Effects of manual therapy on the diaphragm in the musculoskeletal system: a systematic review

ABSTRACT

Objectives: To analyze the effects at the musculoskeletal level of manual treatment of the diaphragm muscle in adults.

Data Sources: Systematic review using four databases: PubMed, Science Direct, Web of Science and Scopus.

Study selection and data extraction: Two independent reviewers applied the selection criteria and assessed the quality of the studies using the Physiotherapy Evidence Database (PEDro) scale for experimental studies. A third reviewer intervened in cases where a consensus had not been reached. A total of 9 studies were included in the review.

Results: Manual therapy directed to the diaphragm has been shown to be effective in terms of the immediate increase in diaphragmatic mobility and thoracoabdominal expansion. The immediate improvement in the posterior muscle chain flexibility test is another of the most frequently found findings in the evaluated studies. Limited studies show improvements at the lumbar and cervical level in the range of motion and in pain.

Conclusion: Manual diaphragm therapy has shown an immediate significant effect on parameters related to costal, spinal and posterior muscle chain mobility. Further studies are needed, not only to demonstrate the effectiveness of manual diaphragm therapy in the long term and in symptomatic populations, but also to investigate the specific neurophysiological mechanisms involved in this type of therapy.

Keywords

Diaphragm; manual therapy; stretching; phrenic nerve; physical therapy; connective tissue; mobility; range of movement; musculoskeletal system.

Abbreviations

COPD: Chronic Obstructive Pulmonary Disease.

ROM: Range of Motion.

PPT: Pressure Pain Threshold.

INTRODUCTION

The diaphragm is a musculotendinous structure with a concave dome shape in its lower part, which separates the chest from the abdomen [1]. Regarding anatomical attachments, a costal, a lumbar, and a sternal portion can be identified [2]. The costal or lateral section originates from the inner surface and upper margin of the six lower ribs via six interdigitations that join those coming from the transverse abdominal muscle [1, 2]. The upper diaphragmatic surface fuses into the lung pleura, while the lower surface fuses into the peritoneum [3, 4]. A logical deduction is that the chest and the abdomen are an anatomical continuum, where the diaphragm plays a vital role connecting both cavities [5].

The diaphragm is innervated by the phrenic nerve (C3-C5) and by the vagus nerve, part of the parasympathetic nervous system [6]. It has also recently been shown that the phrenic nerve has vegetative nerve branches that joint it to the celiac plexus [7, 8]. These findings lead several authors to think of a potential source of extraphrenic innervation of the diaphragm muscle [9, 10].

The diaphragm is considered the main muscle of breathing and responsible for maintaining the correct change in lung volume at the moment of inspiration of the respiratory cycle, since it has the highest contribution of the total work done of all inspiratory muscles (from 60 to 80%) [11]. The diaphragm generates a craniocaudal movement of its dome during its contraction, this change is responsible for most of the variation in volume [12]. The diaphragm carries out more than 20,000 movements per day, and in each of them it drags the lungs and abdominal viscera with it [13]. The diaphragm muscle assists in breathing, but it also has many functions connected to bodily health [14]: it is important for a proper function in phonation and swallowing [5], it prevents gastroesophageal reflux [5] and ensures the maintenance of urinary continence during respiration, by presenting symmetric mobility with the pelvic floor muscles [15]. Furthermore, the pressure differences created by the diaphragm influence lymphatic flow and could affect the gastrointestinal and cardiovascular systems, mediated autonomously and by compression forces through the myofascial tissue [16].

63

64 Numerous studies have demonstrated the fundamental role of the diaphragm in stabilizing the
65 trunk [17, 18] with a coactivation of the transversus abdominis, coordinating breathing and control of
66 the spine during different postural tasks [18]. Benefits have also been demonstrated by applying
67 in many cases manual therapy on the diaphragm, not only in spinal mobility [19, 20], but also in
68 pulmonary parameters, such as improving both ventilatory functions and functional capacity in
69 COPD patients [21], as well as maximal respiratory pressures, forced vital capacity and forced
70 expiratory volume in the first second in healthy adults [22].
71
72 The relationship between the phrenic nerve and shoulder pain has even been demonstrated,
73 analyzing a high incidence of this after visceral surgery [23], which reaches up to 97% of the
74 subjects operated by thoracotomy [24], up to 71.4% of those operated by laparoscopy [25] and up to
75 40% of women operated by cesarean section [26]. These findings make the diaphragm a muscle
76 that could have relevance on the biomechanics and function of many structures to which it is
77 anatomically related, as some studies have shown [19, 27].
78
79 Muscle stretching and myofascial release are known as manual therapy techniques [28] and have
80 been used to approach the diaphragm in different studies [19, 29]. There is limited information on
81 the possible mechanisms of performance of this type of therapies [30, 31]. The stretching
82 techniques focus on increasing the length of a musculotendinous unit, in essence increasing the
83 distance between the origin and insertions of the diaphragmatic muscle to reduce the tension
84 generated by the shortening of their fibers and promote greater effectiveness of muscle
85 contraction [32], and are some of the most frequently studied in the scientific literature [19, 33]. On the
86 other hand, through myofascial release techniques, the connective tissue could be indirectly
87 stretched after a static load, due to its innate viscoelastic properties, causing a modification of
88 the nociceptive sensation and possible reflex changes [34]. Diaphragmatic myofascial release
89 techniques have obtained benefits in both muscle and joint mobility in different studies [19, 35]. No
90 significant differences have been found between both types of techniques applied at the
91 diaphragm level in the benefits obtained in terms of rib mobility [36].
92

Before beginning this work, a search was carried out in PROSPERO, an international database of systematic reviews on health and social welfare, registered prospectively (http://www.crd.york.ac.uk/prospero/) with the objective of identifying possible systematic reviews related to our object of study that could have been performed without obtaining conclusive results. *Simonelli et al.* [37] conducted a review on different methods of manual therapy in patients with chronic obstructive pulmonary disease (COPD) and their effects at the respiratory level. Only two studies in this review used manual techniques specifically targeting the diaphragm [35, 38]. The study by *Rocha et al.* [35] was the only one who investigated musculoarticular mobility parameters.

Musculoskeletal conditions are a major burden on individuals and health systems with indirect costs prevailing, strongly associated with pain and impaired physical function [39], which commonly affects to mobility [40]. This review aims to analyze the effectiveness of manual treatment of diaphragm muscle in variables related to the musculoskeletal system, at the level of mobility and pain of muscular, bone or joint structures in adults.

MATERIAL AND METHODS

Protocol and register

This review protocol was registered in PROSPERO (CRD42020156186). The PRISMA statement [41] was used, with the purpose of adjusting the methodology to the guidance for the performance and publication of systematic reviews.

PICOS question

The specific statement of questions addressed in this systematic review is shown in Figure 1:

------ insert Figure 1 here ------

Figure 1. PICOS question of the study.

Inclusion criteria

The inclusion and exclusion criteria are shown in Table 1:

------ insert Table 1 here ------

Table 1. Criteria for inclusion and exclusion of the studies.

Search strategy for the identification of studies

The following databases were consulted until march 31, 2020: PubMed, Science Direct, Web of Science and Scopus.

The filters used in the review for the search were: studies in Spanish or English language. The full electronic search strategy for one database and Medical Subject Headings (MeSH) terms included in the search are detailed in Table 2.

------ insert Table 2 here ------

Table 2. Full electronic search strategy for Pubmed.

In a second phase, a manual search was carried out by consulting the bibliographic references of the previously identified studies.

Studies selection process

In the first phase, two reviewers analyzed all the results of both searches and decided the eligibility of the study, classifying them as relevant, possibly relevant, or irrelevant based on the reading of the title and abstract, and depending on whether the studies address manual therapy on the diaphragm to obtain any results in muscle or joint function or not.

In a second phase, again two reviewers analyzed the full text of all the selected results as relevant or possibly relevant in phase 1, to determine whether they met the inclusion / exclusion criteria. A third reviewer was called in to settle disputes about inclusion or exclusion.

Critical evaluation

151 The quality of studies was assessed using the validated and reliable PEDro scale [42, 43]. It was
152 developed to be used in experimental studies and offers an important source of information to
153 support the practice based on clinical evidence [44, 45]. The PEDro data base [46] was consulted to
154 verify if any of the articles had already been scored by PEDro. For this review, a score
155 assessment using the Harbor and Miller guidelines and score was used [47]: a study with a very
156 high quality (VHQ) is 9-10 with a very low risk of bias, a high quality study (HQ) is 7-8 with low
157 risk of bias, moderate quality (MQ) is 4-6 with high risk of bias, and low or poor quality (LQ)
158 studies were scored 1-3 with a very high risk of bias.
159
160 The articles were read, reviewed, and assessed with PEDro scale by two reviewers
161 independently. Both reviewers met to resolve disagreements and reach consensus. A third
162 reviewer was approached if a homogeneity in the critical review was not reached below one
163 point in the PEDro scale.
164

165 ## Data extraction

166 Data were extracted and generated in two independent sheets by the main reviewer and
167 checked by a second reviewer. Any disagreement over data was resolved by a third reviewer. A
168 third reviewer followed the same methodology presented independently and a consensus was
169 subsequently reached among the 3 reviewers.
170
171 Due to the heterogeneity of data from the studies selected for this review, a review of the main
172 results of each study besides a critical review for methodology was performed.
173
174

175 # RESULTS

176

177 ## Selection of studies

178 A total of 9 studies met the inclusion criteria and were included in the review. All articles were
179 randomized controlled trials. The initial search yielded a total of 1258. The complete
180 bibliographic search strategy is presented in Figure 2.
181 ------ insert Figure 2 here ------
182 **Figure 2. PRISMA flow diagram of study selection process.**
183

184 ## Clinical characteristics of the studies

185 Most of the studies were conducted in subjects without a specific pathology, three of them in
186 healthy adults [19, 29, 48], one of them with sedentary women [20] and one in a condition that cannot
187 be classified as pathological which is short hamstring syndrome [33]. The study by *Martí-Salvador*
188 *et al.* [27] used subjects with chronic non-specific low back pain, while 3 studies used a sample
189 with respiratory disease [35, 36, 49].
190

191 The samples included in each study and their summary characteristics are presented in Table
192 3.
193 ------ insert Table 3 here ------
194 **Table 3. Study characteristics.**
195

196 ## Critical evaluation and risk of bias

197 Based on the critical evaluation with the PEDro scale, the methodological quality of 3 articles [27,
198 35, 48] was considered very high with a very low risk of bias. 5 studies [19, 20, 29, 33, 49] were assessed
199 as high quality with a low risk of bias. One study [36] was considered of moderate quality with a
200 high risk of bias. 6 of the articles [20, 27, 33, 35, 36, 49] were critically reviewed by PEDro database [46]
201 using their scores. The other 3 studies [19, 29, 48] have been assessed in a systematic way
202 following the same PEDro evaluation criteria.
203

204 The full score of PEDro scale of the 9 selected studies is presented in Table 4.
205 ------ insert Table 4 here ------

Table 4. PEDro Methodological Quality scale.

206

207 ## Main results

208

209 ***Studies with presence of a specific clinical condition***

210 In the 4 studies that analyzed subjects with a specific clinical condition [27, 35, 36, 49], manual
211 therapy on the diaphragm obtained benefits in the mobility of the diaphragm assessed by
212 ultrasonography [35, 36], mobility of the thoracic cage [36, 49] and abdominal excursion [49] during the
213 respiratory cycle, increased flexibility of the posterior chain [49], and improvements in parameters
214 related to the lumbar spine [27].

215

216 ***Studies with absence of a specific clinical condition***

217 Of the 5 studies found [19, 20, 29, 33, 48], positive results were also achieved in the mobility of the
218 diaphragm [48], thoracic cage [19, 20] and abdominal excursion [20], Improvements in parameters
219 related to posterior chain flexibility [19, 20, 33], lumbar [20] and cervical spine [19, 29, 33] were also
220 obtained.

221

222 ***Type of intervention***

223 Most of the studies analyze the immediate effect in a single session of manual diaphragmatic
224 therapy [19, 20, 29, 33, 36, 48, 49]. Only two studies evaluated the musculoskeletal effect of this type of
225 techniques in long term with more than one day of intervention [27, 35]. One of them [27] carried out
226 the assessment 8 weeks after the fifth and last intervention performed, while in the other study it
227 was assessed before and after the first and sixth treatment [35].

228

229 Table 5 shows the main methods and significant results from the studies analyzed in this
230 review.

231 ------ insert Table 5 here ------

232 **Table 5. Summary of findings.**

233

234

235 **DISCUSSION**

236

237 This is the first review, for which the authors have evidence, that assesses the musculoskeletal
238 effects of manual treatment on the diaphragm muscle. This type of treatment has been shown

239 to have significant effects on muscle and joint mobility in the adult population both in absence
240 and presence of a specific clinical condition.
241
242 Several of the published studies obtained positive results using a single diaphragmatic
243 approach technique [19, 29, 33, 35, 36, 49], while other research used more than one technique for
244 treating this same muscle [20, 27, 48]. The short length of the therapeutic session (5-7 minutes) has
245 been mentioned as a possible limitation in those studies that evaluated the immediate effect of
246 a single session and used a single technique [19]. Due to the complexity and dimensions of the
247 diaphragm muscle, the authors consider that for obtaining a greater benefit and response in
248 different regions that may be anatomically related to the diaphragm muscle, more complete
249 approaches would be necessary and with a wider number of techniques that seek aiming to
250 reduce the tension of different fibers from this muscle.
251

252 Effects on diaphragmatic mobility and thoracoabdominal excursion

253 Three studies investigated the improvement of diaphragmatic mobility in respiratory movement
254 by ultrasonography with positive results [35, 36, 48]. Two of them achieved these benefits after a
255 single intervention [36, 48], while the study by *Rocha et al.* [35] made the improvement significant just
256 before the sixth and last of the treatments.
257
258 At the level of thoracoabdominal expansion, 4 studies obtained improvements in mobility of the
259 thoracic cage [19, 20, 36, 49] and 2 in basal / abdominal mobility [20, 49] during the respiratory cycle. The
260 method used by all studies for its evaluation was cirtometry, using a tape measure to obtain the
261 thoracic-abdominal amplitude between maximum inspiration and expiration at the different
262 points. Dysfunctions in diaphragmatic respiration can be demonstrated by a reduction in the
263 mobility of the rib cage [50]. These indirect measurements have an inter-observer reliability of
264 0.84-0.87 with correlation coefficients not less than 0.84 [50, 51].
265
266 Regarding the results found in the different studies, this improvement in thoracic mobility was
267 achieved at the level of the xiphoid process of the sternum [19, 20, 36], at the axillary level in the
268 second intercostal space [20, 49] and in the fourth intercostal space [36], while benefits at the

269 abdominal level were achieved in 2 studies [20, 49]. From these 4 studies that measured
270 thoracoabdominal mobility, the research by *González-Álvarez et al.* [19] was the one that had the
271 worst results, as it did not obtain significant improvement in mobility in two of the measurements
272 they made, both at the axillary level and at the abdominal level. *Marizeiro et al.* [20] suggest that
273 this fact may be due to the different positioning of the patient during the application of the
274 technique. *González-Álvarez et al.* [19] adopted a sitting position of the patient that could limit the
275 mobility of the diaphragm muscle when it was in a shortening position. On the other hand, in
276 another study [36] a significant improvement in thoracic mobility was obtained at the level of the
277 fourth intercostal space and at the level of the xiphoid in the two groups that underwent
278 diaphragmatic techniques, one of them in a sitting position with the same technique as used by
279 the aforementioned research [19] but in individuals with COPD. A protocol of multiple techniques
280 performed with the patient positioned in different positions may be necessary for the most
281 complete and effective approach to the diaphragm.
282
283 On the other hand, one study used sedentary women as a sample to evaluate changes in
284 thoracoabdominal excursion [20]. Sedentary behavior is a risk factor for many diseases, including
285 musculoskeletal and respiratory disorders [52, 53]. In the diaphragm, muscle fibers that are
286 generally arranged vertically in the area of apposition of the diaphragm can become more
287 transversely oriented in these types of individuals [54]. This makes the contraction of the
288 diaphragm less effective, reducing its ability to generate pressure [55]. Many sedentary people
289 develop dysfunctions in thoracic mobility, posterior chain flexibility, and lumbar ROM (Range of
290 Motion) compared to physically active people [20]. This contributes to hindering rib expansion,
291 increasing lung work, and reducing respiratory function [56]. The authors consider that this type of
292 behavior and excess hours in a sitting position could contribute to a shortening in the
293 thoracoabdominal region and be an important factor in limiting mobility of the diaphragm
294 muscle.
295

296 Effects on musculoarticular range

297 *1-At the posterior chain level*

298 One of the most present findings in the studies analyzed is the improvement of the flexibility of
299 the posterior muscle chain [19, 20, 33, 49]. The posterior myofascial chain is the association of the
300 posterior muscles of the body joined by connective tissue and has been suggested to have
301 strong evidence of its existence by a systematic review [57].
302
303 It mainly intervenes in posture and mobility in the sagittal plane, either by limiting the movement
304 of bringing the trunk forward or, in case of dysfunction, exaggerating or maintaining excessive
305 backward movement [58]. Limitation of the flexibility of the hamstrings is the pattern with the
306 greatest scientific evidence, as it is associated with specific disorders of the lumbar spine [59, 60]
307 and with an increased risk of injury [61]. For example, it is suggested that a part of this posterior
308 chain would be the junction between the biceps femoris and the erector spinae muscles through
309 the sacrotuberous ligament and the lumbar fascia [57].
310
311 The 4 studies that positively evaluated the effects of diaphragmatic treatment on this chain
312 mainly carried out an assessment at the lumbopelvic level in the standing position using the
313 Schober test [19, 33, 49], Forward Flexion Distance test [33] or Finger to Floor test [19, 49], and in a sitting
314 position with knees extended for the Sit and Reach test [20]. The study by *Valenza et al.* [33] also
315 performed a more specific assessment of supine hamstring extensibility through the Popliteal
316 Angle test. Three of these studies [19, 33, 49] used only the manual stretching technique in the
317 sitting position described by *Chaitow* [62], while *Marizeiro et al.* [20] used a supine diaphragmatic
318 relaxation technique and another directed at the pillars of this muscle in prone position, placing
319 the cranial hand at the level of the lower ribs and the caudal hand in the popliteal fossa for one
320 minute and on each side, with the objective of obtaining greater relaxation in the region where
321 the hamstring tendon is inserted, since it considers that the tests they used were more sensitive
322 to changes in the length of the hamstring muscles than to those of the lumbar muscles as
323 described *Melo et al.* [63].
324
325 The fact of having obtained important improvements in the posterior myofascial chain
326 assessment tests could indicate the possible efficacy of diaphragmatic treatment in other
327 compensation patterns described by *Myers* [58] and which he considers to be related to the

328 shortening of this chain: limitation of ankle dorsiflexion, knee hyperextension, anterior pelvic
329 displacement, sacral nutation, suboccipital muscle restriction, and incoordination between eye
330 and spinal movements.
331
332 ***2-At the lumbar level***
333 To the studies that obtained improvements in parameters related to the lumbar spine such as
334 ROM through goniometry [20], pain and function scales [27], those with significant results in
335 lumbopelvic flexion tests that evaluated the posterior chain could be added [19, 33, 49]. The only
336 movement that *Marizeiro et al.* [20] did not achieve significant benefits was the lumbar flexion
337 ROM, achieving them in the extension and inclinations on both sides, confirming their idea of
338 the importance of hamstring extensibility in the posterior chain tests. The difference of this one
339 [20] with the 3 studies who evaluated the Schober test [19, 33, 49] was that the intervention group of
340 manual diaphragmatic techniques was compared with a placebo control group (sham) in which
341 the same contacts and position were made but without therapeutic intention [20], instead of
342 comparing it with a group that received the application of a disconnected ultrasound [19, 33, 49]. In
343 addition, having selected a sedentary sample [20] could already predispose to presenting
344 dysfunctions in spinal mobility [64] that could affect later results.
345
346 The study by *Martí-Salvador et al.* [27] obtained a significant and clinically relevant improvement
347 in terms of pain and disability assessed in the short and long term in the experimental group to
348 which lumbar manual techniques were applied with a protocol of techniques for diaphragmatic
349 relaxation in patients with non-specific lumbar pathology. In addition, in the study they found a
350 significant decrease in anxiety and depression in this group, considering the numerous
351 investigations that have demonstrated the psychological factors associated with pain [65, 66].
352
353 These results confirm the fundamental role of the diaphragm in lumbar mechanics, in addition to
354 other findings evidenced about its role in stabilizing the trunk and in postural control [17, 18, 67, 68]
355 that could make this muscle a key structure in the therapeutic approach to lumbopelvic
356 dysfunctions.
357

358 ***3-At the cervical level***

359 The significant results that were achieved in the 3 studies that assessed parameters at the
360 cervical level [19, 29, 33] consisted of improvements in cervical ROM assessed with goniometry [33]
361 and inclinometry [19], and a hypoalgesic effect at the segmental level with an assessment of the
362 pressure pain threshold (PPT) using C4 algometry [29].

363

364 Regarding cervical ROM, improvements were achieved with respect to the control group in the
365 movements of lateral inclination and cervical extension in the two studies [19, 33], while the flexion
366 movement only achieved significant results between groups in the study by *Valenza et al.* [33].
367 Manual therapy on the diaphragm could achieve changes in the respiratory pattern by improving
368 mobility and causing an increase in cervical ROM. This fact was demonstrated in a study that by
369 re-education of the respiratory musculature, improvements were obtained both in pain and in
370 cervical mobility in a single session [69].

371

372 The research by *McCoss et al.* [29], studied the effects of manual treatment of the diaphragm
373 muscle in the PPT on both sides of the spinous process of C4, which corresponds to the most
374 significant medullary level for the phrenic nerve [23]. An hypoalgesic effect in PPT was obtained
375 immediately after the application of the supine diaphragm release technique, being considered
376 clinically significant [29]. The results were superior in the experimental group when comparing
377 them both with a group that was simply commanded to breathe normally, and with one that did
378 not apply pressure with therapeutic barriers by placing the same contact with the hands [29].

379

380 The myofascial relationship of the diaphragm with the cervical region [19, 33] and the activation of
381 afferent neurones in the phrenic nerve achieved through therapy applied to this muscle [29], have
382 been suggested as possible causes of these positive effects in the reviewed studies.

383

384 Mechanical and neurophysiological basis of the effects achieved by 385 diaphragmatic manual therapy

386

387 The mechanisms of action of these techniques applied to the diaphragm to achieve these
388 results are not clear. According to different reviews of studies that apply some type of manual
389 therapy [30, 31], there is limited information on the possible mechanisms involved, especially on the
390 mechanical aspects of pressure and movement on muscle mass, such as passive or perhaps
391 energetic muscle stiffness. Research has reported the effects of some type of manual therapy
392 on physiological (investigated by simply blood flow [70]), neurological (investigated by the
393 excitability of the nervous organs measured by H-reflex [71]), psychological (investigated simply
394 by questionnaire [27, 72] and psychophysiological recommendations such as heart rate or blood
395 pressure [73]).
396
397 As several authors comment [20, 35], and given this beneficial effect on diaphragmatic [35, 36, 48] and
398 thoracic mobility [19, 20, 36, 49], it can be hypothesized that the manual action on the underside of the
399 last costal cartilages allows the traction of the lower rib cage in a cranial direction and that the
400 manual compression of the tissues in the insertion area of the anterior costal diaphragm fibres
401 lengthens the diaphragm in its insertional zone [35], and due to the acute activation of the muscle
402 spindle caused by muscle stretching, could improve muscle viscoelasticity, and consequently
403 decrease muscle stiffness [36]. Only the study by *Mancini et al.* [48] assessed possible changes in
404 diaphragm thickness without achieving significant changes, concluding that it is unlikely that in a
405 single session of manual therapy benefits will be obtained in this parameter, since it is
406 correlated with muscle contractibility.
407
408 Moreover, activation of core stabilizing muscles with an improvement of the movement patterns
409 of spine [27, 33], as well as the anatomical relationship of the diaphragm with distant structures
410 through myofascial chains [19] could be other mechanical aspects causing the good results using
411 these techniques.
412
413 As some authors comment, long-term studies would be necessary for a better understanding of
414 the mechanical aspects that influence manual therapy on the diaphragm, and to be able to
415 attribute the changes to modifications in the tissue such as muscle length or thickness [19, 48].
416

417 The neurophysiological effects of this type of therapy could also be important to understand
418 these results. The elimination of tension in the soft tissues and in trigger points, which is
419 noticeable by palpation [48], could act on the sensory system through the Golgi tendon organs [74],
420 thereby causing an inhibitory effect [36]. This review demonstrates that there is a paucity within
421 the scientific literature that supports the benefit of manual diaphragmatic therapy on pain
422 variables. Only two of the selected studies [27, 29] included these types of variables, making it
423 necessary to be able to investigate in a more in-depth way the neurophysiological effect of this
424 technique. The research by *McCoss et al.* [29] supports the existence of an Inhibitory Regional
425 Interdependence [75] as an ascending mechanism of hypoalgesia, where directing treatment to
426 distal somatic tissue, in this case the diaphragm, can cause a decrease in specific pain in its
427 spinal segment of origin, normalizing facilitated cervical vertebrae and demonstrating this direct
428 neurological relationship. This fact has been demonstrated in other scientific studies that found
429 an improvement in the medullary segment of origin after visceral mobilization at the colon level
430 [76] and after treatment at the elbow level [77]. A systematic review on the influence of the phrenic
431 nerve in shoulder pain [23], shows us how infiltration with anesthetic in the vicinity of the phrenic
432 nerve was the most effective treatment to reduce shoulder pain after thoracic surgery and
433 laparoscopy, a problem very common in this type of patient. Therefore, a disorder of the phrenic
434 nerve, even if it is peripheral, such as diaphragmatic dysfunction, transmits chemical and
435 metabolic information to the medulla and to the interneurons adjacent to the motor neurons of
436 the phrenic nerve, affecting other sensory motor neurons or neurons of the same level, either
437 ipsilateral or contralateral [78]. This makes it possible to verify a symptomatology that is different
438 from a mere respiratory disorder, such as neck pain or brachialgia [79, 80].
439
440 Five studies [20, 27, 29, 35, 48] obtained a higher score on the PEDro scale by blinding the subjects by
441 also applying a placebo (sham) technique, using the same contacts as for the diaphragm
442 relaxation technique but without reaching barriers or therapeutic intention. The analgesic effect
443 of hand contact has been quantified by *Mancini et al.* [81], their experiments demonstrated how
444 tactile stimulation lasting just 1.5 seconds resulted in a reduction in pain perception. This
445 phenomenon has been demonstrated by more authors [82-84]. Even the effect of a heat stimulus
446 applied to a part of the body, such as the hand, has been shown to activate a part of the brain,

447 the anterior cingulate cortex, which is related to a wide range of autonomous functions, with
448 touch pleasant and with emotions [85, 86]. These investigations help to explain how prolonged
449 contact on the skin, as was done in the 5 studies [20, 27, 29, 35, 48] that used sham groups without
450 reaching therapeutic barriers, could alter pain perception and create a significant hypoalgesic
451 effect. In all of them, the results were significantly higher in favor of the experimental group. We
452 suggest that only manual therapy on the diaphragm would favor the inhibitory mechanisms of
453 nociception. These are not only mediated by the phrenic nerve and its connections with
454 important nerves that share similar medullary levels, but also by stimulation of the vagus nerve
455 as suggested by some authors [27, 87], due to the large number of sensory and motor nerve fibers
456 from the vagus nerve that have been found in the crural region of the diaphragm [6, 88]. Also the
457 unions that have been recently demonstrated between the phrenic nerve and vegetative nerve
458 branches that join it to the celiac plexus [7, 8], to the aorticorenal ganglia, and the presence of a
459 small ganglion called the phrenic ganglion [7], indicate a powerful extraphrenic innervation of the
460 diaphragm [9, 10]. The role that the autonomic nervous system plays in the generation and
461 maintenance of certain painful states is significant, and therefore its approach could be a key
462 objective in the work of the physiotherapist in daily clinical practice.
463

464 Practical application and future studies

465 Manual therapy of the diaphragm has shown an immediate significant effect on parameters
466 related to costal, spinal, and posterior muscle chain mobility. The results obtained are important
467 from the therapeutic context since it has been shown that obtaining and maintaining joint
468 mobility is very important and a key factor in the prevention of injuries [19]. It would be interesting
469 to train the healthcare professional in the correct evaluation of the mobility of the diaphragm,
470 where it has already been shown that there is a relevant correlation between the amplitude of
471 the change in the mobility of this muscle assessed by ultrasound, and the score assigned by the
472 operator by means of a manual physical examination after application of therapy to the
473 diaphragm muscle [48]. The purpose of performing this type of manual assessment is to check if
474 there is a restriction of movement in a specific area of the diaphragm muscle, in order to plan a
475 manual treatment focused on the dysfunctional area and thus improve respiratory and
476 myofascial performance. The diaphragm muscle should be considered a nexus of information

477 and transmission of forces from different parts of the body through the myofascial and nervous
478 systems, and its therapeutic approach could be necessary as prevention and treatment in
479 several musculoskeletal disorders.
480
481 Given the results achieved, the authors consider it important to highlight the need for future
482 research studies to demonstrate the effectiveness of manual diaphragm therapy applied in
483 several sessions to determine its long-term effects, in populations with musculoskeletal and / or
484 visceral symptoms, and in compensation patterns that are considered related to myofascial
485 chain shortening, in which the diaphragm is involved, and which could affect remote structures
486 such as the shoulder, hip or spine. Future studies are needed specially designed to investigate
487 the long-term effect of manual therapy on the diaphragm on thickness change and other
488 aspects that demonstrate neurophysiological or mechanical changes in the tissue.
489
490
491 **Limitations**
492 Due to heterogeneity of studies it has not been possible to perform a quantitative analysis
493 related to the included studies. We have identified limitations regarding the small number of
494 studies that met the inclusion criteria. Most of the studies investigated the immediate effect of
495 diaphragmatic treatment and in populations without a specific musculoskeletal pathology. As
496 these are studies on manual therapy, it is not feasible to blind the professional applying the
497 technique.
498
499 **CONCLUSION**
500
501 Manual therapy directed to the diaphragm has been shown to be effective in terms of the
502 immediate increase in diaphragmatic mobility and thoracoabdominal expansion in adults.
503
504 Immediate improvement in the posterior muscle chain flexibility test is another of the most
505 frequently found findings in the evaluated studies.
506

Limited studies show improvements at lumbar and cervical level in the range of motion and in pain.

Further studies are needed to demonstrate the effectiveness of manual therapy of the diaphragm in long term and in symptomatic populations, and the specific neurophysiological mechanisms involved in this type of therapy.

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737

Figure legends

Figure 1. PICOS question of the study.

Figure 2. PRISMA flow diagram of study selection process.

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P	In adults.
I	Manual techniques focused on diaphragm muscle (stretching or myofascial release).
C	In comparison with placebo treatment (disconnected ultrasound), sham techniques without pressure, no treatment, and different treatment protocols without diaphragm techniques.
O	Improves the effectiveness at the musculoskeletal level (mobility or pain of muscle, bone or joint structures).
S	Systematic review of experimental studies with a prospective design.

Figure 1. PICOS question of study.

Figure 2 Click here to access/download;Figure;figure 2.jpg

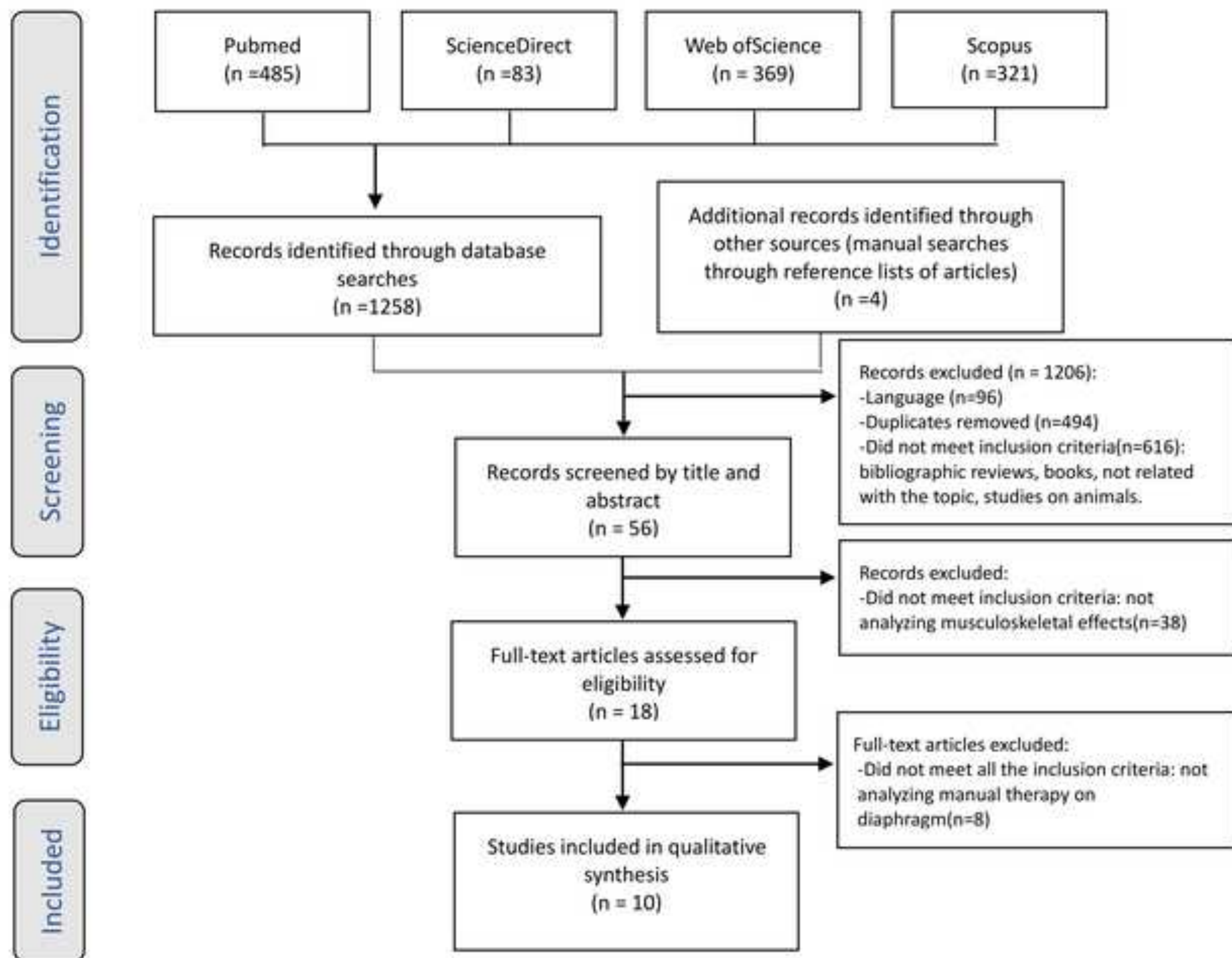

Figure 2. PRISMA flow diagram of study selection process.

 Click here to access/download;Table;Table 1.docx

Table 1. Criteria for inclusion and exclusion of the studies.

Inclusion criteria	Exclusion criteria
-Articles from inception to march 2020. -Articles in English or Spanish. -Studies with a prospective design, randomized and controlled. -Experimental studies that analyze musculoskeletal effects (muscular or joint function) of manual therapy on diaphragm muscle. -In adults.	-Unpublished work (brochures, editorials, pamphlets, posters, reports). -Bibliographic reviews and books. -Low quality studies in Quality Assessment (PEDro scale). -Studies done on animals. -Studies that only analyze pulmonary effects of manual therapy on diaphragm muscle.

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Table 2. Full electronic search strategy for Pubmed.

Database	**Search equations**	**Number of references after bibliographic search**	**Number of references after applying filters (english/spanish and no books or documents)**	**Number of references after reading the title and adjusting to the objective of the review**	**Number of references after being retrieved in full text (position number of the initial search)**	**Number of references after being subjected to in-depth reading (position number of the initial search)**
Pubmed	(“diaphragm”) AND ((“stretching”) OR ("manual therapy") OR ("physical therapy")) **All Medical Subject Headings (*MeSH*) terms*	485	82	32	12 (1, 2, 3, 7, 8, 21, 23, 39, 41, 43, 80, 81)	**7.** Nair et al. (1), González-Álvarez et al. (2), Rocha et al. (3), Martí-Salvador et al. (7), Marizeiro et al. (21), McCoss et al. (23), Valenza et al. (43)

Table 3 Click here to access/download;Table;Table 3.docx

Table 3. Study characteristics.
*: did not report sample size and general demographic data of all participants.
Abbreviations: n, number of participants; M, male; F, female; IG, intervention group; CO, control healthy group; SD, standard deviation; COPD, chronic obstructive pulmonary disease; RCT, randomized controlled trial.

Study	Design of study	Clinical condition	Sample size (n) IG	CO	Sex Gender (M/F) IG	CO	Age (years) mean ± SD IG	CO
Rocha et al. (2015) [35]	RCT	COPD	9	10	6/3	8/2	71 ± 6	71 ± 5
Valenza et al. (2015) [33]	RCT	Short Hamstring Syndrome	30	30	10/20	13/17	22.33±4.9	23.40±5.8
González-Álvarez et al. (2016) [19]	RCT	Healthy adults	43	37	19/24	15/22	36.33 ± 15.93	37.40 ± 15.82
McCoss et al. (2017) [29]	RCT	Healthy adults	17 total*	-	5/12	-	21.2±1.3 (males)* 20.4± 1.6 (females)*	-
Marizeiro et al. (2017) [20]	RCT	Sedentary women	50	25	0/50	0/25	21.24 ± 2.86	21.12 ± 2.12
Leonés-Macías et al. (2018) [49]	RCT	Asthmatic patients	18	14	5/13	4/10	27.44 ± 8.162	26.86 ± 4.849
Martí-Salvador et al. (2018) [27]	RCT	Chronic Nonspecific Low Back Pain	33	33	16/17	13/20	43.4± 10.8	41.7 ± 10.3
Mancini et al. (2019) [48]	RCT	Healthy adults	23	22	12/11	9/13	41.9±14.6	41.7±15.6
Mancini et al. (2019) [48]	RCT	Healthy adults	22	22	11/11	9/13	37.7±13.6	41.7±15.6
Nair et al. (2019) [36]	RCT	COPD	10	10	12/8*	-	66.85 ± 8.37*	-

Table 4. PEDro Methodological Quality scale.
Abbreviations: VHQ, very high-quality; HQ, high-quality; MQ, moderate-quality; LQ, low-quality.

Items	Rocha *et al.* (2015) [35]	Valenza *et al.* (2015) [33]	González-Álvarez *et al.* (2016) [19]	McCoss *et al.* (2017) [29]	Marizeiro *et al.* (2017) [20]	Leonés-Macías *et al.* (2018) [49]	Martí-Salvador *et al.* (2018) [27]	Mancini *et al.* (2017) [48]	Nair *et al.* (2019) [36]
1. eligibility criteria were specified	+	+	+	+	+	+	+	+	-
2. subjects were randomly allocated to groups	+	+	+	+	+	+	+	+	+
3. allocation was concealed	+	+	+	+	+	+	+	+	+
4. the groups were similar at baseline regarding the most important prognostic indicators	+	+	+	+	+	+	+	+	-
5. there was blinding of all subjects	+	-	-	+	-	-	+	+	-
6. there was blinding of all therapists who administered the therapy	-	-	-	-	-	-	-	-	-
7. there was blinding of all assessors who measured at least one key outcome	+	+	+	+	+	+	+	+	-
8. measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	+	+	+	+	+	+	+	+	+
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"	+	-	+	-	+	+	+	+	-
10. the results of between-group statistical comparisons are reported for at least one key outcome	+	+	+	+	+	+	+	+	+
11. the study provides both point measures and measures of variability for at least one key outcome	+	+	+	+	+	+	+	+	+
Total PEDro score (ítem 1 not counted on final score)	9	7	8	8	8	8	9	9	5
Quality of study	VHQ	HQ	HQ	HQ	HQ	HQ	VHQ	VHQ	MQ

Table 5. Summary of findings.
Abbreviations: IG, intervention group; CO, control group; COPD, chronic obstructive pulmonary disease; ROM, range of motion; SF-MPQ, Short-Form McGill Pain Questionnaire; VAS, visual analog scale; RMQ, Roland Morris Questionnaire; ODI, Oswestry Disability Index.

Study	Clinical condition	Type of intervention IG	Type of intervention CO	Methodology of treatments IG	Methodology of treatments CO	Number of treatments	Outcome measures	Main results
Rocha et al. (2015) [35]	COPD	Manual Diaphragm Release Technique in supine	Sham technique without pressure or traction	Two sets of 10 deep breaths, with a 1-minute interval between them	Same as in the experimental group	6 treatments on non-consecutive days within a 2-week period	Diaphragmatic mobility (ultrasonography)	Significant increase in diaphragmatic mobility.
Valenza et al. (2015) [33]	Short Hamstring Syndrome	Doming of the diaphragm in a sitting position	Disconnected ultrasound	Position was held for 5 minutes	5 min	1	Hamstrings flexibility (forward flexion distance and popliteal angle tests). Spinal motion (modified Schober´s test and the cervical ROM using a full-circle goniometer)	Significant differences in the intervention group compared to the placebo group for hamstrings flexibility and spinal motion (modified Schober´s test and the cervical ROM)
González-Álvarez et al. (2016) [19]	Healthy adults	Stretching of the diaphragm technique by Chaitow	Disconnected ultrasound	Traction was maintained during 5-7 min	7 min	1	Cervical ROM (inclinometry). Flexibility of the posterior chain (Schober´s test and Finger to Floor test). Abdominal and rib cage excursion measures (cirtometry)	Significant differences in cervical extension, right and left flexion, flexibility of the posterior chain, and ribcage excursion at xiphoid level
McCoss et al. (2017) [29]	Healthy adults	Diaphragm release described by Ward	a) Sham technique without pressure or traction. b) Control group: observation	5 respiratory cycles	Same as in the experimental group	1	Pain pressure thresholds in the cervical spine (C4 level), clavicles and tibialis anterior muscle	Clinically significant hypoalgesic effect (17.17%) in the spinal segment C4 in both the right and left sides in the IG. Statistical significant hypoalgesic effect (6.81%) on the right side of the

			normal breathing					cervical spine
Marizeiro et al. (2017) [20]	Sedentary women	Two diaphragmatic myofascial release techniques: “lift diaphragm” in supine, and relaxation of the diaphragm pillars in prone position.	Sham technique without pressure or traction	Lift technique was performed in two sets of 10 deep breaths on each side. Pillars technique was performed for 1 min on each side	Same as in the experimental group	1	Chest wall mobility (cirtometry). Posterior chain muscle flexibility (Sit and Reach test). Lumbar spine ROM (goniometry)	Significant improvement of chest wall mobility, and the posterior chain muscle flexibility. Significant improvement of lumbar ROM (extension and right and left flexion)
Leonés-Macías et al. (2018) [49]	Asthmatic patients	Stretching of the diaphragm technique by Chaitow	Disconnected ultrasound	Traction was maintained during 5-7 min	5-7 min	1	Abdominal and rib cage excursion (cirtometry). Lumbar spine mobility (Schober´s test). Flexibility (Finger to Floor test)	Improvement in abdominal and axillary mobility of the rib cage at 5 min, which remains at 20 min. Improvement in lumbar spine mobility and flexibility immediately after the technique

Martí-Salvador et al. (2018) [27]	Chronic Nonspecific Low Back Pain	Lumbar manual techniques plus diaphragm protocol: a) Functional diaphragm balancing; b) Muscle fiber stretching technique; c) Phrenic-center inhibition; d) Global abdominal hemodynamic	Lumbar manual techniques plus a sham diaphragm protocol without pressure or traction	Diaphragm protocol: a) 5 min; b, c and d) 10 respiratory cycles	Same as in the experimental group	5 manual therapy sessions, first 4 sessions administered twice a week and the fifth session administered 1 month after the first session	Degree of pain (SF-MPQ, VAS). Degree of disability and movement restrictions (RMQ, ODI)	Significant and clinically relevant improvements in pain and disability assessed at week 4 and at week 12: SF-MPQ, VAS, RMQ and ODI
Mancini et al. (2019) [48]	Healthy adults	Manual techniques applied to the diaphragmatic pillars (sitting position) and domes (myofascial release in supine position)	a) Sham group: a light touch approach without any therapeutic purpose; b) control group: observation, no treatment	3 respiratory cycles in a row each side and each technique	Deep inspirations (sham group)	1	Diaphragmatic mobility (ultrasonography). Diaphragmatic thickness (ultrasonography). Manual evaluation of diaphragmatic mobility pre- and post- intervention	Significant increase in diaphragmatic mobility (only group IG). A relevant correlation between the amplitude of the change in diaphragmatic mobility and the score assigned by the operator evaluating the change after intervention (IG). No significant modification of diaphragmatic thickness after the intervention.

Nair et al. (2019) [36]	COPD	Diaphragmatic Stretch Technique in a sitting position by Chaitow	Manual Diaphragm Release Technique in supine position by Rocha et al.	Traction was maintained during 5-7 min	Two sets of 10 deep breaths, with a 1-minute interval between them	1	Diaphragmatic mobility (ultrasonography). Rib cage excursion at the level of the 4th intercostal space and at the level of the xiphoid process (cirtometry)	Both groups obtained a significant improvement in diaphragmatic mobility and chest expansion after the treatment. There was no statistically significant difference in diaphragmatic mobility and chest excursion in the comparison of the postintervention values of both techniques