Physiotherapy 105 (2019) 24–34

Systematic review

Relationship between diastasis of the rectus abdominis muscle (DRAM) and musculoskeletal dysfunctions, pain and quality of life: a systematic review

Deenika R. Benjamin [a,*], Helena C. Frawley [b,c], Nora Shields [a], Alexander T.M. van de Water [d], Nicholas F. Taylor [a,e]

[a] *Department of Rehabilitation, Nutrition & Sport, School of Allied Health, La Trobe University, Victoria, Australia*
[b] *School of Primary and Allied Health Care, Faculty of Medicine, Nursing and Health Sciences, Monash University, Victoria, Australia*
[c] *Centre of Allied Health Research & Education, Cabrini Hospital, Victoria Australia*
[d] *Department of Physiotherapy and Lectorate of Health and Movement, Academy of Health Sciences, Saxion University of Applied Sciences, Netherlands*
[e] *School of Allied Health, Allied Health Clinical Research Office, Eastern Health, Victoria, Australia*

Abstract

Background Diastasis of the rectus abdominis muscle (DRAM) is common during and after pregnancy.
Objectives To determine the association between: the presence of DRAM and low back pain, lumbo-pelvic pain, incontinence, pelvic organ prolapse, abdominal muscle performance or health-related quality of life; and between DRAM width and severity of these outcomes.
Data sources Six electronic databases (EMBASE, Medline, CINAHL, PUBMED, AMED and PEDro).
Study selection Included studies of all designs with adults with DRAM that assessed low back pain, lumbo-pelvic pain incontinence, pelvic organ prolapse, abdominal performance or health-related quality of life.
Study appraisal & synthesis methods Methodological quality was assessed using the Effective Public Health Practice Project tool. A narrative summary was completed for DRAM presence and presence of the various musculoskeletal dysfunctions, and DRAM width and the severity of these dysfunctions.
Results Twelve studies involving 2242 participants were included. There was no significant association between the presence of DRAM and lumbo-pelvic pain or incontinence. There was a small association between the presence of DRAM and pelvic organ prolapse. DRAM width may be associated with health-related quality of life, abdominal muscle strength and severity of low back pain.
Limitations Quality of studies was weak. There was variability in the methods used to assess DRAM.
Conclusion There is weak evidence that DRAM presence may be associated with pelvic organ prolapse, and DRAM severity with impaired health-related quality of life, impaired abdominal muscle strength and low back pain severity.

Systematic Review Registration Number: PROSPERO CRD42017058089.

Keywords: Rectus abdominis; Abdominal muscles; Pelvic organ prolapse; Pelvic pain; Low back pain; Urinary incontinence; Diastasis

Introduction

Diastasis of the rectus abdominis muscle (DRAM) is a widening of the inter-recti distance between the two bellies of the rectus abdominis muscle at the linea alba [1,2]. DRAM most commonly occurs during and post pregnancy and its

* Corresponding author.
E-mail addresses: d.benjamin@latrobe.edu.au (D.R. Benjamin), helena.frawley@monash.edu (H.C. Frawley), N.Shields@latrobe.edu.au (N. Shields), a.vandewater@latrobe.edu.au (A.T.M. van de Water), N.Taylor@latrobe.edu.au (N.F. Taylor).

https://doi.org/10.1016/j.physio.2018.07.002
0031-9406/

reported incidence varies between 66 and 100% in the final trimester of pregnancy, 53% post-delivery (within 24 hours) and up to 36% post-natally (up to 12 months) [1,3]. DRAM has also been identified in non-obstetric cohorts such as urogynecological, menopausal, older populations [3,4] and in populations with abdominal aortic aneurysm [5]. Radiological and cadaveric studies have identified inter-recti distances ranging from 1.3 to 2.3 cm at the umbilicus at rest [6,7]. An inter-recti widening of more than 2.2–2.3 cm as identified by ultrasound is regarded as clinically meaningful [7,8]. This widening has been postulated to be associated with adverse health consequences such as lumbo-pelvic instability, low back pain and incontinence [9–12]. However, to date, there has been little evidence to support the postulated associations.

DRAM ensues due to the stretching of the linea alba [6]. The linea alba is the insertion point for the central seam of connective tissue fascia of the rectus abdominis, transversus abdominis and the oblique muscles [1]. This lattice of collagen fibres spans the length from the xiphoid to the pubic symphysis, and a number of studies have demonstrated that the greatest widening occurs at the level of the umbilicus [7–9]. In pregnancy stretching of the linea alba occurs as a consequence of hormonal elastic connective tissue changes and the mechanical strain put on the abdominal wall by a growing foetus, increasing weight and displacement of abdominal organs [1,9,10]. These stresses alter the spatial arrangement of the abdominal muscles and fascia, and modify their optimal line of action reducing their ability to generate force [9]. Maintenance of a tension of the linea alba is necessary to ensure proximity of the rectus bellies and torque of the transversus abdominis, rectus abdominis and the oblique muscles [6]. It has been hypothesised that imbalance between strength and length of these muscles of the abdominal wall and consequent altered fascial tension, may be associated with altered movement patterns resulting in pain and dysfunction [2,12,13]. Multiparity, maternal age, child care responsibilities, heavy lifting and a higher body mass index have been identified as risk factors linked with DRAM presence [3,10].

Although there is substantial research that examines the role of abdominal muscles in low back pain, lumbo-pelvic pain, respiration and abdominal functional strength [13–15] less is known about the effects and implications of increased inter-recti distance of the abdominals. Some studies have reported associations of DRAM with low back pain, lumbo-pelvic pain, incontinence, pelvic organ prolapse and abdominal strength, while others found no association. To date there has not been a synthesis or meta-analysis of this research. Resources are directed clinically and towards research in the assessment and management of DRAM on the premise that it is deleterious to the functions of the abdominal wall and may lead to pain and dysfunction. It is anticipated that findings of this systematic review might determine if this is justified, and so inform clinical practice.

Therefore the aims of this systematic review were to determine if there is an association between:

- The presence of DRAM and low back pain, lumbo-pelvic pain, pelvic pain, incontinence, pelvic organ prolapse, abdominal performance and health-related quality of life (primary outcome).
- DRAM width and severity of these outcomes (secondary outcome).

Methods

This systematic review was prospectively registered in the PROSPERO database (CRD 42017058089).

Data sources

Systematic searches (see Appendix 1 in supplementary material) were conducted on Medline, CINAHL, AMED, PEDro, PUBMED and EMBASE, from the earliest date available to May 2017. Manual searching of reference lists of included studies and citation tracking *via* Web of Science and Google Scholar was also conducted. There was no restriction for language or study design.

Study selection

Two reviewers applied the selection criteria (Fig. 1) independently to titles and abstracts of the studies retrieved. Reviewer agreement was evaluated. Kappa statistic (κ) scores of at least 0.61 were interpreted as substantial agreement [16]. Where it was unclear if studies should be included, the full text was retrieved and eligibility criteria re-applied. Disagreements were resolved by discussion and if consensus could not be reached, a third reviewer was consulted.

Data extraction

A form based on the Cochrane Consumers and Communication Review Group [17] template was used. The form was piloted and then refined. Data were extracted by one reviewer and checked for accuracy by a second reviewer. Attempts were made to contact the authors of individual studies where data were missing. Data extracted included: participant characteristics, study design, outcomes investigated, methods of measurement, quality of internal validity, and results.

Quality assessment

Methodological quality was appraised independently by two reviewers using the eight-item Effective Public Health Practice Project tool (EPHPP) [18]. The EPHPP was chosen as there was no restriction on study design. A rating of ‘strong’, ‘moderate’ or ‘weak’ is based on 6 items that evaluate ‘selection bias’, ’study design’, ‘confounders’, ‘blinding’, ‘data collection’ and ‘withdrawals and drop-outs’. A global rating of ‘strong’ was given if four items were rated strong

INCLUSION	EXCLUSION
Population	
• adult ≥18 with diastasis of rectus abdominis muscle (including, for example, pre- and post-natal women, adults with abdominal aortic aneurysm/ abdominoplasty patients)	• any populations with: pre-existing neurological disorders/ fractures, arthritis/ medically unstable conditions/ previous abdominal surgery unrelated to pregnancy. • non-human • cadaver studies
Outcomes	
• low back pain • lumbo-pelvic pain • incontinence • pelvic organ prolapse • abdominal muscle performance • health-related quality of life	
Study design	
	• case studies/ case series
Publication type	
• full-text study publications	
	• systematic reviews • abstracts • conference proceedings • editorial opinions
Publication Period	
• no limits on publication period	
Language	
• no limits to publication language	

Fig. 1. Study selection criteria.

and no items were rated weak, 'moderate' if less than four items were deemed strong and there was one weak rating, and 'weak' if there were two or more weak ratings. The EPHPP was identified as an appropriate tool for assessing the quality of RCTs and non-RCT designs [19]. Quality was taken into consideration when interpreting results, however trials were not excluded based on quality. Reviewer agreement was evaluated using the kappa statistic.

Outcomes

The primary outcome was association between presence or absence of DRAM with presence of low back pain, lumbo-pelvic pain (low back pain with pelvic girdle pain), pelvic pain, incontinence, pelvic organ prolapse, impaired abdominal muscle performance, or impaired health-related quality of life. The secondary outcome was association between DRAM width (cm) and severity of low back pain, lumbo-pelvic pain, pelvic pain, incontinence, pelvic organ prolapse, impaired abdominal performance or impaired health-related quality of life. No restrictions were placed on timing of measures nor how DRAM was measured for all outcomes.

Data analysis

A narrative summary was completed for DRAM presence and presence of the various musculoskeletal dysfunctions, and DRAM width and the severity of these dysfunctions. Risk ratios and odds ratios are presented for most associations. Risk ratio was estimated in prospective studies and odds ratios in all other designs as incidence cannot be calculated when exposure is unknown [20]. Pearson correlation meta-analysis was considered for secondary outcomes (DRAM width and severity of outcomes), however the number of studies (<30) in this review was not suitable for standard correlation meta-analysis [21]. Therefore correlation data were synthesised descriptively.

Results

Flow of studies

The search strategy identified 553 potentially relevant studies [Fig. 2]. Fifteen full text articles were reviewed of

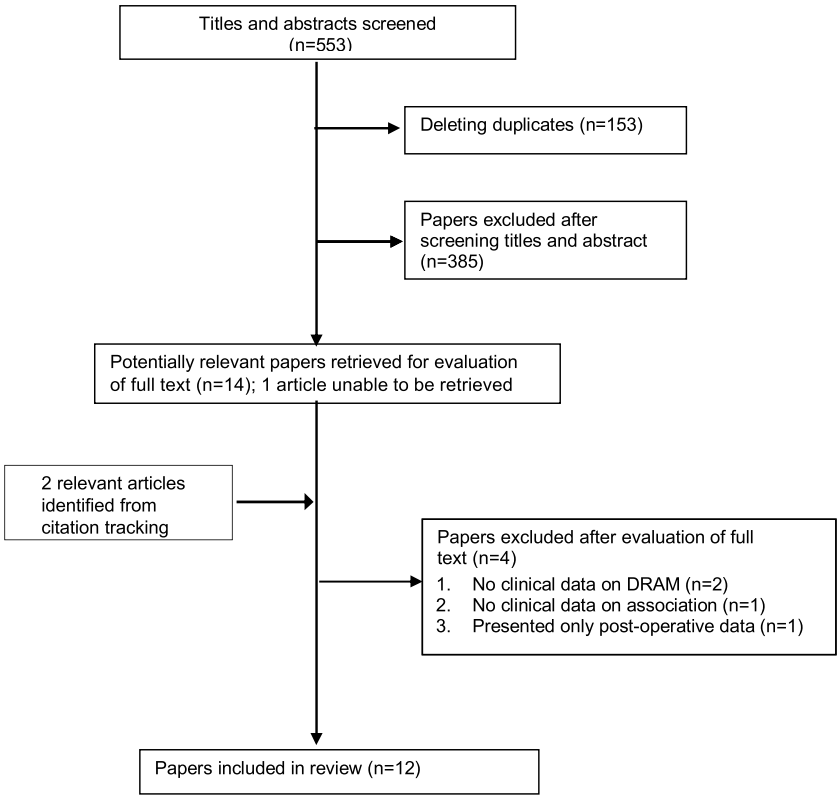

Fig. 2. Flow of studies through the review.

which 10 were included. Two relevant articles were identified through citation tracking. Consensus was reached to include 12 studies [Fig. 2]. There was substantial agreement of study selection ($\kappa = 0.80$, 95%CI 0.66 to 0.94).

Characteristics of the studies

The 12 included studies investigated the relationships between DRAM and lumbo-pelvic pain ($n = 5$), incontinence ($n = 4$), pelvic organ prolapse ($n = 3$), abdominal muscle strength ($n = 2$) and health-related quality of life ($n = 2$). Ten of the 12 studies were observational analytical (cohort, case-control and cross-sectional) in design [Table 1]. Of these, 8 were prospective and 2 retrospective. Two studies were clinical trials, from which only pre-operative data were extracted.

Participants

This review included 2242 participants, of whom 229 were controls and four were males. Participants were aged 25–60 years, of mixed parity and modes of delivery with reported body mass index (BMI) scores ranging from 20 to 38 kg/m^2 [Table 1, supplementary Table].

Methodological quality

The methodological quality of the included studies was found overall to be 'weak' [Table 2]. One prospective longitudinal cohort study [7] and one case-controlled study [22] were assessed as 'moderate' quality. Selection bias was well controlled for and participants were representative of the target population in all but two studies [23,24]. In both these studies, DRAM was a secondary outcome. The study designs made confounding difficult to control, yielding a 'weak' rating for 10 studies. Blinding was either absent or poorly reported. Many studies employed patient-reported outcome measures, where participants were aware of their own exposure status. Rating the EPHPP yielded substantial agreement between reviewers ($\kappa = 0.75$, 95%CI 0.61 to 0.88).

Measurement of DRAM

DRAM was measured using a variety of methods [Table 1, supplementary Table]. Five studies used finger-width measurement to determine presence of DRAM [4,24–27], two studies applied ultrasound to determine inter-recti distance [7,28], two studies used computerised tomography, one of these in addition to a tape measure [22,29], two studies used calipers [11,30], and one study employed a customised patient-reported questionnaire [23]. The performance of DRAM measures was typically standardised among the finger-width, caliper and ultrasound studies, with partici-

Table 1
Study characteristics.

Study	Design	No of participants	Age in years mean (SD)	Parity	Other participant characteristics	Mode of delivery	Association assessed	DRAM assessment tool	DRAM assessment method	DRAM measurement time-points	Outcome tools used for association
Blyholder *et al*. 2016	Cross- sectional study	$n = 416$	NR	**Primiparous**: 31.3% **Multiparous**: 67.3%	All female	**Vaginal** 68%; **Vaginal assisted** 19.2%; **Caesarean** 29.8%	DRAM, stress UI) and musculoskeletal Pain	**Survey** of awareness of separation		NR	Stress urinary incontinence and musculoskeletal pain measured by author-created survey
Bo *et al*. 2016	Prospective Cohort study	$n = 300$	28.7 years (4.3)	**Primiparous**: 100%	All female **BMI** (mean): 23.9 kg/m^2 (SD:3.9)	**Vaginal** 255 (85.28%); **Caesarean** 44 (14.72%)	DRAM, UI and POP	**Finger-breadth** measurement of DRAM width for presence of DRAM. DRAM defined as width ≥2 fingers	Measured at 3 points: at umbilicus, 4.5 cm below and above umbilicus. Participant in crook lying performing modified curl up contraction.	21 weeks gestation; post-partum: 6 weeks, 6 months & 12 months	Urinary incontinence *via* electronic questionnaire (ICIQ-UI-SF, POP-Q)
Braekken *et al*. 2009	Case Control	$n = 98$	47.1 years (10.57)	Parity median = 2 (range 1 to 5)	All female **BMI** (mean): 24.9 kg/m^2 (SD: 3.8 kg/m^2) **Post-menopausal**: $n = 36$ (37%) **Heavy work**: $n = 16$ (16%)	**Vaginal** 100%	DRAM and POP	**Finger-breadth** measurement of DRAM width for presence of DRAM. DRAM defined as width ≥2 fingers-width.	Specifics NR	NR—post questionnaire	POP-Q
Dalal *et al*. 2014	Correlation study	$n = 30$	27.4 years	Number of children: range 1 to 4; majority had 2 children, specifics NR	All female	**Vaginal** 81%; **Caesarean** 19%	DRAM and Lumbopelvic pain	**Finger-breadth** measurement of DRAM width for presence of DRAM. DRAM defined as width ≥2.5 cm.	Measurement at 3 points: umbilicus, 4.5 cm below and above umbilicus. Participant in crook lying performing modified curl up contraction.	NR	LBP *via* modified oswestry LBP disability questionnaire, and VAS (one for back and one for pelvis); Pelvic Floor function: PFDI questionnaire
Emanuelsson *et al*. 2014	Randomised controlled study	$n = 64$	40 years (range 25 to 60)	All women had at least 1 pregnancy	Females 62; males 2 **BMI** = 23 kg/m^2 (range 18 to 31). DRAM needed to be width ≥3 cm.	NR	DRAM, pain and QOL	**CT** measurement of DRAM width No other specifications of CT scanning reported	NR	Pre-op measures only included this review.	Pain measured using VHPQ, QOL using the SF-36
Gitta *et al*. 2017	Case-controlled study	$n = 200$	32.53 years (range 19 to 50)	All women had at least 1 pregnancy	All female BMI = 23.98 kg/m^2 (range 17 to 38 kg/m^2)	**NR**	DRAM, lumbar- LBP, UI and QOL	**Digital caliper** measurement of DRAM. DRAM defined as width ≥3 cm.	Measurements taken directly above and below, 5 & 10 cm above navel and 2.5 & 5 cm below navel. Participant in crook lying performing modified curl up contraction (shoulder blade off surface) with exhalation.	NR	LBP *via* Oswestry; incontinence *via* ICIQ-UI-SF; and QOL *via* the SF-36
Gonclaves Fernadez de Mota *et al*. 2015	Longitudinal observation study	$n = 84$	32.1 years (range 25 to 37)	**Primiparous**: 100%	All female **BMI**: postnatal with DRAM 22.3 (3.7) kg/m^2; with no DRAM 22.5 (3.2) kg, m^2	**Vaginal** 61.9%; **Caesarean** 38.1%	DRAM and lumbopelvic pain	**Ultrasound** measurement of DRAM width. DRAM width defined as width ≥16 mm 4–12 MHz (linear transducer)	Measurements taken at 2 cm below umbilicus centre. Participant n crook lying and images taken at the end of exhalation in resting relaxed position.	Gestational: 35 weeks; Post-partum: 6 to 8 weeks, 12 to 14 weeks and 24 to 26 weeks	Lumbopelvic pain *via* participant-identified location of pain from 5 categories (low back, low back with radiation, pubic symphysis, unilateral SIJ, bilateral SIJ); and scoring pain intensity (0 = no pain, 1 = moderate pain, 3 = severe pain)
Gunnersson *et al*. 2014	Randomised controlled study (component of)	n = 57	39.8 years (range 25 to 60)	All women were parous. specifics NR	Females 55: males 2 **BMI**: (mean all subjects) = 23 kg/m^2 (range 18 to 31)	NR	DRAM and Abdominal muscle strength	**Tape measure and CT.** DRAM defined as 'true width'	Measurement taken in supine at two points (between xiphoid and umbilicus and between umbilicus and pubic symphysis in relaxed position.	All measures taken prior to operation.	Abdominal strength *via* biodex system 4 machine (flexion, extension and isometric measures)

Table 1 (*Continued*)

Study	Design	No of participants	Age in years mean (SD)	Parity	Other participant characteristics	Mode of delivery	Association assessed	DRAM assessment tool	DRAM assessment method	DRAM measurement time-points	Outcome tools used for association
Liaw *et al*. 2011	Prospective longitudinal study	n = 60 (parous group n = 40, age-matched nulliparous group n = 20)	Parous: 31.3 years (3.3); Nulliparous: 31.9 years (4.1)	**Parous group: Primiparous:** 56.7%; **Multiparous** 43.3%	All female **Weight/BMI**: Primiparous (6 months post-partum) = 54.4 kg (SD 6.3), BMI 21.5 (SD 2.8) kg/m^2; Nulliparous 53.5 kg (SD 9.0), BMI 20.7 (SD 2.7) kg/m^2	NR	DRAM and abdominal muscle strength and endurance	**Ultrasound** measurement of DRAM width. 7.5 MH,	DRAM measured at 4 points—upper and lower margin of umbilicus, 2.5 cm below and above umbilicus. Client in crook lying with exhalation in relaxed position. DRAM defined as width ≥1.5 cm (2 finger-breath)	Post-partum: 4 to 8 weeks, and 6 to 8 months. Nulliparous only measured once	Abdominal strength/endurance—assessed *via* manual muscle testing and curl-ups
Parker *et al*. 2008	Prospective exploratory study	*n* = 100 (39 patient group; 53 control	41.4 years [12]	≤2 children in: 80% patient group; 60% control group; and 88% of laparoscopy group	All female	**Vagina**l Patient group 77%; control group 83%; laparoscopy group 62%. **Caesarean** = patient group 23%;	DRAM and lumbopelvic pain	**Dial Caliper** measurement of DRAM width.	Measurement taken at 3 points, upper margin of umbilicus, 4.5 cm below and above umbilicus. Client in crook lying performing modified curl up contraction. DRAM defined as width ≥2 cm	NR	LBP *via* the modified oswestry, LBP disability questionnaire, and VAS; pelvic floor function *via* PFDI, and pelvic floor impact questionnaire
Sperstad *et al*. 2016	Prospective cohort study	*n* = 300	28.7 years (4.3)	**Primiparous**: 100%	All female **Ethnicity** = European 96% **Heavy Lifting** (>20 hour/week): 22.03%	**Vaginal** 80.79%; **Caesarean** 19.2%	DRAM and lumbopelvic pain	**Finger breadth** measurement of DRAM width for presence of DRAM.	Measurement at 3 points, at umbilicus, 4.5 cm below and above umbilicus. Client in crook lying performing modified curl up contraction. DRAM defined as width ≥2 finger-breadths	21 weeks gestation; post-partum: 6 weeks, 6 months & 12 months	Lumbopelvic pain *via* author-created questionnaire
Spitznagle *et al*. 2007	Retrospective study	*n* = 541	52.45 years (16.65)	**Nulliparous:** 14.78%; **Parity**:2.32	All female **Ethnicity** = Caucasian 84.94%; African American 13.65%; Other 1.41% **Menopausal** = 57.86%	**Vagina**l 79.8%; **Caesarean** 20.20%	DRAM, PF strength, UI, POP myofascial pain	**Finger breadth** measurement of DRAM width.	Measurement taken above or below umbilicus. DRAM defined as width ≥3 cm (2 finger-breadths). Participant in crook lying performing curl up contraction.	NR	Outcome tool for all other diagnoses NR.

Legend: BMI = body mass index; CT = computerised tomography; DRAM = diastasis rectus of the abdominal muscles; ICIQ-UI-SF = the international consultation on incontinence urinary incontinence short form. LBP = low back pain; NR = not reported; PFDI = pelvic floor distress inventory; POP = pelvic organ prolapse: POP-Q = pelvic organ prolapse quantification system; QOL = quality of life; SF-36 = short form with 36: SIJ = sacroiliac joint; UI = urinary incontinence; VAS = visual analogue scale; VHPQ = ventral hernia pain questionnaire.

Table 2
Methodological quality—Effective Public Health Public Practice Project.

Study	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawals	Global rating for study
Blyholder *et al*. 2016	Weak	Weak	Weak	Weak	Weak	Weak	Weak
Bo *et al*. 2016	Strong	Moderate	Weak	Weak	Strong	Weak	Weak
Braekken *et al*. 2009	Weak	Moderate	Strong	Moderate	Strong	Strong	Moderate
Dalal *et al*. 2014	Strong	Moderate	Weak	Weak	Moderate	Strong	Weak
Emmanuelsson *et al*. 2014	Strong	Strong	Weak	Weak	Strong	Strong	Weak
Gitta *et al*. 2017	Moderate	Moderate	Weak	Weak	Strong	Strong	Weak
Gonclaves Fernadez de Mota *et al*. 2015	Strong	Moderate	Weak	Weak	Strong	Moderate	Weak
Gunnersson *et al*. 2014	Strong	Moderate	Weak	Weak	Weak	Strong	Weak
Liaw *et al*. 2011	Strong	Moderate	Moderate	Weak	Strong	Moderate	Moderate
Parker *et al*. 2008	Strong	Moderate	Weak	Weak	Strong	Strong	Weak
Sperstad *et al*. 2016	Strong	Moderate	Weak	Weak	Weak	Weak	Weak
Spitznagle *et al*. 2007	N/A	Weak	Weak	Weak	Weak	Strong	Weak

pant in a crook lying position. Measurement of DRAM was recorded in six studies with participants performing a curl up (or modified curl-up) contraction, while others were measured in resting position [Table 1]. Four studies [11,25–27] reported three consistent points of measurement (at umbilicus and 4.5 cm above and below umbilicus). Definition of DRAM varied; a gap of 2 finger-widths between recti bellies or a distance of at least 1.5–3 cm, or a perception of gapping. Only four studies reported specific time-points at which DRAM measurements were taken. These included following pregnant women from 21 weeks gestation to 8–12 months postnatally [7,25,26,28].

Outcomes

Low back pain, pelvic girdle pain and lumbo-pelvic pain were assessed by the Modified Oswestry Low Back Pain Disability Questionnaire and Visual Analogue Scale (VAS) in three studies [11,27,30], by a questionnaire in one study [23], and by participant-reported location and intensity of pain [28]. Pelvic organ prolapse was measured by the Pelvic Organ Prolapse Quantification System (POP-Q) in two studies [24,25]. The measurement tool was not reported in a third study on pelvic organ prolapse [4]. Assessment of urinary incontinence was *via* the Urinary Incontinence Short Form Questionnaire (ICIQ-UI-SF) in two studies [25,30] by a customised patient reported questionnaire in another [23] and by an unreported method in one study [4]. Abdominal strength was determined by Biodex System 4 Machine [22] in one study and by manual muscle testing in another [7]. Health-related quality of life was measured in two studies [29,30] using the Short Form 36 (SF-36).

DRAM Presence Associations

Lumbo-pelvic pain

The association of DRAM with lumbo-pelvic pain was examined in four studies ($n = 355$ participants). Three studies report no significant correlation between lumbopelvic pain and DRAM when measured with ultrasound [28] finger-width method [26] and calipers [11] respectively [Table 3]. One study [31] reported a moderate positive and significant correlation (<0.05) between DRAM and lumbopelvic pain ($n = 30$) using the finger-width method [Table 3, Fig. 3].

Low back pain & pelvic girdle pain

The association between DRAM with low-back pain or pelvic girdle pain was examined in 141 participants by Sperstad *et al*. (2016). There was no significant association between DRAM and low back pain (RR = 1.39, (95%CI 0.91 to 2.14), $p = 0.17$) or DRAM and pelvic girdle pain (RR = 1.09 (95%CI 0.61 to 1.94), $p = 0.82$) using the finger-width measurement [Table 3].

Incontinence

The association of DRAM with incontinence was investigated in 3 studies with 1169 participants in total [4,23,25]. Blyholder *et al*. (2016) collected data *via* survey from 416 participants and found a two-fold increase in incontinence when DRAM was present (OR = 2.25, (95%CI 1.02 to 5.08)). Spitzinagle *et al*. (2007) measured DRAM in 541 participants using the finger-width method and found an association with faecal incontinence (OR = 2.56, (95%CI 1.04 to 6.31)) but not with urinary incontinence (OR = 1.28, (95%CI 0.91 to 1.80)). In contrast, a prospective cohort study of 212 participants by Bo *et al*. (2016) measuring DRAM using the finger-width method did not establish an association between DRAM and incontinence (RR = 0.86, (95%CI 0.55 to 1.33) $p > 0.65$) [Table 3 Fig. 4].

Pelvic organ prolapse

The association of DRAM with pelvic organ prolapse was investigated by 3 studies involving 849 participants [4,24,25] using the finger with measurement. Bo *et al*. (2016) and Braekken *et al*. (2009) found no association between DRAM and pelvic organ prolapse. A retrospective study by Spitzinagle *et al*. (2007) however, reported a significant association between DRAM and pelvic organ prolapse (OR = 2.25, 95%CI 1.51 to 3.37) [Table 3, Fig. 5].

Table 3
Study results.

Study	DRAM Association risk ratio (95% CI)	DRAM Association odds ratio (95% CI)	Other findings
DRAM Presence			
Lumbopelvic pain			
Delal *et al*. 2014			*Moderately positive correlation that was significant ($p < 0.05$) Study included graphical representations, but exact correlation (Pearson) coefficient was not provided.*
Gonclaves Fernandez da Mota *et al*. 2015	0.99 (0.55 to 1.81)	0.99 (0.37 to 2.65)	
Parker *et al*. 2008			*No significant difference established for lumbopelvic pain with DRAM compared to No DRAM—raw data not provided. Only significant difference for abdominal and pelvic pain association with DRAM t-2.313, df = 96.4, (p = −0.023) for VAS*
Sperstad *et al*. 2016	1.45 (0.94 to 2.20)	1.74 (0.91 to 3.32)	
Low back pain			
Sperstad *et al*. 2016	1.39 (0.91 to 2.14)	1.66 (0.85 to 3.23)	
Pelvic girdle pain			
Sperstad *et al*. 2016	1.09 (0.61 to 1.94)	1.14 (0.47 to 2.73)	
Incontinence			
Blyholder *et al*. 2016		2.25 (1.02 to 5.08)	*Raw data not provided*
Bo *et al*. 2016	0.97 (0.71 to 1.34)	0.95 (0.53 to 1.72)	At 6 months
Bo *et al*. 2016	0.86 (0.55 to 1.33)	0.79 (0.42 to 1.52)	At 12 months
Spitznagle *et al*. 2007	1.13 (0.96 to 1.32)	1.28 (0.91 to 1.80)	Stress urinary incontinence
Spitznagle *et al*. 2007		2.56 (1.04 to 6.31)	Faecal incontinence
Pelvic organ prolapse			
Bo *et al*. 2016	0.87 (0.29 to 2.58)	0.79 (0.13 to 4.82)	At 6 months
Bo *et al*. 2016	1.56 (0.68 to 3.58)	2.13 (0.42 to 10.88)	At 12 months
Braekken *et al*. 2009	1.00 (0.81 to 1.24)	1.00 (0.39 to 2.58)	
Spitznagle *et al*. 2007	1.26 (1.10 to 1.46)	1.79 (1.26 to 2.53)	Combined association/analysis for all pelvic floor support disorders (stress incontinence, faecal incontinence and pelvic organ prolapse)
Spitznagle *et al*. 2007	1.44 (1.23 to 1.68)	2.25 (1.51 to 3.37)	Pelvic organ prolapse only
DRAM WIDTH			
Abdominal muscle performance			
Liaw *et al*. 2011			(Spearman rho = 0.38 $p = 0.04$).
Gunnarsson *et al*., 2015			Abdominal strength – correlation = Spearman rho = −0.39, $p < 0.001$ (Flexion 30°); abdominal strength – correlation = Spearman rho = −0.35, $p < 0.001$ (Flexion 60°); abdominal Isometric strength – correlation = Spearman rho = −0.34, $p = 0.01$
Health-related quality of life			
Emanualsson *et al*. 2014			*Reported that SF36 scores for body pain, general health vitality and social function in people with DRAM were significantly lower pre-operatively than the normal Swedish population. Raw data not provided*
Low back pain			
Gitta *et al*. 2017			Pearson correlation r = 0.15 ($p = 0.04$)
Urinary incontinence			
Gitta *et al*. 2017			Pearson correlation r = 0.07 ($p = 0.31$)
Health-related quality of life			
Gitta *et al*. 2017			Pearson correlation r = 0.17 ($p = 0.02$) *SF36 domain – physical health*

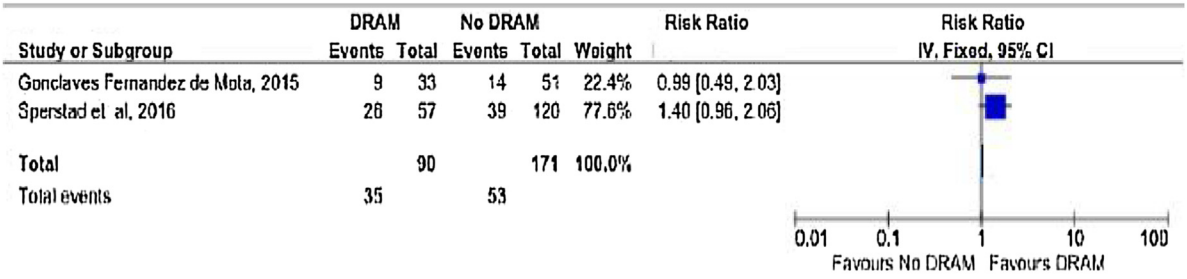

Fig. 3. Lumbo-pelvic pain in the presence of DRAM.

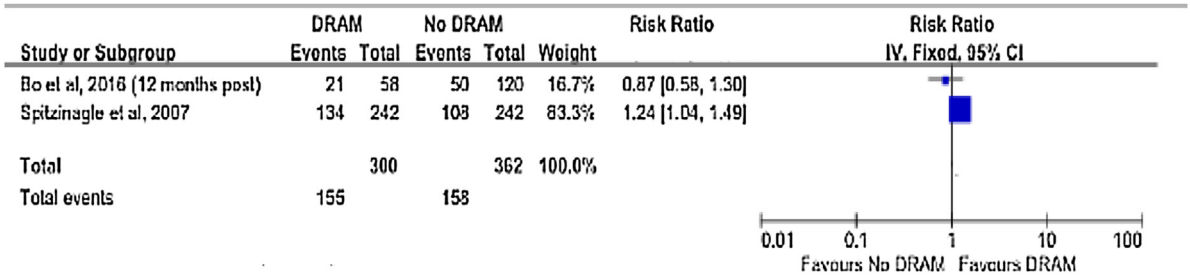

Fig. 4. Incontinence in the presence of DRAM.

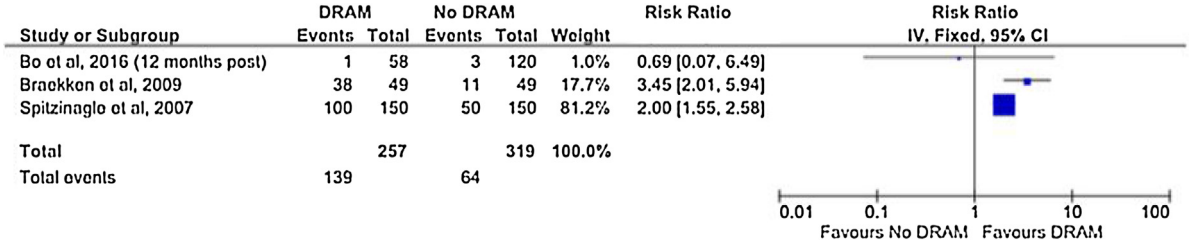

Fig. 5. Pelvic organ prolapse in the presence of DRAM.

Health-related quality of life

The association between presence of DRAM and health-related quality of life was explored by one trial ($n = 57$). Emanuelsson *et al*. (2014) reported SF-36 scores for eight domains encompassing physical wellbeing, emotional well-being and other physical and emotional dimensions, and found these were lower in people with DRAM measured by CT pre-operatively compared to age-matched controls.

DRAM width and association with severity of outcomes

Abdominal muscle performance—strength

The association between DRAM width and abdominal muscle strength was examined in a controlled trial [22] and prospective cohort study [7] ($n = 107$). Liaw *et al*. (2011) established a significant negative correlation (Spearman's rho = −0.38, $p = 0.04$) between abdominal flexor strength *via* manual muscle testing and DRAM width measured by ultrasound. This relationship was supported by pre-operative (prior to plication) findings of below umbilicus DRAM width by Gunnarsson *et al*. (2015), who examined abdominal isometric and flexor strength *via* the Biodex System Machine [Table 3]. However, clinical pre-operative assessment of DRAM width *via* tape measure and muscle strength association was non-significant ($p = 0.17$–0.54). Correlation meta-analysis was not possible due to limited number of studies [21].

Low back pain severity & other DRAM width associations

Gitta *et al*. (2017) in a case-control study ($n = 200$), established a significant positive association between DRAM width measured by caliper and severity of low back pain ($r = 0.148$; $p = 0.039$), and a negative association between DRAM width and ratings of health-related quality of life – in particular for physical health ($r = -0.171$; $p = 0.017$). No association was found between DRAM width and urinary incontinence ($r = 0.072$; $p = 0.313$).

Discussion

We found some evidence that DRAM presence may be associated with pelvic organ prolapse, and preliminary data that DRAM width may be associated with health-related quality of life, abdominal muscle strength and severity of low back pain. Based on the available data we could not conclude DRAM presence was associated with lumbo-pelvic pain or incontinence.

A potential explanation for the small association of DRAM presence with pelvic organ prolapse could be due to the pathophysiology of muscle and connective tissue stretch and weakening that is prevalent in the childbearing year, which affects both abdominal and pelvic floor muscle groups. An association between both conditions may therefore be due to another factor which underlies both conditions, demonstrating a frequent co-occurrence in the child-bearing years. This stretching and weakening reduces fascial tension in both conditions [12] leading to changes in the abdominal cylinder that may predispose to both DRAM and pelvic organ prolapse. Transversus abdominis provides lumbo-pelvic and intra-pelvic stability [13], and can work synergistically with the pelvic floor muscles that support the pelvic organs [32]. Alterations in this tension due to these pathophysiological changes can put these functions in jeopardy. Weakening and stretching of connective tissue and muscle also occurs in

menopause and as we age. Although histological studies of the linea alba are lacking, histopathological investigations of pelvic organ prolapse demonstrate decreased collagen content and predominance of type III collagen which has been associated with increased flexibility and decreased tensile strength [33,34]. Pelvic organ prolapse is more prevalent in women who are hypermobile [35]. Hormonal changes in pregnancy and ageing may also influence the connective tissue, enabling stretch, reducing resilience and becoming susceptible to collagen changes and dysfunction and may result in myofascial weakness.

One reason for not detecting an association of DRAM presence with other sources of musculoskeletal pains and dysfunctions is that an association may not exist. DRAM, musculoskeletal pain and dysfunctions may co-exist, but may not influence each other. Another potential explanation may be that pain, incontinence and health-related quality of life were measured subjectively *via* patient-reported outcome measures which are indirect and may conceal actual associations. Direct objective measures were only carried out in two pelvic organ prolapse and all abdominal strength studies. Additionally, variability in DRAM measurement tool may have resulted in inconsistent DRAM data. Ultrasound, calipers, differing finger-width methods and a customised patient-reported questionnaire were all used to determine the size and presence of DRAM in the included studies. To date ultrasound is the only validated and reliable outcome to measure DRAM width [36]. Calipers have been shown to be reliable to measure DRAM width above the umbilicus, while finger-width measurements may have sufficient intra-rater reliability for screening, but further testing is required [36]. There was also variability in assessment method relating to patient testing position and DRAM measurement location. These differences in muscle activation, body position and measurement location could alter DRAM width. There was also variability in the outcome measures used to assess low back pain and lumbo-pelvic pain, which may have confounded the results.

Implications for clinical practice

Based on our findings, clinical assessment of DRAM may be relevant in pregnant, postnatal, urogynaecological, menopausal and older populations presenting with pelvic organ prolapse, low back pain or impaired abdominal strength. There may be an underlying connective tissue – myofascial pathophysiology that explains the association. It is important to note that identification of association does not imply causation. In these at-risk populations, assessment and identification of DRAM may increase the likelihood of clinical observation of pelvic organ prolapse, low back pain or impaired abdominal strength. Currently little evidence exists to suggest whether interventions to manage DRAM are effective [37], and if so whether they influence or affect the associated conditions.

Strengths & limitations

This review was reported according to PRISMA Guidelines [38]. A comprehensive search strategy was used with no restriction on language or date reducing the likelihood relevant studies were missed. Methods employed to extract, assess and analyse data were robust and all available evidence investigating DRAM associations with musculoskeletal dysfunctions was included.

There were however some limitations. Overall the methodological quality of the included studies was weak as blinding was poorly reported and the designs of the trials made confounding difficult to control. Additionally, DRAM definition and methods used to measure DRAM were not consistent between studies. Therefore future research requires adequately powered prospective cohort studies with participants with and without exposure, that use validated measurement methods for DRAM and validated and reliable outcome measures to assess association rigorously.

Conclusion

DRAM has a small association with pelvic organ prolapse, and may be associated with impaired health-related quality of life, impaired abdominal muscle strength and low back pain severity.

Key messages

- DRAM presence and size may be linked with other musculoskeletal dysfunctions
- A small association between DRAM presence and pelvic organ prolapse has been shown.
- DRAM width is associated with abdominal strength impairment and severity of low back pain

Acknowledgement

None.

Ethics approval: No ethics approval was required.

Conflict of interests: None declared.

Source(s) of support: La Trobe University.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.physio.2018.07.002.

References

[1] Boissonnault JS, Blaschak MJ. Incidence of diastasis recti abdominis during the childbearing year. Phys Ther 1988;68(7):1082–6.

[2] Wade M. Diastasis recti and low back pain. Orthop Phys Ther Pract 2005;17(3):20–2.

[3] Candido G, Lo T, Janssen P. Risk factors for diastasis of the recti abdominis. J Assoc Chart Physiother Womens Health 2005;97:49–54.

[4] Spitznagle TM, Leong FC, Van Dillen LR. Prevalence of diastasis recti abdominis in a urogynecological patient population. Int Urogynecol J 2007;18(3):321–8.

[5] McPhail IR. Abdominal aortic aneurysm and diastasis recti. Angiology 2009;59:736–9.

[6] Rath AM, Attali P, Dumas JL, Goldlust D, Zhang J, Chevrel JP. The abdominal linea alba: an anatomo-radiologic and biomechanical study. Surg Radiol Anat 1996;18:281–8.

[7] Liaw LJ, Hsu MJ, Liao CF, Liu MF, Hsu AT. The relationships between inter-recti distance measured by ultrasound imaging and abdominal muscle function in postpartum women: a 6-month follow-up study. J Orthop Sports Phys Ther 2011;41(6):435–43.

[8] Coldron Y, Stokes M, Newham D, Cook K. Postpartum characteristics of rectus abdominis on ultrasound imaging. Manual Ther 2008;13:112–21.

[9] Gilleard WL, Brown JM. Structure and function of the abdominal muscles in primigravid subjects during pregnancy and the immediate postbirth period. Phys Ther 1996;76(7):750–62.

[10] Lo T, Candido G, Janssen P. Diastasis of the recti abdominis in pregnancy: risk factors and treatment. Physiother Can 1999;51(1):32–44.

[11] Parker JM, Millar LA, Dugan SA. Diastasis rectus abdominis and lumbo-pelvic pain and dysfunction—are they related? J Women's Health Phys Ther 2009;32(2):15–22.

[12] Lee DG, Lee LJ, McLaughlin L. Stability, continence and breathing: the role of fascia following pregnancy and delivery. J Bodyw Mov Ther 2008;12:333–48.

[13] Richardson CA, Snijders CJ, Hides JA, Damen L, Pas MS, Storm J. The relationship between the transversely oriented abdominal muscles, sacroiliac joint mechanics and low back pain. Spine 2002;27(4):399–405.

[14] Hodges PW, Erikssond AEM, Shirleye D, Gandevia SC. Intra-abdominal pressure increases stiffness of the lumbar spine. J Biomech 2005;38(9):1873–80.

[15] Ferreira PH, Ferreira ML, Maher CG, Refshauge K, Herbert RD. Changes in recruitment of transversus abdominis correlate with disability in people with chronic low back pain. Br J Sports Med 2010;44(16):1166–72.

[16] Viera AJ, Garrett JM. Understanding interobserver agreement: the kappa statistic. Fam Med 2005;37(5):360–3.

[17] Cochrane Consumers and Review Group. Data extraction template for Cochrane reviews; 2010.

[18] EPHPP. In: Nursing MUSo, editor. Effective public health practice project (EPHPP). Ontario, Canada: McMaster University School of Nursing; 2009. p. 1–4. Available at: http://wwwephppca/PDF/QAToolpdf. [Accessed April 2017].

[19] Deeks JJ, Dinnes J, D'Amico R, Sowden AJ, Sakarovitch C, Song F, *et al.* Evaluating non-randomised intervention studies. Health Technol Assess 2003;7(iii–ix):1–173.

[20] Straus SE, Richardson WS, Glasziou P, Haynes BR. Evidenced based medicine: how to practice and teach EBM. 3rd ed. London: Churchill Livingstone; 2005.

[21] Field AP. Meta-analysis of correlation coefficients: a Monte Carlo comparison of fixed and random effects methods. Psychol Methods 2001;6(2):161–80.

[22] Gunnarsson U, Stark B, Dahlstrand U, Strigard K. Correlation between abdominal rectus diastasis width and abdominal muscle strength. Dig Surg 2015;32(2):112–6.

[23] Blyholder L, Chumanov E, Carr K, Heiderscheit B. Exercise behaviors and health conditions of runners after childbirth. Sports Health 2016;14:14.

[24] Brækken IH, Majida M, Ellstrom Engh M, Holme I, Bø K. Pelvic floor function is independently associated with pelvic organ prolapse. BJOG 2009;116:1706–14.

[25] Bø K, Hilde G, Tennfjord MK, Sperstad JB, Engh ME. Pelvic floor muscle function, pelvic floor dysfunction and diastasis recti abdominis: prospective cohort study. Neurourol Urodyn 2017;36(3):716–21.

[26] Sperstad JB, Tennfjord MK, Hilde G, Ellstrom-Engh M, Bo K. Diastasis recti abdominis during pregnancy and 12 months after childbirth: prevalence, risk factors and report of lumbopelvic pain. BJSM Online 2016;50(17):1092–6.

[27] Dalal K, Kaur A, Mitra M. Correlation between diastasis rectus abdominis and lumbopelvic pain and dysfunction. Indian J Physiother Occup Ther 2014;8(1):210–4.

[28] Goncalves Fernandes da Mota P, Pascoal A, Carita A, Bø K. Prevalence and risk factors of diastasis recti abdominis from late pregnancy to 6 months postpartum, and relationship with lumbo-pelvic pain. Manual Ther 2015;20(1):200–5.

[29] Emanuelsson P, Gunnarsson U, Dahlstrand U, Strigard K, Stark B. Operative correction of abdominal rectus diastasis (ARD) reduces pain and improves abdominal wall muscle strength: a randomized, prospective trial comparing retromuscular mesh repair to double-row, self-retaining sutures. Surgery 2016;160(5):1367–75.

[30] Gitta S, Magyar Z, Tardi P, Fuge I, Jaromi M, Acs P, *et al.* Prevalence, potential risk factors and sequelae of diastasis recti abdominis. Orv Hetil 2017;158(12):454–60.

[31] Dalal K, Kaur A, Mitra M. Correlation between diastasis rectus abdominis and lumbopelvic pain and dysfunction. Indian J Physiother Occup Ther 2014;8(1):210–4.

[32] Neumann P, Gill V. Pelvic floor and abdominal muscle interaction: EMG activity and intra-abdominal pressure. Int Urogynecol J Pelvic Floor Dysfunct 2002;13:125–32.

[33] Kerkhof MH, Hendriks L, Brölmann HAM. Changes in connective tissue in patients with pelvic organ prolapse—a review of the current literature. Int Urogecol J 2009;20:461–74.

[34] Wong MY, Harmanli OH, Agar M, Dandolu V, Grody MH. Collagen content of nonsupport tissue in pelvic organ prolapse and stress urinary incontinence. Am J Obstet Gynecol 2003;189:1597–9.

[35] Norton PA, Baker JE, Sharp HC, Warenski JC. Genitourinary prolapse and joint hypermobility in women. Obstet Gynecol 1995;85(2):225–8.

[36] van de Water ATM, Benjamin DR. Measurement methods to assess diastasis of the rectus abdominis muscle (DRAM): a systematic review of their measurement properties and meta-analytic reliability generalisation. Manual Ther 2016;21:41–53.

[37] Benjamin DR, van de Water ATM, Peiris CL. Effects of exercise on diastasis of the rectus abdominis muscle in the antenatal and postnatal. Physiotherapy 2014;100(1):1–8.

[38] Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009;6:e1000097.