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The Importance of the Posterolateral Area of the Diaphragm Muscle for Palpation and for the Treatment of Manual Osteopathic Medicine

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Keywords

Osteopathic manipulative treatment · Diaphragm · Fascia · Phrenic nerve · Breathing · Tongue

Abstract

The eupneic act in healthy subjects involves a coordinated combination of functional anatomy and neurological activation. Neurologically, a central pattern generator, the components of which are distributed between the brainstem and the spinal cord, are hypothesized to drive the process and are modeled mathematically. A functionally anatomical approach is easier to understand although just as complex. Osteopathic manipulative treatment (OMT) is part of osteopathic medicine, which has many manual techniques to approach the human body, trying to improve the patient's homeostatic response. The principle on which OMT is based is the stimulation of self-healing processes, researching the intrinsic physiological mechanisms of the person, taking into consideration not only the physical aspect, but also the emotional one and the context in which the patient lives. This article reviews how the diaphragm muscle moves, with a brief discussion on anatomy and the respiratory neural network. The goal is to highlight the critical issues of OMT on the correct positioning of the hands on the posterolateral area of the diaphragm around the diaphragm, trying to respect the existing scientific anatomical-physiological data, and laying a solid foundation for improving the data obtainable from future research. The correctness of the position of the operator's hands in this area allows a more effective palpatory perception and, consequently, a probably more incisive result on the respiratory function.

Bedeutung des posterolateralen Bereichs des Zwerchfellmuskels für die Palpation und Behandlung in der manuellen osteopathischen Medizin

Schlüsselwörter

Osteopathische Manipulationstherapie · Zwerchfell · Faszien · Nervus phrenicus · Atmung · Zunge

Zusammenfassung

Der eupnoische Akt beinhaltet bei Gesunden eine koordinierte Kombination aus funktioneller Anatomie und neurologischer Aktivierung. Aus neurologischer Sicht wird die Hypothese aufgestellt, dass ein zentraler Pattern-Generator, dessen Komponenten auf Hirnstamm und Rückenmark verteilt sind, als Antrieb fungiert, und er wird mathematisch modelliert. Ein funktionell-anatomischer Ansatz ist einfacher zu verstehen, aber nicht minder komplex. Die osteopathische Manipulationstherapie (OMT) ist ein Teil der osteopathischen Medizin, die viele verschiedene manuelle Techniken umfasst, um sich dem menschlichen Körper zu nähern und zu versuchen, die homöostatische Reaktion des Patienten zu verbessern. Das Prinzip, auf dem die OMT beruht, ist die Stimulation von Selbstheilungsprozessen unter Betrachtung der intrinsischen physiologischen Mechanismen der Person und unter Berücksichtigung nicht nur des körperlichen Aspekts, sondern auch des emotionalen sowie des Kontexts, in dem der Patient lebt. Dieser Artikel gibt einen Überblick darüber, wie sich der Zwerchfellmuskel bewegt; die Anatomie und das neuronale Netzwerk der Atmung werden kurz

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besprochen. Das Ziel ist es, die kritischen Fragen der OMT zur korrekten Positionierung der Hände im posterolateralen Bereich des Zwerchfells und um das Zwerchfell herum herauszuarbeiten, unter bestmöglicher Einbeziehung der vorliegenden wissenschaftlichen anatomisch-physiologischen Daten, als solide Grundlage zur Verbesserung der Daten, die aus zukünftiger Forschung gewonnen werden können. Die korrekte Positionierung der Hände des Behandlers in diesem Bereich ermöglicht eine effektivere palpatorische Wahrnehmung und entsprechend eine wahrscheinlich einschneidendere Wirkung auf die Atemfunktion.

Introduction

Osteopathy and osteopathic manipulative treatment (OMT) place central importance on efficient function of the respiratory diaphragm. Andrew Taylor Still, the founder of OMT, coined the term osteopathy in 1891, and the American School of Osteopathy was born the following year in Kirksville, MO, in 1892 [1]. Although the first students who completed study with Dr. Still were given the title "Diplomate of Osteopathy" (DO), he later changed it to "Doctor of Osteopathy" in 1900 [2]. Still described principles of osteopathic medicine that have become a touchstone for contemporary daily clinical practice. Osteopathic manipulative treatment uses the hands to palpate the patient and applies manual manipulative treatments to improve the patient's adaptive response to the dysfunction that afflicts the physical, mental and spiritual status [3]. According to Still's view, the body is a unit in perfect functional balance, the body system has the inherent tools to restore functional homeostasis following pathology or dysfunction, structure and function are interconnected, and the rationale for choosing a subjective treatment is based on these principles [3].

Osteopathic manipulative treatment can be classified based on 5 osteopathic models: respiratory-circulatory, neurological, biomechanical, metabolic and behavioral [4]. The models are a guide for the clinical classification of the patient from an evaluative point of view, while, in actual practice, the osteopath is aware that these models are not an absolute constraint and that they are found, at the same time, in the adaptation of the body system. Osteopathic models complement each other.

According to the osteopathic perspective and the respiratory-circulatory model, a dysfunction (nonphysiological alteration of function of the organism) interrupts the correct behavior of body fluids (blood, lymph, cellular and extracellular fluids); the result of the dysfunction can produce local or reported symptoms, and negatively affect either somatic and visceral structures or both [5]. The respiratory diaphragm is central to this model, with numerous systemic neurological and fascial, vascular and lymphatic connections, whose functions go beyond breathing alone. A dysfunctional diaphragmatic mechanism may not only cause local problems [6]. Symptoms can range from the gastric sphere (reflux) to the psychological sphere (depression and anxiety), from the orthopedic sphere (pain in the lumbar area) to the neurological sphere (neuromuscular discoordination) [7–9].

Looking at the research literature around the osteopathic approach to the diaphragm, it has been shown that various respiratory parameters can improve with treatment. Some recent studies, carried out on healthy subjects, demonstrated the increase in peak expiratory flow, the improvement of the forced expiratory volume in the first second of expiration, along with an increase in the forced vital capacity [10, 11]. Another study evaluated the range of motion of the diaphragm muscle after an OMT approach. Using an ultrasound, the clinician highlighted improvement in diaphragmatic excursion in healthy subjects [12]. In the field of pathology, the use of OMT on the respiratory diaphragm has allowed for clinical patient improvement. In patients with chronic nonspecific low back pain, osteopathic treatment aimed at the diaphragm demonstrated elevation of the pain threshold assessed through various pain scales (Short-Form McGill Pain Questionnaire, visual analog scale) and consistently improved the level of measured disability (Roland-Morris Questionnaire, Oswestry Disability Index) [13].

To understand whether OMT was able to improve the symptomatological picture in the presence of pneumonia, a review of the literature highlighted the positive effect of manual therapy, with reduction of edema, a better immune response and improved respiratory flows [14]. In a study with patients suffering from severe chronic obstructive pulmonary disease (COPD), the use of OMT and work on the diaphragm showed an improvement in respiratory flows and physical performance (measured with the 6-min walk test) [15]. In elderly patients with COPD who underwent OMT including a diaphragmatic approach, the results were not immediately positive after treatment, although other authors have argued the reasons for the ambiguity [16, 17]. In other research, working the diaphragm with osteopathic techniques also improves pain of the cervical region, in particular C_4, without directly treating the neck [18].

We must emphasize that there is a lack of further insights into the reasons for the improvements recorded in the research, compared to other body areas related to the diaphragm; for example, the adaptive response (local and in relation to the nervous and metabolic system) of the viscera adjacent to the diaphragm muscle. Furthermore, yet not always, the illustrated research discusses the peripheral and central neurological adaptations of the breath, as well as the coreactions related to the technique used in the individual studies.

This article reviews how the diaphragm muscle moves, with a brief discussion on anatomy and the respiratory network. The goal is to highlight the critical issues around OMT and the correct positioning of the hands in palpation of the diaphragm, while trying to respect the existing scientific anatomical-physiological knowledge and laying a solid foundation for improving the data obtainable from future research. It is easier to palpate the diaphragm in its posterolateral area where there is greater movement, compared to the usual palpations of the anterior and/or lateral area with less excursion. Positioning the hands where a contractile district is able to express its movement more easily facilitates the understanding of any presence of movement restrictions (muscular, articular, visceral); such restrictions are felt by osteopathic palpation. Furthermore, once the diaphragmatic area has been palpated, if the operator needs to obtain more clinical information, he will be able to carry out further tests, local and more distant, as is customary in OMT, identifying local or distant dysfunctions, including emotional ones. To the knowledge of the authors, this is the first article in the panorama of scientific literature that suggests palpating the posterolateral area to better manually evaluate the movement of the diaphragm muscle.

The Respiratory Neural Network

To understand the function of a structure and its position within a body context, as well as its local and systemic three-dimensionality, it is necessary to know the anatomical and neurological connections of the same structure, locally and distally. Before understanding where to place the hands, one must know the anatomical-functional reasons that allow a given structure to move. By doing so, not only will a scientific sense be found in palpation, but also the possibility of testing the connected structures, culminating in an adequate clinical vision.

The neural component of the eupneic act in healthy subjects involves a central pattern generator, the components of which are distributed between the brain stem and the spinal cord. Although we can easily count about 700 human breaths per hour in a state of rest, the neural connections that explain the mechanisms of inhalation and exhalation remain elusive, just as the characteristics of the different nuclei involved in respiration are not fully understood [19]. Breathing initially occurs in 3 phases: preinspiratory, inspiratory and expiratory phases which all depend on the different aspects of the respiratory network. Preinspiration comes from a nucleus of the brain stem, the pre-Bötzinger complex (preBötC). This contains about 20% of autonomous depolarization activity (pacemaker) and is probably due to a balanced interchange of cationic currents between calcium and sodium [20, 21]. The preBötC neurons implement a ramp-like depolarization, for a maximum of 100–400 ms (preinspiratory phase), before carrying out the impulse of the active inspiration, or the second phase of the eupneic cycle [22]. In the preinspiratory phase, the preBötC neurons send activating signals to the neurons of the hypoglossal nerve (CN XII) [19]. CN XII also receives impulses from other sites, such as the trigeminal nerve (CN V), the facial nerve (CN VII), the glossopharyngeal nerve (CN IX), and the vagus nerve (CN X) as the phases of the breath are also influenced by the orofacial region [19, 23]. Other areas involved in the action of respiration are connected efferently to CN XII: the raphe-pontomedullary network, the parabrachial/Kölliker-Fuse complex, the nucleus subcoeruleus, the medullary division of the lateral tegmental field and the nucleus tractus solitarii (NTS) [23–28].

The inspiratory phase begins when the preBötC reaches a complete depolarization of its neurons, about 13% of which are able to synchronize the neurons of the contralateral preBötC [19]. The ramp-like depolarization and complete depolarization of the preBötC are modulated by various central information areas (cerebellum, midbrain, cortical and subcortical centers), as well as by peripheral afferents monitoring quantity of blood oxygen, along with mechanical changes in the lungs and large vessels [21]. In the inspiratory phase, the preBötC continues with the stimulation of the cranial nerve XII, starting to stimulate the premotor neurons and the medullary phrenic motor neurons (from C_1 to C_5). About 3% of phrenic motor neurons send dendrites to the contralateral phrenic motor neurons [21, 29]. Phrenic motor neurons also receive efferents from the ventral rostral area or group and the ventral caudal area or group (VRGc) of the brain stem, from the NTS or dorsal neural group of the brain stem, along with the pontine area (parabrachial/Kölliker-Fuse complex) [29]. We can also find bulbophrenic projections and from premotor cortical areas [29]. The preBötC sends various information towards the pontine and suprapontine areas, and exchanges multiple neural and biochemical impulses in a bidirectional way with the nuclei present in the ventral rostral area or group and VRGc [19]. PreBötC neurons will affect accessory inspiratory skeletal muscles [21]. The next eupneic phase is passive exhalation, which coincides with the inhibitory activity of Bötzinger's neurons towards the preBötC, found in the VRGc. Bötzinger's neural bodies are stimulated by the parabrachial/Kölliker-Fuse complex, which are located in the pontine area [21]. The NTS, located in the dorsal neural group of the brain stem area, manages Bötzinger neurons and its connections; afferents come to NTS from chemoreceptors, baroreceptors and other receptors involved in the regulation of respiration, such as pulmonary

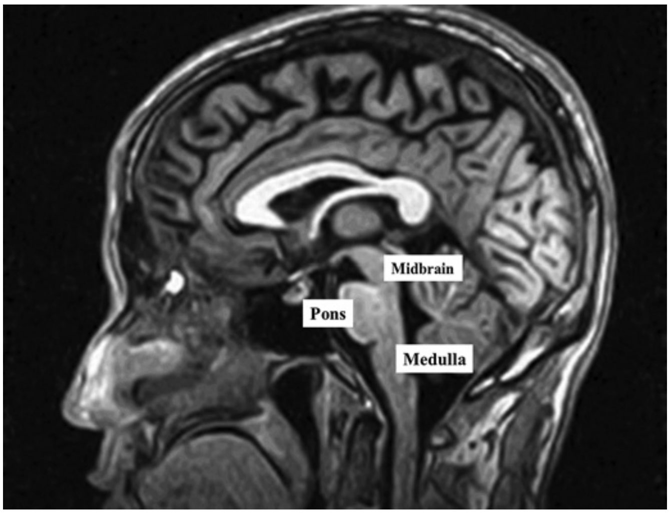

Fig. 1. The figure illustrates a magnetic resonance image without contrast medium, highlighting, on a sagittal plane, the area of the midbrain, pons and the medullary area. This anatomical zone encloses the kernel of the respiratory network. Image owned by Bordoni Bruno.

receptors (slow-adapting stretch receptors; rapidly adapting irritation receptors; juxtacapillary or J receptors) and various receptors of the respiratory musculature [23]. The NTS also affects the behavior of the preBötC [23].

For completeness, we can identify 2 other secondary phases: the postinspiratory phase and the active expiratory phase. The postinspiratory phase, immediately following the inspiratory phase, involves the neural area postinspiratory complex, located caudal to the nucleus of the VII cranial nerve (facial nucleus), and in the dorsomedial proximity to the nucleus ambiguus [19, 20]. The postinspiratory complex influences the phrenic nerve and CN XII, prolonging the inspiratory period. The contraction of the adductor muscles of the larynx (and the vagus nerve) is stimulated in order to increase the resistance of the upper airways [19, 23]. Pulmonary deflation is thus delayed, and the gas exchange times of the alveoli are lengthened. Generally, this phase reflects some respiratory functions, such as coughing, swallowing and the use of the voice [19]. The postinspiratory complex is mutually inhibited by Bötzinger's neurons so that the eupneic inspiration does not coincide with the postinspiratory phase [19]. The active expiratory phase is present when metabolic demand increases and during the REM or rapid eye movement phases of sleep, and mainly involves the VRGc area, stimulated by Bötzinger neurons. The latter are excited by the retrotrapezoid nucleus and the parabrachial/Kölliker-Fuse complex [19, 21, 30–32]. The active exhalation phase and its neurological areas influence the expiratory muscles [19, 21]. Although distinct, the autonomic pathways involved in the breathing patterns overlap the somatic pathways that manage the ventilation network; the sympathetic and parasympathetic system will coordinate the visceral functions for a correct modulation of body fluids [25] (Fig. 1).

Diaphragmatic Functional Anatomy

The diaphragm muscle is the primary muscle of breathing. It is so primary to functional integration that in the rat model, the motion of breathing begins in the fetus on the thirteenth day of gestation [33]. In the adult human, the diaphragm is a very thin muscle (2–4 mm), with diverse morphology and movement having differences between the right and left areas [34]. The purely connective area and the area of confluence of the contractile fibers are defined as the central tendon or tendon center. The term "central" is not wholly accurate, as the size and position of the connective mass is strongly variable [35]. It is true that the diaphragm muscle separates the thoracic cavity from the abdominal one but, despite its anatomical position, it is a muscle full of holes for the passage of different structures. When viewed from above it looks like a "clover" or a "saddle", if viewed from below we can associate it with a "colander" [35].

We can identify, anteriorly and adjacent to the sternum, a sternocostal triangle or foramina of Morgagni on the right and a sternocostal triangle on the left or foramina of Larrey (for the passage of the superior epigastric vessels) More posteriorly and centrally, the esophageal hiatus, which is inclined towards the front and with a surface of about 1,037 mm^2, has an elliptical shape and is located at the level of T_{10}–T_{11}. The aortic hiatus is near T_{11}–T_{12}, posterior to the previous hiatus and through which the thoracic duct also passes. The hiatus of the vena cava is near T_{10}–T_{11}, posteriorly and to the right [35–37]. The esophageal hiatus and the aortic hiatus pierce the muscle tissue, while the caval hole pierces the purely connective tissue. Other diaphragmatic spaces are found in the paravertebral areas for the passage of muscular structures, such as the psoas and the quadratus lumborum, and for the passage of the sympathetic nerve branches through the contractile tissue, the phrenic nerve, venous structures such as the azygos and hemiazygos veins and the ascending lumbar venous plexus [38, 39].

The diaphragm can be divided into sternal, costal and lumbar regions [35]. From the xiphoid process to the superior fascial system of the rectus abdominis muscle, fibers branch off bilaterally to the connective area of the diaphragm. The dorsal-lumbar portion is described by the medial pillars, extending superiorly from T_{11} to L_4, inferiorly [6, 40]. The medial pillars form the diaphragmatic crura (or cross), a formation of muscle tissue that creates a kind of "eight", for the esophageal hiatus (above) and the aortic hiatus (below and posteriorly,

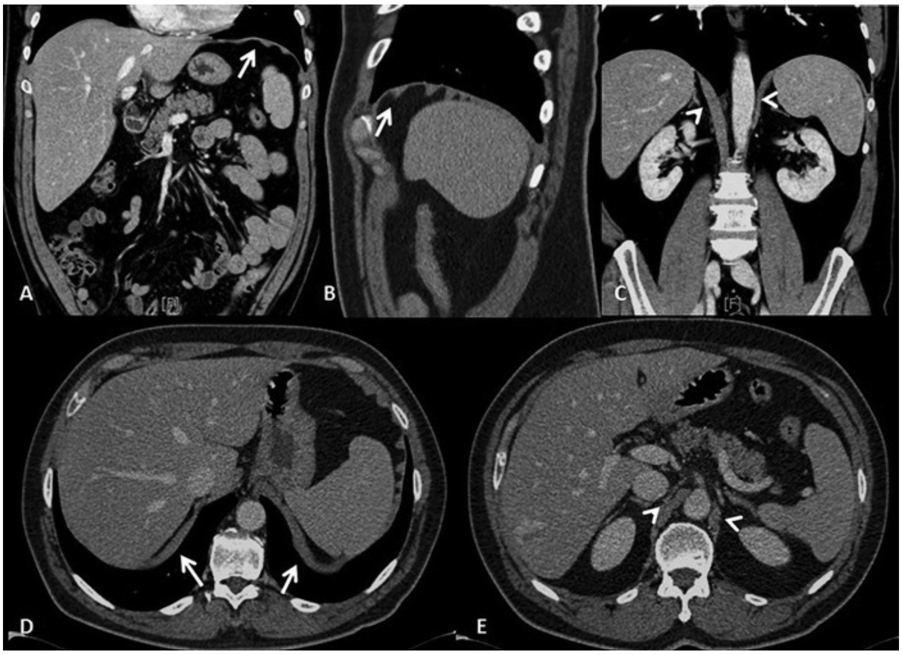

Fig. 2. The CT images in the coronal and axial planes allow visualization of the diaphragm as a hyperdense linear band interposed between the chest and the abdominal cavity (**A** and **D**, respectively; arrows). Sagittal images highlight a sort of "corrugated" morphology that shows the orientation of the muscle bundles (**B**; arrow), which may appear more or less pronounced in wellness or pathological conditions, such as COPD. Clearly visible diaphragmatic pillars also appear in both the coronal plane (**C**) and the axial plane (**E**) (arrowheads) [7]. Image owned by Bordoni Bruno.

also called median arched pillar); the right pillar with terminal contractile and connective tissue, involves the anterior vertebral bodies of T_{11} to L_4, passing over the intervertebral disks [39, 40]. The left pillar is less thick and shorter, reaching inferiorly to the vertebral body of L_3 [40]. From the left pillar and the body of the diaphragm medially, a small muscle called Low's muscle (10–15 mm thick) is born, which crosses the aortic hiatus anteriorly, to end in the hiatus of the vena cava [40]. Another muscular structure called the transverse intertendinous muscle, arises bilaterally from the connective area of the upper portion of the diaphragm ending behind Low's muscle [40].

The crural area of the diaphragm is innervated autonomically by the vagus nerve, while the remaining diaphragmatic body is somatically innervated by the phrenic nerve [6]. Inferior to the diaphragm muscle and from the right lateral border of the right medial pillar, a group of contractile fibers is born, called the Hilfsmuskel muscle; the latter ends up on the celiac artery and is innervated by the phrenic nerve [7]. The intermediate pillars consist of intertwining muscle fibers with the medial pillars, forming small holes for the passage of nerves and vessels [6]. The lateral pillars are part of the costal area. Muscle fibers of the diaphragm attach themselves to the last 6 ribs/cartilages, in the posterior and anterior portion of the same ribs, to converge towards the tendon area [40]. The rib fibers form the medial arcuate ligament extending over the psoas muscle, and the lateral arcuate ligament extending over the quadratus lumborum muscle. The first attaches laterally to the vertebral body of L_1 or L_2 and anterior to the transverse process of L_1, while the second attaches laterally to the apex of the last rib and medially to the transverse process of the first lumbar vertebra [39] (Fig. 2).

Movement of the Diaphragm during the Eupneic Ventilation

Before the movement of the diaphragm, the lingual complex moves. During the preinhalation and inhalation phases, the lower posterior portion of the tongue (near the hyoid bone) undergoes an anterior movement; in doing so, it pulls the pharynx forward and opens the upper respiratory tract [41]. At the same time, the posterosuperior portion undergoes a movement towards posteriority/caudality, with an oblique vector. Probably, this last action occurs as this lingual portion is pulled down by the contraction of the posteroinferior area [41]. The subjective sensation is that of a retrusion of the tongue. The opposite happens during the exhalation phases.

When the diaphragm descends in inhalation, the external intercostal muscles are activated and, at the same time, the abdominal muscles, the internal intercostal muscles and the contractile regions of the pelvic floor are inhibited allowing for expansion of the abdomen and pelvic floor [6, 19, 21]. The position and morphology of the diaphragm muscle reflect its morphogenesis, which has a dorsal/ventral course, starting from the pleuriperitoneal folds during fetal development [42]. Muscle fibers are in smaller quantities and shorter in the parasternal area, becoming longer and with greater protein quantity towards the dorsal-lumbar part, turning along the ribs [40]. This

Fig. 3. The sagittal section of magnetic resonance imaging highlights, through the addition of arrows and the diaphragm line before inhalation, a caudal and oblique movement of the diaphragmatic body, particularly in the posterolateral area.

will affect the range of movement. The rib area, also known as the apposition area, represents about 60% of the total surface of the diaphragm muscle [43]. During an effortless eupneic cycle, aerobic fibers will intervene most, representing about 55% of the phenotypic total of the muscle fibers of the diaphragm [44].

Studies on a human model show how a diaphragmatic contraction is able to increase the lower rib diameters (anteroposterior and transverse); the ribs are tractioned and rotated in an active manner cranially from the muscle fibers and, thanks to the abdominal displacement towards the anterior, the ribs are pushed laterally in passive mode [43, 45]. The addition of these forces during inspiration generates an increase in the aforementioned diameters, with a greater effect in the supine position; the costochondral joints take an angle towards 90°, while the rib cartilages become more oblique [43, 45]. The external intercostal muscles have less effect on the movement of the last 6 ribs, compared to the intervention of the diaphragm muscle [46].

When the diaphragm is activated for inspiration, it descends between 2 and 10 cm, with an oblique and caudal vector; the force expressed derives in particular from the posterolateral area, where the fibers are longer and can act with greater emphasis [46, 47]. The right and left hemidiaphragms move unevenly, with the right portion having a smaller excursion than the left area. Due to the presence of the liver, the shape of the right diaphragmatic dome remains unchanged, while the ribs move a few millimeters [47, 48]. Overall, the anterior area of the diaphragm moves significantly less (caudally and dorsoventrally), compared to the posterolateral area, which descends more and reaches an inclination of about 23.80° [46]. The left hemidiaphragm not only has a greater excursion, but has also a faster movement time than the right side [49]. The posterolateral portion of the diaphragm has a movement capacity of about 40% more, compared to the anterior area [50]. Before inhalation, the right dome is raised by about 1.9 cm compared to the left dome due to the presence of the liver, and with inhalation, the right area remains more cephalad for about 1.3 cm; there does not seem to be a difference between males and females [50] (Fig. 3).

We must keep in mind that, in the presence of local, systemic or traumatic pathologies, movement of the diaphragm may be altered. In patients undergoing thoracic surgery, from 9 to 85% of the diaphragm can undergo alterations in its functions and movements [50]. In patients suffering from COPD, not only will the diaphragmatic muscle reduce its excursion but will have a preference for the inspiratory position; in patients with chronic heart failure the diaphragm mass becomes thinner with smaller respiratory excursions [8, 51]. In patients with anemia, the right portion of the diaphragm has a greater excursion than the left area, the opposite compared to healthy subjects [52]. In healthy elderly subjects, the diaphragm muscle reduces its strength and the ability to induce effective intra-abdominal pressure by about 20–41%, decreasing the excursion efficiently. Athletes suffering from lumbopelvic pain show a reduction in diaphragmatic movement on inhalation and less force expressed [9, 53]. The diaphragm is subject to intrinsic alterations (fibrosis) in the presence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), and this adaptation could be a contributing factor to the need for mechanical ventilation in the intensive care unit [54]. Patients in the intensive care unit generally lose the contractile force of the diaphragm when subjected to mechanical ventilation, with atrophy and phenotypic shift, but not fibrosis [55].

Osteopathic Consideration in Palpation and Treatment of the Diaphragm

Based upon our current understanding in healthy subjects, (1) the diaphragmatic area that produces greater movement is the posterolateral area and (2) despite the reductions or alterations of movement related to pathologies or trauma, the gross anatomy of the diaphragm and the length of the fibers that constitute it are the same such that the posterolateral costal area will move more, compared to the anterolateral area, albeit to a lesser degree. Why is it important to combine a manual diaphragm assessment with the usual respiratory assessment tools, such as spirometry and nasal sniff testing? Instrumental tests are not always able to give precise indications about the function or movement of the diaphragm. Forced expiratory volume in the first second is not always indicative of diaphragmatic function in patients with COPD; equally, in patients with chronic heart failure and low ejection frequency (<35%) this is not indicative of peripheral muscle functional status [56, 57]. Pulse oximetry or cardiopulmonary exercise testing does not always highlight how the diaphragm works, how it moves and how it affects body function [58, 59].

Manual evaluation of the diaphragm muscle has good agreement between different operators, and associating palpatory information with data obtainable from instrumental tests can only be an advantage for the patient [60]. Furthermore, knowing how the diaphragm moves allows a clinician to correctly evaluate and manually work the most mobile areas, influencing the resulting treatment in a more efficient way. Too often, manual evaluations use the anterior area as an important functional mirror of the mobility of the diaphragm (parasternal/anterior costal area), by placing the hands under the sternum and ribs, whereas we know that it is an anatomical area with minimal diaphragmatic movement [12, 14, 16, 61]. Trying to understand how the muscle mass of the diaphragm moves by placing the hands only under the sternum-ribs anteriorly is a conceptual error. It is also a mistake to try to positively influence the diaphragm as a whole with an osteopathic technique, using only the treatment position under the parasternal-costal area [62].

To better identify how the diaphragmatic contractile mass moves and to try to improve the movement response of the same muscle, it is necessary to place the hands on the posterior-lateral area of the thoracic cage [48, 63, 64]. If the operator decides to examine and treat the patient standing because he cannot lay supine or prone, the spinous process of T_{11} is identified posteriorly and the thumbs are placed laterally, the hands are inclined at about 45° in order to palpate as much surface of the costotransverse region as possible. The patient performs a gentle augmented inhalation to avoid respiratory strategies not connected to the diaphragm such as activating the accessory muscles of respiration. From an osteopathic point of view and from a manual medicine point of view in general (doctors, physiotherapists), it is feasible to palpate the movement of the diaphragm, but for operators not accustomed to making the best use of the sense of touch, this action requires palpatory training [60]. The best position for palpating the diaphragm is with the patient supine or prone, since in these positions the diaphragm is not involved in the postural maintenance action, and its movement is wider [48, 65]. If the patient is able to remain in the prone position, the hands rest as previously described; if the patient is supine, the manual grip will be different. The spinous process of T_{11} will be searched for with the fingers (index); once the landmark has been identified, the hands are moved a few centimeters lateral from the spinous process, and the palms of the hands are placed, listening (Fig. 4).

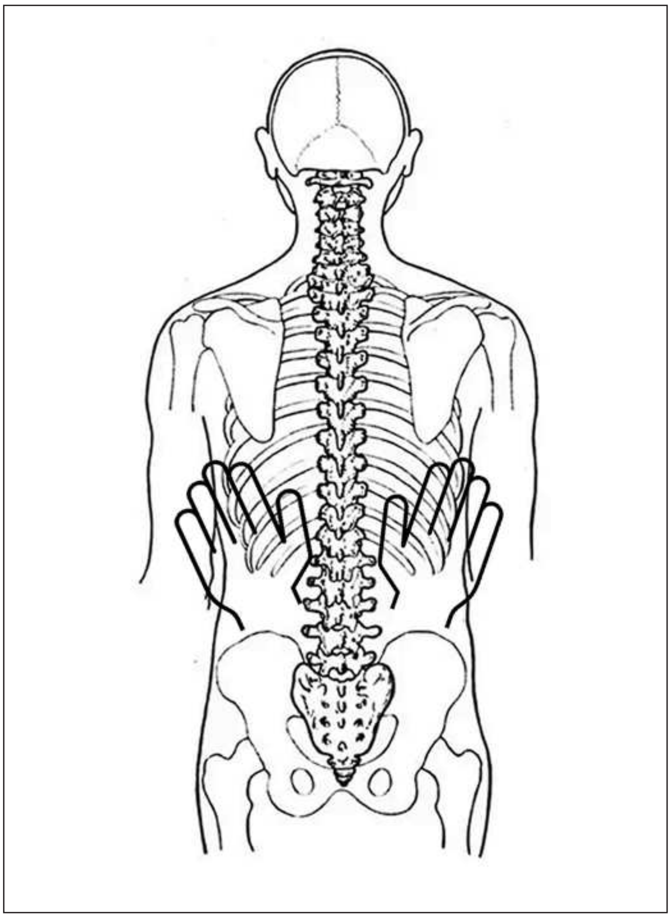

Fig. 4. The figure illustrates how the hands should be positioned in the posterolateral area, with the patient prone or standing: the spinous process of T_{11} is sought, and the thumbs are placed slightly away from the same landmark; from this position the hands are tilted at about 45°, so as to take as much surface as possible.

Several studies in the literature have used the anterior approach to understand or palpate the movement of the diaphragm [61, 66–68]. Considering that in this region the muscle only moves a few millimeters, we can say posterior palpation will be more indicative, probably, of the overall movement of the diaphragm. Similarly, if you decide to perform an osteopathic or manual technique in this area, the operator will be able to influence a larger area of the respiratory complex. We hope that this text can be a stimulus to improve future research in the osteopathic manual field, with a palpation and treatment of the diaphragm muscle closer to anatomical and physiological notions.

We conclude by recalling that a complete evaluation, when necessary and for medical indication, must consider all areas of the diaphragm, as we have already illustrated previously [63].

Conclusions

This article reviews the respiratory neural network and draws from the current hypotheses that most delineate the relationships of the midbrain and respiratory functions. The text briefly reviews the anatomy of the diaphragm muscle, the modes of movement, including how the ribs move which are connected to it. The text reviewed some research carried out on the response of the diaphragm muscle and manual palpation/treatment, highlighting that the adaptation resulting from the research does not always deepen the systemic or local response of the viscera adjacent to the main respiratory muscle. The purpose of the article was to highlight the need to improve the osteopathic manual approach to palpation and diaphragmatic treatment, suggesting to palpate the posterolateral area, as most of the current texts use palpation and treatment that does not fully reflect the dynamic functional anatomy of the ventilatory muscle. The diaphragmatic mass that makes a wider movement is the posterolateral area. Further studies and research with this hand position are awaited for the evaluation and treatment of the diaphragm muscle.

Statement of Ethics

No statement of ethics is necessary.

Conflict of Interest Statement

The authors declare that there is no conflict of interests concerning this paper.

Author Contributions

B.B. wrote and conceived the article; S.W. checked the scientific assertions and revised the grammar; A.E. checked the scientific assertions; B.D. checked the scientific assertions.

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