



Synergism between abdominal and pelvic floor muscles in healthy women: a systematic review of observational studies

Sinergismo da musculatura abdomino-pélvica em mulheres hípidas: uma revisão sistemática

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Abstract

Introduction: The training of the pelvic floor muscles is widely used for treating pelvic floor dysfunctions, like urinary incontinence. During the training, abdominal contractions are avoided; however several studies support the use of the synergy between these muscle groups. **Objective:** Carrying out a systematic review of studies that seek to identify the presence of synergy between the muscles of the abdomen and the pelvic floor and its functionality in women without pelvic floor dysfunction. **Methodology:** To conduct the review, we have followed the recommendations proposed by the Cochrane Collaboration for systematic reviews. The literature search included the databases SCIELO, PEDro, MEDLINE, Cochrane CENTRAL and EMBASE, and manual research, the starting date of the databases until August 2013. We included cross observational studies with healthy women who were assessed to find the presence of synergy between the abdominal muscles and the pelvic floor. **Results:** We included 10 articles and they all showed the existence of synergy between the abdominal and pelvic floor muscles in healthy women in the supine, sitting and standing positions. **Conclusion:** Thus, we can conclude that there is synergy between the muscles of the abdomen and the pelvic floor in healthy women. Better understanding the behavior of these muscles and synergy may favor the development of strategies for the prevention and treatment of disorders of the female pelvic floor muscles.

Keywords: Pelvic Floor. Abdominal Muscle. Women. Review.

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Resumo

Introdução: O treinamento dos músculos do assoalho pélvico é amplamente utilizado no tratamento de disfunções do assoalho pélvico, como a incontinência urinária, e durante sua execução evita-se a contração abdominal, entretanto vários estudos defendem a utilização do sinergismo entre estes grupos musculares.

Objetivo: Revisar sistematicamente os estudos que buscam identificar a presença de sinergismo entre os músculos do abdômen e do assoalho pélvico e sua funcionalidade em mulheres sem disfunções do assoalho pélvico.

Metodologia: Para a realização da revisão, foram seguidas as recomendações propostas pela Colaboração Cochrane para revisões sistemáticas. A busca na literatura incluiu as bases SCIELO, PEDro, MEDLINE, Cochrane CENTRAL e EMBASE, além de busca manual, do início das bases até agosto de 2013. Foram incluídos estudos observacionais transversais com mulheres saudáveis que foram avaliadas quanto à presença de sinergismo entre os músculos abdominais e do assoalho pélvico. **Resultados:** Foram incluídos 10 artigos e todos demonstraram a existência de sinergismo entre os músculos abdominais e músculos do assoalho pélvico em mulheres saudáveis nas posturas supina, sentada e em ortostase. **Conclusão:** Dessa forma, pode-se concluir que há sinergismo entre os músculos do abdômen e do assoalho pélvico em mulheres saudáveis. Conhecer melhor o comportamento dessas musculaturas e do sinergismo pode favorecer a elaboração de estratégias de prevenção e tratamento das disfunções dos músculos do assoalho pélvico feminino.

Palavras-chave: Assoalho Pélvico. Músculos Abdominais. Transverso do Abdômen. Mulheres. Revisão.

Introduction

The pelvic floor (PF) is composed of the muscle, ligament and fascia structures which span the area underneath the pelvis. In women, the role of PF is to support the pelvic viscera, controlling urinary and fecal continence and allowing the passage of the fetus during labor (1). The phasic contraction of the pelvic floor muscles (PFM) produces a movement of the entire structure of the PF in the ventral and cranial direction, along with an anterior movement (2, 3). During the abrupt increase in intra-abdominal pressure (IAP), the PFM should activate fast fibers to counteract the increase in pressure and prevent the downward movement of the bowels and urinary discharge (4).

Alterations in the structure and function of the PF can cause dysfunctions. These dysfunctions are common, affecting one in nine women, with its prevalence increasing as age increases. Among these dysfunctions, urinary incontinence (UI) is the most commonly related (5, 6, 7, 2). Pelvic floor muscle training (PFMT), created by Arnold Kegel in the 1940s, is used to strengthen the PFM in women with dysfunctions, especially UI (8, 9). Training these muscles is recommended as the first option of treatment for UI (9). During the training, patients are instructed to avoid contracting the abdominal muscles, especially the transversus abdominis (TrA), since it is considered that the increase in intra-abdominal pressure (IAP)

caused by the contraction of these muscles has a negative impact on the PFM (10).

However, several studies suggest that the TrA muscle helps with lumbar support, and it is the first muscle to be activated when the stability of the lumbar is challenged by rapid movements of the upper limbs; avoiding the contraction of this muscle during the PFM training might counteract the synergistic action of these muscle groups (11, 12). The existence of synergism between the PFM and the TrA has been the basis for recent studies that support the idea that the PFM are an intrinsic part of the physiological complex of the abdominal muscles (13). These studies suggest that training the PFM and the deep abdominal muscles should be carried out concomitantly so as to treat PF dysfunctions (10). Despite the fact that synergism has been the subject of study of many researchers for some time, a consensus has not been reached regarding the synergy between abdominal muscles and PFM, since this synergy can be altered in women with PF dysfunctions (14).

Only one systematic review that talked about synergism between the abdominal and pelvic floor muscles in healthy women was found in the literature (15). The goal of this study was to identify if there were evidences to support the hypothesis that there is a co-contraction of the TrA when the PFM are contracted and vice-versa. The authors (15) came to the conclusion that there was some evidence that a co-contraction

of the TrA occurs when the PFM are contracted, but a co-contraction of the PFM may be lost or weakened in patients with symptoms of PF dysfunctions. However, this systematic review has many methodological flaws, and it was even refuted, in a letter to the editor, by authors mentioned in the study (16).

Thus, it is relevant to investigate if there is scientific evidence for the presence of synergism between the abdominal muscles and the PF in healthy women by verifying if the contraction of one of these muscle groups is accompanied by the contraction of the other. The goal of this study is to perform a systematic review of studies that aim to identify the presence of synergism between abdominal muscles and the PF, and how it functions in healthy women.

Methodology

This study followed the recommendations of the Cochrane Collaboration (17).

Eligibility criteria

The studies included in this systematic review were cross-sectional observational studies with healthy women. These studies evaluated the participants as to the presence of synergism between the abdominal muscles and the PF, that is, they assessed if the contraction of one of these muscle groups was accompanied by the contraction of the other during the assessment of the abdominal groups, the PF or both.

Research strategy

To reach the goal of this study, a literature research was carried out in electronic databases: SCIELO, PEDro, MEDLINE (accessed via PubMed), Register of Controlled Trials (Cochrane CENTRAL) and EMBASE, from starting date of the databases until August 2013. In addition, a manual research of the references of published studies on the subject was performed. The full research strategy used on PubMed can be found in Table 1. There was no language restriction in the research.

Selection of the studies and data extraction

In the first stage of the selection, two authors, independently and in duplicate form, reviewed the title and abstract of the articles found by the research engines. All abstracts that did not provide sufficient information concerning the inclusion and exclusion criteria were selected, so the full article could be read. In the second stage, the same reviewers independently assessed the full articles and made their selection according to the eligibility criteria.

The same reviewers conducted, independently and in duplicate, data extraction with regard to the methodological characteristics of the studies, interventions and outcomes using standardized forms; disagreements were resolved by consensus or by a third reviewer. Authors were contacted in order to ask questions and request full articles.

Table 1 - Research strategy used on PubMed

##1	"Abdominal Muscles"[Mesh] OR "Abdominal Muscles" OR "Abdominal Muscle" OR "Muscle, Abdominal" OR "Muscles, Abdominal" OR "Abdomen"[Mesh] OR "Abdomen" OR "abdomens" OR "transversus abdominis"
##2	"Pelvic Floor"[Mesh] OR "pelvic floor" OR "Floor, Pelvic" OR "Pelvic Diaphragm" OR "Diaphragm, Pelvic" OR "Diaphragms, Pelvic" OR "Pelvic Diaphragms" OR "Pelvic Floor Muscles" OR "abdomino-pelvic musculature" OR "perineal musculature" OR "Perineum"[Mesh] OR "perineum" OR "perineums" OR "Pelvis"[Mesh] OR "pelvis" OR "Pelvic Region" OR "Region, Pelvic" OR "perineal function" OR "pelvic floor contraction"
##3	"Women"[Mesh] OR women OR woman OR "Women's Groups" OR "Group, Women's" OR "Groups, Women's" OR "Women Groups" OR "Women's Group" OR "Pelvic Floor"[Mesh] OR "pelvic floor" OR "Floor, Pelvic" OR "Pelvic Diaphragm" OR "Diaphragm, Pelvic" OR "Diaphragms, Pelvic" OR "Pelvic Diaphragms" OR "Pelvic Floor Disorders"[Mesh] OR "pelvic floor disorders" OR "Disorder, Pelvic Floor" OR "Disorders, Pelvic Floor" OR "Pelvic Floor Disorder" OR "Pelvic Floor Diseases" OR "Disease, Pelvic Floor" OR "Diseases, Pelvic Floor" OR "Pelvic Floor Disease" OR "Urinary Incontinence"[Mesh] OR "Urinary Incontinence" OR "Incontinence, Urinary" OR "Urinary Incontinence, Urge"[Mesh] OR "Urinary Incontinence, Urge" OR "Urinary Reflex Incontinence" OR "Incontinence, Urinary Reflex" OR "Urinary Urge Incontinence" OR "Urge Incontinence" OR "Incontinence, Urge" OR "Urinary Incontinence, Stress"[Mesh] OR "Urinary Incontinence, Stress" OR "Urinary Stress Incontinence" OR "Incontinence, Urinary Stress" OR "Stress Incontinence, Urinary"
#4	#1 AND #2 AND #3

Description of the methodology quality

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) initiative proposes items for describing observational studies, which, even though they do not have the objective of evaluating the quality of observational studies, allow authors to better describe them (18, 19). Six criteria were considered when describing the methodological quality of the studies included in this review: (1) detailing of the theoretical framework and reasons for performing the research; (2) presentation of the eligibility criteria; (3) presentation of the sources and methods of selection of participants; (4) definition of the sample size; (5) description of the characteristics of the study participants (e.g., demographic, clinical and social data); (6) presenting the main findings relating to the goals of the study.

Results

Description of the studies

The result strategy resulted in 5212 studies. Of these studies, 120 remained for the detailed analysis of the article. In the end, 10 studies met all the inclusion criteria and were included. Figure 1 shows the flowchart of the studies included and Table 2 shows the characteristics of these articles. The average number of participants in the trials was 10, and the smaller-scale study had four participants (23), and the one with the greatest number had 20 participants (24).

Seven studies (21 - 23, 25 - 28) evaluated the abdominal muscles and, among these, all used electromyography (EMG), four used surface EMG (22 - 25 to 27), one used needle EMG (21) and two used surface and needle EMG (23, 28). Several instruments were used to evaluate the PFM: needle EMG (20), intravaginal probe EMG (despite being intravaginal, this considered to be a surface EMG) (21 - 28), intravaginal probe and pressure EMG (22, 23, 26), transabdominal ultrasound (24) and modified intravaginal probe (pressure and EMG) (25, 27). The intravaginal probe EMG was the predominant evaluation method to record the activation of the PFM, used in seven (21-23, 25 - 28) of the ten studies. The evaluation of the abdominal muscles and PFM was carried out, most often, in the supine position in all ten studies (20 - 29) and some also conducted assessments in sitting (27) and standing (22, 23, 27) positions.

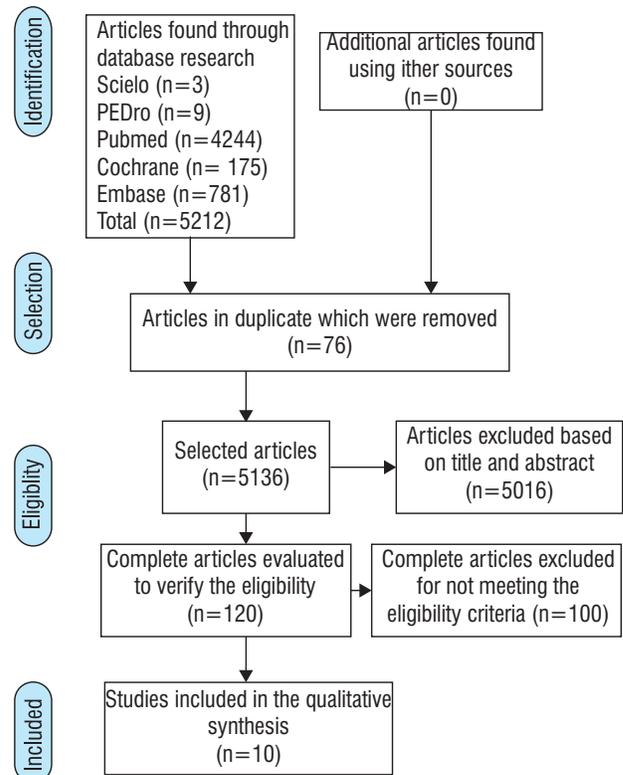


Figure 1 - Flowchart of the studies included in this review

Description of methodological quality

Regarding the criteria mentioned in the description of the methodological quality of the studies included in this review, all articles (21 - 29) met the criteria in their introduction and methodology, respectively, detailing the theoretical framework and the reasons for performing the research. As to the presentation of the sources and methods for selecting the participants and defining the sample size, none of the studies (21 - 29) included such items in their methodology. But the description of characteristics of the participants (e.g., demographic, clinical and social data) was present in 50% of the studies (21, 22, 24, 28, 29). As regards the criterion of presentation of the main findings relating to the objectives of the study, only one study (23) did not meet this criterion.

Synergy

As to the presence of synergism between the PFM and the abdominal muscles, all the selected studies found a pattern of synergy between these muscles in healthy women.

Table 2 - Characteristics of the studies included in this review

(To be continued)

Study, publishing date	Participants (n)	Way of assessing synergism	Assessed position	Protocol	Results
Bø, Stien, 1994 (20)	6	Needle EMG on the anterior wall of the urethra and the side wall of the urethra in the PFM.	Supine	Contracting the PFM; Valsalva maneuver; coughing; contracting the hip adductors; contracting the gluteus; of pelvic tilt; abdominal exercise.	The striated muscle of the urethral wall contracted in synergy during contraction of the PFM and of the hip adductors, but not during abdominal contraction. The contraction of the hip adductors, gluteus and abdominal muscles generated synergism with the PFM.
Sapsford et al., 2001 (21)	7	Abdominal muscles (needle EMG), PFM (EMG probe).	Supine	Voluntary contraction of the PFM in three different positions of the lumbar spine: lumbar flexion, lumbar extension and neutral position.	Activity in the abdominal muscles increase as a result of the contraction of the PFM. The opposite is also true, with increased EMG activity of the pubococcygeus in response to contraction of the abdominal muscles.
Sapsford, Hodges, 2001 (22)	7 (6♀, 1♂)	PFM (vaginal/anal EMG probe); PFM (vaginal/anal pressure probe); abdominal muscles (surface EMG).	Supine and standing	(1) Mild abdominal contraction (activates TrA, mostly); (2) moderate abdominal contraction (contraction of all the abdominal muscles); (3) maximum abdominal contraction (all abdominal muscles).	Voluntary activity in the abdominal muscles results in increased activity of the PFM. Increased pressure of the pelvic floor, before increase in abdominal pressure, indicates that this response is preprogrammed.
Neumann, Gill, 2002 (23)	4	PFM (pressure probe and EMG); abdominal muscles (surface and needle EMG).	Supine and standing	Abdominal testing was carried out only in the supine position. Voluntary contraction of the PFM (1st) without instructions to avoid contracting the abdomen; (2nd) with instructions to avoid contracting the abdomen; (3rd) holding in the stomach; (4th) coughing; (5th) forced expiratory volume (FEV).	Maximum contraction of the PFM resulted in simultaneous contraction of the TrA and the IO, but not of the EO and RA in the four participants.
Bo, Sherburn, Allen, 2003 (24)	20	Transabdominal US (movement of the PF).	Supine	Contracting the TrA, the PFM, and both muscle groups at the same time, adding a contraction of the PFM on top of a contraction of the TrA.	Instructions to contract the PFM cause a movement 61.6% > of the PF in the correct direction than contracting the TrA. Synergism between the PFM and the TrA was observed.
Madill, McLean, 2006 (25)	13	PFM (modified pressure probe and EMG); abdominal muscles (surface EMG).	Supine	Three voluntary contractions of the four abdominal muscles and the PFM.	There was response of the abdominal muscles during the contraction of the PFM and vice-versa. TrA is more active during the contraction of the PFM than when it is contracted by itself.

Table 2 - Characteristics of the studies included in this review

(Conclusion)

Study, publishing date	Participants (n)	Way of assessing synergism	Assessed position	Protocol	Results
Thompson et al, 2006 (26)	13	Abdominal muscles (surface EMG); PFM (EMG probe, pressure probe); IAP (anal probe); bladder position (transabdominal US).	Supine	PFM contraction and Valsalva maneuver.	There is increase in abdominal activity when the PFM are contracted. The pattern of muscle activation varies depending on the position of the test: supine, sitting or standing. However, in general, it can be described as beginning with EO, followed by the simultaneous activation of the PFM, RA and TRA and, finally, activation of the IO.
Madill, McLean, 2008 (27)	15	PFM (modified pressure probe and EMG); abdominal muscles (surface EMG).	Supine, Sitting, Standing.	MVC of the PFM and the abdominal muscles in the supine, sitting and standing positions.	Bladder neck elevation occurred consistently only during contractions of TRA and mild contraction of the PFM. The study also showed that the co-contraction of the PFM and TRA occurs only with submaximal efforts.
Junginger et al., 2010 (28)	9	Perineal US (movement of the bladder neck); PFM (EMG probe); abdominal muscles (surface and needle EMG); IAP (anal probe).	Supine	Mild/moderate/maximum contraction of the PFM, in this order. Contraction with abdominal belt. Valsalva maneuver. Holding head up.	
Sapsford, Clarke, Hodges, 2012 (29)	7	Anal, urethral and vesical pressure.	Supine	(1) Maximum contraction of the PFM, (2) abdominal contraction (instructions to contract the PFM voluntarily during the maneuver were not given), (3) bulging the abdominal wall ("belly out, without contracting the abdominal muscles").	The gradual contraction of the abdominal muscles is associated with the increase in urethral pressure and the synergistic activity of abdominal muscles and PFM may contribute to the urethral closure in healthy women.

Note: PFM: pelvic floor muscle; EMG: electromyography; MVC: maximum voluntary contraction; TRA: transversus abdominis; IAP: intra-abdominal pressure; US: ultrassom; IO: internal oblique; EO: external oblique; RA: rectus abdominis; PF: pelvic floor

Table 3 - Description of the methodological quality of the studies

Study	(1)	(2)	(3)	(4)	(5)	(6)
Bø, Stien, 1994 (20)	Yes	Yes	No	No	No	Yes
Sapsford et al., 2001 (21)	Yes	Yes	No	No	Yes	Yes
Sapsford, Hodges, 2001 (22)	Yes	Yes	No	No	Yes	Yes
Neumann, Gill, 2002 (23)	Yes	Yes	No	No	No	No
Bo, Sherburn, Allen, 2003 (24)	Yes	Yes	No	No	Yes	Yes
Madill, McLean, 2006 (25)	Yes	Yes	No	No	No	Yes
Thompson et al., 2006 (26)	Yes	Yes	No	No	No	Yes
Madill, McLean, 2008 (27)	Yes	Yes	No	No	No	Yes
Junginger et al., 2010 (28)	Yes	Yes	No	No	Yes	Yes
Sapsford, Clarke, Hodges, 2012 (29)	Yes	Yes	No	No	Yes	Yes

The first study found was published in 1994 by Bø and Stien (20). In this study it was observed that the PFM contract synergistically during the contraction of the abdominal muscles. Thus, the authors suggest that abdominal exercises can strengthen the PFM.

The second study found was published in 2001 by Sapsford *et al.* (21). It investigated the response of the abdominal muscles during voluntary contraction of the PFM in three positions of the lumbar spine. These authors observed that the amplitude of the EMG of the TrA was higher than the other abdominal muscles in all positions of the spine, and the amplitude of the EMG of the TrA was higher when observed with the lumbar spine in a neutral position. It was also verified that the TrA acted in synergy with the PFM, that is, an increase of the muscular activity in the PF was accompanied by an increase in activity of the TrA. In the same study, an additional experiment was performed. It was similar to the main experiment, with two participants using the needle EMG in both the abdominal muscles and the PFM. In the case of the PFM, the needle was placed on the right side of the pubococcygeus through the side vaginal wall. The objective was to verify the pattern of activity of the pubococcygeus during voluntary contraction of the abdominals. It was observed that during the contraction of the abdominal muscles there

was increased activity of the pubococcygeus muscle in the participants.

Also in 2001, Sapsford and Hodges (22) aimed to determine whether the voluntary contraction of the abdominal muscle is associated with muscle activity in the PF in the supine and standing positions, and if so, whether this response depends on the magnitude of the abdominal contraction. The authors found that during abdominal contraction there is increased activity in the PFM, in all levels of contraction (mild, moderate, maximum), although this increase was higher at maximum contraction. The results obtained when participants were standing were similar to data found in the supine position, in which the contraction of the abdominal muscles was associated with an increased electromyographic activity of the PFM. This finding indicates that the mechanical response of the PFM precedes the abdominal muscles and the PFM activity is not simply a response or increase in IAP. The increased pressure in the pelvic floor before the increased IAP indicates that this response is preprogrammed and the authors believe that training the abdominal muscles can be useful in the treatment of dysfunctions of the PFM. Although the study by Sapsford and Hodges (2001) (22) had the participation of a man, the results and discussion were different for men and women

and, in this study, we considered the data regarding the six women.

The authors Neumann and Gill (23) developed, in 2002, a study with four participants. One of its aims was to investigate the interaction between the abdominal muscles and the PF in the supine (neutral lumbar spine) and standing positions. The participants underwent an abdominal test (lift your head and shoulders simultaneously off the bed and hold the position for three seconds) only in the supine position in order to obtain a maximum activation of all abdominal muscles. This test was used to normalize the data from the abdominal muscles throughout the study. The collection protocol consisted of five activities performed in the supine position, with four of those tested also in the standing position. The MVC of the PFM without guidance to avoid contracting the abdomen caused the activation of TrA up to 66% of its maximum EMG activity. The MVC of the PFM with guidance to avoid contracting the abdomen (supine posture) only activated up to 26% of its maximum contraction, that is, the activity of the PFM was reduced in an attempt to isolate the contraction. In addition, during the contraction of the PFM there was no activity of the abdominal muscles, regardless of the lumbar spine position. Contracting only the TrA produced a 12% increase in its EMG activity and the PFM were activated to 40% of its capacity, which is higher than its activity of 26% during MVC of the PFM without contraction of the abdomen. With this, the authors showed that there is presence of synergy between the abdominal muscles and the PF.

A study by Bo, Sherbun and Allen (24) in 2003 assessed the presence of synergy between the abdominal muscles and the PF using a transabdominal US, comparing three different instructions for contraction of the abdominal muscles and PFM. Comparisons were made by evaluating the movement of the PF. The average of six contractions for each instruction was completed. Even though the capacity for PFM contraction had been previously observed during data collection, one participant showed caudal movement of the PF when instructed to contract the PFM. In the instruction to contract the TrA, six participants (30%) showed caudal movement of the PF. During instruction for simultaneous contraction of the TrA and PFM, two participants showed caudal movement of the PF. This study suggests that the isolated contraction of the PFM is more efficient for PF elevation than

contracting the TrA alone, and also more efficient than the associated contraction of TrA and PFM.

Authors Madill and McLean (25) published, in 2006, a study that aimed to describe the relationship between the activation of the PFM, the activation of abdominal muscles while performing MVC of each of the four abdominal muscles and the PFM. The study showed that the TrA was more active during the contractions of the PFM than during its isolated contraction. In 2008 (27), the same authors (25) conducted a study to observe, through MVC of the abdominal muscles and the PFM in the supine, sitting and standing positions, the synergistic patterns of these muscles. They found that all the abdominal muscles were activated when the PFM were contracted.

In 2006, Thompson *et al.* (26) published a study that had the goal of investigating the activation pattern of the abdominal and PFM during the contraction of the PFM. The participants were put in the supine position, with the lumbar spine in a neutral position. In this study, the authors observed only three of the abdominal muscles: IO, EO and RA. They considered that an electrode on the IO could also access the activity of the TrA, which is located directly under it. Comparing the muscles while resting and while contracting the PFM, the authors concluded that during the contraction of the PFM there is an increase in the activity of the IO and EO.

Junginger *et al.* (2010) (27) observed the movement of the bladder neck using a perineal US, and also using the EMG of the abdominal muscles and the PFM. This was carried out during six activities: (1) mild contraction of the PFM; (2) moderate contraction of the PFM; (3) isolated contraction of the TrA; (4) contraction of the abdominal muscles; (5) Valsava maneuver; (6) flexing of the upper body. The authors observed that the bladder neck was elevated consistently only during contraction of the PFM and isolated contraction of the TrA. When other abdominal muscles were contracted there was increase in intra-abdominal pressure and the activity of the PFM was not enough to elevate the bladder.

The last study found, by Sapsford, Clarke and Hodges (2012) (29), tested the hypothesis that the activation of deep abdominal muscles is associated to an increase in urethral pressure comparable to the increase obtained during the voluntary contraction of the PFM. These authors observed that the gradual contraction of the abdominal muscles is associated with an increase in urethral pressure, and the

synergetic activity between the abdominal muscles and the PFM may contribute to the urethral closure in healthy women.

Discussion

The goal of this study was to perform a systematic review to identify if there is scientific evidence of the presence of synergy between the abdominal muscles and the PFM in healthy women. To this date, only one systematic review (14) about this subject has been published, and it has several methodological flaws. In it, the authors concluded that there is some evidence that a co-contraction of the TrA occurs when the PFM are contracted. In our systematic review, we observed that all studies brought evidence of the presence of synergy between the abdominal muscles and the PFM, that is, there is a response of the abdominal muscles during the contraction of the PFM and vice-versa. It is important to note that none of the studies met all the criteria regarding methodological quality considered in this review. Five studies met four of the six criteria chosen to describe the methodological quality (21, 22, 24, 28, 29). None of the studies presented the sources and methods for selecting the participants or defining the size of the sample. This puts into question the reliability of the studies present in this review. The fact that they used different evaluation instruments also limited the comparison between studies.

The most common instrument used to assess the PFM and the abdominal muscles was the EMG, especially the surface EMG. This technique registers bioelectric extracellular activity generated by muscle fibers. It can be carried out using surface electrodes, which captures the activity of several motor units, or using a needle, which captures the activity of fewer motor units (30). Despite the fact that data collection using EMG still requires standardization of a few variables - for example, the position of the sensor and the patient, the number of contractions for evaluating phasic fibers and the amount of time the contraction must be held for evaluating tonic fibers - this is a tool used very often in research and in clinical practice, because it has good reproducibility and reliability (31). The type of electrode and the parameters of analysis are important factors in the discussion about surface electromyography. According to Deffieux et al. (32), surface electrodes are more suited for capturing

the electronic activity of the PFM because they engage and capture the signal better than the needle electrodes, which are painful and can move during the movement caused by the muscular contraction. Thus, the fact that an intravaginal EMG probe was used in four of the selected studies (21, 23, 26, 28) is due to the fact that it is an instrument described in the literature as a reliable method for evaluating muscular activity of the PF in healthy women.

The supine position (20 - 29) is considered to be the most convenient for evaluating the PFM, for both the therapist and the patient, and that is possibly the reason why it was used in the ten studies (20 - 29) that make up this review. However, this position is only one of the behaviors that the PF may have, since urinary incontinence in women with SUI depends on physical effort and often increases when they are standing, since in this position there is the action of gravity acting on the PF (34, 35).

Only three studies (22, 23, 27) evaluated other positions in addition to the supine. The study of Madill and McLean (27) did not identify differences in the activation of the PFM between the supine and standing positions, suggesting that gravity had little or no impact on the activation of the PFM. The comparison study by Madill and McLean (27), with results found in a study with women who suffer from SUI, such as the one by Rett *et al.* (35), suggests that there is difference in the behavior of the PF of healthy women and the PF of women with dysfunctions. The authors identified, using an intravaginal EMG probe, that the amplitude of the contractions of the PFM was higher in the supine position and subsequently lower in the sitting and standing positions.

The analyzed studies (20 - 29) can be divided into three groups: (1) response of the TrA muscle during contraction of the PFM (21, 26); (2) PFM response during abdominal contraction (20 - 22); (3) TrA response during contraction of the PFM and response to contraction of the TrA (23, 25, 27 - 29). All groups provided evidence of the presence of synergism between the abdominal muscles and the PFM in the supine position, that is, there is response of the abdominal muscles during the contraction of the PFM and vice versa.

Among the studies of group 3 we can identify two approaches. Bo, Sherbun and Allen (24), despite identifying the presence of synergism between the abdominal muscles and the PF, maintain that the isolated contraction of the PFM is more effective

than the isolated contraction of the TrA muscle, and also more efficient than the associated contraction of the TrA and the PFM. They claim that the contraction of the TrA, by increasing the IAP, hinders the elevation of the PF. They also say that the TrA has nothing to do with the urethra and it does not support its function, which is only associated with the activation of the PFM. In women with weak PFM, training the PFM by activating the TrA without instructions for voluntary and simultaneous contractions of the PFM could, with the increased IAP and without an effective action on urethra closure, make the UI worse (24).

Neumann e Gill (2002) (23), on the other hand, argue that the MVC of the PFM, with instruction to avoid contracting the abdominal muscles, reduces its EMG activity, and that the contraction of the TrA is capable of increasing the EMG activity of the PFM more than the MVC. According to Sapsford et al. (21) and Neumann and Gill (23), the practice of avoiding the contraction of the abdominal muscles during the PFM training with women suffering from UI should be reconsidered, since the activity in the abdominal muscles is a natural response to the contraction of the PFM and vice-versa. This fact may be confirmed by the study by Korelo et al. (36) that verified if strengthening the abdomen influences the PFM in young, healthy women. In the study, the women were divided into two groups: one received instructions to contract the PFM while contracting the abdominal muscles at the same time; the other group was not instructed to contract the PFM. The authors suggested that associating exercises that strengthen abdominal muscles with the PFM may increase the strength and function of these muscle groups, and not associating them might harm the function of the PF. Recently, Arab e Chehrehrizi (2011) (37) demonstrated in their study, which compared healthy and incontinent women, that a co-activation of the abdominal muscles occurs during the contraction of the PFM equally in both groups.

Our review analyzed 10 studies, five more than the review by Bo et al. about the same subject (15), probably because it counted with four more years and used a more sensible and complete research strategy. The review by Bo et al. (15) did not follow the recommendations proposed by the Cochrane Collaboration (17) for systematic reviews, such as well-defined eligibility criteria, specific ways of

selecting the studies, extracting data and describing the methodological quality of the studies included in the review. Besides, despite the fact that the authors (15) concluded that a co-contraction of the PFM during the contraction of the TrA might be lost or weakened in patients with PF dysfunctions, they did not include studies that assessed women who suffered from UI.

The limitations of our study are the restriction of researching articles only in English and Portuguese and the difficulty comparing the studies because of the use of different forms of evaluation of the synergy between the abdominal muscles and the PFM.

Research on the synergy between the abdominal muscles and the PF provide the physical therapist who works in the treatment of dysfunctions involving both pelvic and abdominal areas with a greater insight into the normal functioning of these body regions. With this review, we can demonstrate that studies suggest the existence of a synergism between the abdominal muscles and the PF in healthy women, and the associated contraction of the TrA and the PFM can be possibly useful to optimize the functionality of the PFM. However, it is still not possible to state how this synergy could be used to improve the functionality of the PFM. There is also the need for systematic reviews to assess women with disorders of the PFM, studies comparing women with and without dysfunction of the PFM, as well as studies about the use of abdominal training in the treatment of disorders of the PFM, in order to better understand this function and choose more effective treatments for dysfunctions of the PF.

Final considerations

All the studies selected for this review showed the existence of a synergy between the abdominal muscles and the PF in healthy women in the supine, sitting and standing positions. However, none of the studies included in this review presented the sources and methods for selecting the participants and defining the sample size, which limits the reliability of the findings. Better understanding the behavior of the abdominal muscles and the PF, and the synergism between these muscle groups may favor the development of strategies for the prevention and treatment of disorders of the female PFM.

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