the abdomen. At the same time, the slower resonant frequency breathing would enhance the sympathetic-parasympathetic balance and reduce sympathetic arousal and trigger-point activity (Lehrer, Vaschillo, & Vaschillo, 2000).

Self-Practices to Increase Lower Abdominal Movement During Slower Breathing

The following practices can be used by the client to facilitate lower abdominal breathing (Klemmetsen, 2005; Jonker-Kaars Sijpensteijn, 1996):

1. Holding the hands against the lower abdomen

Clients place their hands below their belly button with the outer edge of hands resting on the groin. During inhalation, they practice bringing their lower abdomen/belly into their hands so that the person can feel the lower abdomen expanding. During exhalation, they pull their lower abdomen inward and away from their palms, as shown in Figure 6.

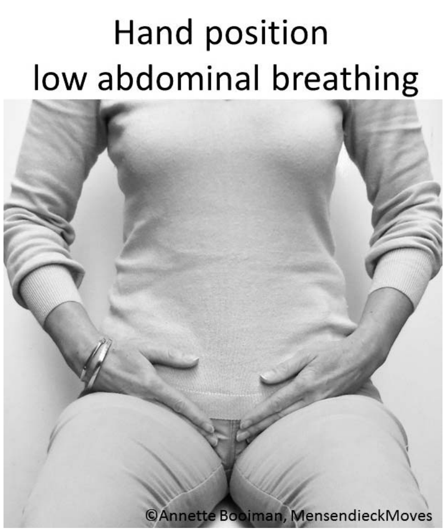

Figure 6. Hands placed below the belly button to sense the movement of the lower abdomen.

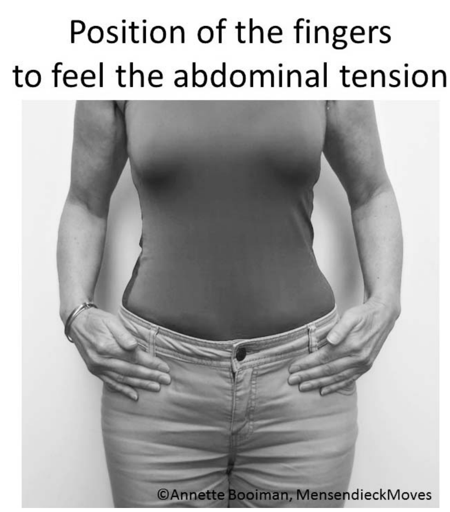

Figure 7. Position of fingers to feel the lower abdominal tension during exhalation and relaxation (expansion) during inhalation.

Figure 8. Illustration of "cats and dogs" practice. During inhalation, the lower abdomen expands while arching the back and lifting the head up; during exhalation, the lower abdomen is moved upward from the pubic bone to the ribcage while curling the back and tucking the head down.

2. Feeling the muscles contracting

Clients place their fingertips just inside the SIAS on the abdomen with a light pressure, as shown in Figure 7. While exhaling, they focus on feeling the muscles of the abdomen slightly tighten and relax/soften during inhalation. Clients can also practice this covertly during the day by putting their fingers/hands in the pockets of their pants and feeling the muscles of their own abdomen; nobody will know that they are doing their home practice.

3. Cats and dogs

The client is on all fours on the floor on their hands and knees. The arms and upper thighs are perpendicular from the trunk and floor. During exhalation, the client tightens the abdominal muscles upward from the pubic bone to the ribcage (like pulling up a zipper) while curling the back and tucking the head down. During inhalation, the client relaxes and expands the lower abdomen and stomach while arching the back and lifting the head up, as shown in Figure 8.

4. Pelvic rocking

The client sits erect on a chair on the "sit" bones of the pelvis. Then the client moves the pelvis slowly backward with use of the abdominal muscles, so he or she sits behind the sit bones, and then moves the pelvis in the forward position while relaxing the abdominal muscles so that at the end of the movement, the client will sit in front of his or her sit bones. The client slowly rocks the pelvis forward and backward several times with the use of the abdominal muscles, as shown in Figure 9.

This pelvic rocking exercise was so helpful! I am realizing that my hyperventilation was intertwined with my inability to rock the pelvis back and forward. Now I am able to move my pelvis, my breathing problems are becoming better too.

Conclusion

Lower abdominal SEMG feedback is a useful tool to facilitate complete abdominal involvement during breathing. It is especially useful when teaching clients to breath slowly at resonant frequency so that sympathetic and parasympathetic balance can be enhanced. This methodology can be used by psychologists, physical therapists, and biofeedback practitioners who neither want nor are allowed

Figure 9. Illustration of pelvic rocking while sitting on a tool or at the edge of a chair.

to directly interact using internal placements of sensors for pelvic floor problems.

Lower abdominal SEMG feedback is also useful in retraining breathing for people with depression, rehabilitation after pregnancy, operations in the abdomen or chest (e.g., cesarean surgery, hernia, or appendectomy operations), anxiety, hyperventilation, stress-related disorders, difficulty becoming pregnant or maintaining pregnancy, pelvic floor problems, headache, low back pain, and lung diseases.

Biofeedback might be the single thing that helped me the most. When I began to focus on breathing, I realized that it was almost impossible for me since my body was so tightened. However, I am getting much better at breathing diaphragmatically because I practice every day. This has helped my body and it relaxes my muscles, which in turn help reduce the vulvar pain.

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