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Systematic review

Conservative interventions may have little effect on reducing diastasis of the rectus abdominis in postnatal women – A systematic review and meta-analysis

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Abstract

Background Diastasis of the rectus abdominis muscle (DRAM) commonly occurs in pregnancy and postnatally. Physiotherapists routinely guide women in its management, although the effectiveness of these treatments is unknown.
Objectives To determine the effectiveness of conservative interventions to reduce the presence and width of DRAM in pregnant and postnatal women.
Data sources EMBASE, Medline, CINAHL, PUBMED, AMED and PEDro searched until August 2021.
Study selection/eligibility Randomised control trials examining any conservative interventions to manage DRAM during the ante- and postnatal periods were included.
Study appraisal and synthesis methods Methodological quality was assessed using the Cochrane Risk of Bias 2 tool. Meta-analyses were performed using a random effects model to calculate mean differences (MD) and odds ratios (OR). A GRADE approach determined the certainty of evidence for each meta-analysis.
Results Sixteen trials with 698 women during the postnatal period were included. No trials evaluated interventions during the antenatal period. All interventions included some form of abdominal exercise. Other interventions included abdominal binding, kinesiotape and electrical stimulation. There was moderate certainty evidence from six trials ($n = 161$) that abdominal exercise led to a small reduction in inter-recti distance (MD −0.43 cm, 95% CI −0.82 to −0.05) in postnatal women compared to usual care.
Limitations Three of the 16 trials had a low risk of bias.
Conclusion and implications Conservative interventions do not lead to clinically significant reductions in inter-recti distance in women postnatally but abdominal exercises may have other physical and psychosocial benefits in the management of DRAM.
Systematic Review Registration Number PROSPERO (CRD42020172529).

Keywords: Diastasis Recti; DRAM; Exercise; Interventions; Postnatal

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Introduction

Diastasis recti of the abdominal muscles (DRAM) is a common problem in pregnancy and postnatally that can lead to pain, discomfort, impairment, and reduced activity [1]. DRAM is the thinning and separation of the linea alba greater than 2.2 cm above the umbilicus and 2.7 cm at the level of the umbilicus [2]. It is primarily seen in pregnancy, but has also been reported in urogynaecological and menopausal populations and with abdominal aortic aneurysm [3,4]. In pregnancy, hormonal changes to connective tissue, mechanical stresses placed on the abdominal wall by the growing foetus, and displacement of the abdominal organs lead to the development of DRAM. Its prevalence varies from 33% to 100% in pregnancy and 53% postnatally [5]. As the abdominal wall has essential roles in supporting viscera, respiration, postural trunk and pelvic stability, abdominal muscle strength and quality of life [5], it is important to determine optimal management strategies for DRAM.

Physiotherapists use a variety of active and passive interventions to manage and reduce DRAM and its burden. Interventions include transversus abdominis and pelvic floor muscle activation, functional activities with transversus abdominis activation, pilates, multifidus training, splinting of the abdomen with tape/ binders, and manual therapy [6]. Expert consensus recommends progressing from postures and habitual activities that reduce intra-abdominal pressure, to outer unit exercises (e.g. sit-ups) during pregnancy and postnatally [7]. Despite these recommendations from experts, physiotherapists have insufficient evidence from trials with a low risk of bias about exercise prescription and its benefits on patient outcomes.

Research to date has been directed at interventions to reduce DRAM with varying effectiveness. A previous systematic review of non-surgical interventions for DRAM found inconclusive evidence of non-specific exercise to prevent or reduce DRAM in the antenatal and postnatal periods based on limited poor-quality trials [8]. A recent meta-analysis of two trials with a high risk of bias found [9] abdominal and pelvic floor muscle training was ineffective in DRAM reduction [10]. Since those findings were published, five additional randomised controlled trials evaluating the effect of conservative interventions on DRAM have been published.

It is important to establish the effectiveness of all conservative interventions to better guide treatment decisions, enhance patient outcomes and limit potential consequences. Therefore, the aim of this systematic review was to investigate the effectiveness of conservative interventions to prevent or reduce the presence and size of DRAM in pregnant and postnatal women.

Methods

This systematic review was prospectively registered with PROSPERO (CRD42020172529) and followed the PRISMA guidelines for reporting of systematic reviews and meta-analyses.

Data sources

We searched six electronic databases (Medline, EMBASE, CINAHL, PEDro, PubMed, AMED) for randomised controlled trials involving interventions to manage (prevent and/or reduce) DRAM during the antenatal and postnatal periods from the earliest date available to 30th August 2021 (Appendix A). Manual searching of reference lists of included trials and citation tracking via Web of Science and Google Scholar was also completed. There were no restrictions on language. Two reviewers (DB, AvW) applied the selection criteria (Table 1) independently to titles and abstracts of the yield to exclude ineligible studies. Full text of trials that could not be excluded based on title and abstract only were retrieved and the criteria reapplied. Any disagreements were resolved by discussion between the two reviewers. If consensus could not be reached, a third reviewer (NT) was consulted. Kappa statistic (κ) scores of agreements were calculated and interpreted as follows: < 0.20 as slight agreement, 0.21–0.4 as fair, 0.41–0.6 as moderate, 0.61–0.8 as substantial and 0.81–1.0 as almost perfect agreement [11].

Data extraction

A data extraction form was developed *a priori*, pilot tested on a selection of trials and subsequently refined. One reviewer (DB) extracted the data, a second reviewer (AvW) checked the accuracy of the data extracted and any discrepancies were resolved via discussion. Where there were missing data, attempts were made to contact the authors of included trials for clarification. Data were extracted on participant characteristics (age, parity, mode of delivery), outcomes, and adverse events. Details of the interventions used in each study were extracted according to the Template for Intervention Description and Replication (TIDieR) checklist [12].

Outcomes

The primary outcome was reduction in DRAM width/ inter-recti distance in cm. Studies were still included if the outcome used other measurement methods such as number of finger widths, to ensure we captured information on all conservative interventions. Discriptive evaluation of these other measurement methods was included. Secondary outcomes were health outcomes such as body mass index, abdominal strength, waist-hip ratio, back pain, and pelvic floor symptoms.

Risk of bias

All trials were appraised independently by two reviewers (DB, CP) for quality using the Risk of Bias 2 (ROB-2) tool

Table 1
Study selection criteria.

Inclusion	Exclusion
Population	
• antenatal and postnatal women ≥18 years of age with diastasis of rectus abdominis muscle	• any populations with pre-existing neurological disorders/ fractures, arthritis/ medically unstable conditions/ previous abdominal surgery unrelated to pregnancy. • non-human • cadaver trials
Interventions	
• exercise of any form • belts/ binders • kinesiotape • electrical stimulation • education	• surgery • pharmacological interventions
Outcomes	
• diastasis recti of the abdominal muscles • low back pain • lumbo-pelvic pain/ pelvic girdle pain/ sacroiliac pain • incontinence • pelvic organ prolapse • abdominal muscle performance • abdominal muscle strength • health-related quality of life	
Study design	
• randomised controlled trials	• Other designs: systematic reviews, cohort trials, case trials/ case series
Publication type	
• full-text study publications	• abstracts, conference proceedings, editorial opinions
Publication Period	
• no limits	
Language	
• no limits	

[11]. The ROB-2 assessment consists of five domains: (i) the randomisation process, (ii) deviations or alterations from the intended interventions, (iii) missing outcome data, (iv) measurement of the outcome and (v) selection of the reported result [10]. Judgement about each domain's risk of bias is rated as low risk of bias, some concerns or high risk of bias [10]. Any disagreements were resolved by discussion between the two reviewers (DB, CP), and a third reviewer (NT) was consulted if consensus could not be reached.

Data analysis

Analysis was performed separately for interventions to reduce DRAM during the [1] antenatal period and [2] postnatal period. Meta-analysis was performed among trials that reported the same outcomes and where there were sufficient and appropriate post-intervention data to combine. Meta-analyses were conducted using a random-effects model and inverse variance to yield a mean difference (MD) for continuous data (e.g. inter-recti distance) or odds ratio (OR) for dichotomous data (e.g., DRAM presence or absence) with 95% confidence interval (CI) using RevMan 5.3 (The Cochrane IMS. Available at: http://ims.cochrane.org/revman, 2014). Statistical heterogeneity was assessed using the I^2 statistic, with values greater than 50% indicating high levels of heterogeneity [13]. Where it was not possible to pool data, a narrative summary was completed.

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach was used to evaluate the certainty of evidence of each meta-analysis [14]. Randomised controlled trials are considered to start at low risk of bias (i.e. high certainty). The level of evidence was then downgraded if limitations were present: in trial design this was indicated by a 'high risk' of bias in at least 50% of the trials in a meta-analysis; for imprecision of results if the lower band of the confidence interval indicated little or no effect, while the upper band indicated a large effect; or if there was unexplained moderate to high heterogeneity with an I^2 statistic > 50% [15]. The quality of the evidence was downgraded by one level for each of these limitations.

Results

Flow of trials

The search strategy identified 414 potentially relevant trials. After removal of duplicates, citation tracking and

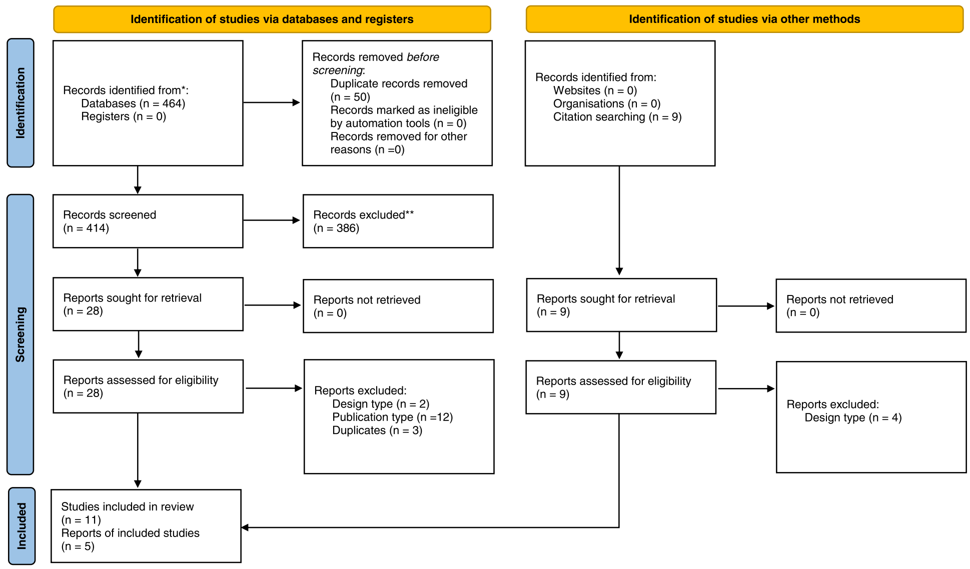


Fig. 1. PRISMA flow diagram for systematic reviews.

screening of titles and abstracts, 37 full-text articles were reviewed with almost perfect inter-rater agreement (Ķ = 0.83, 95% CI 0.72–0.95). Application of selection criteria to full texts yielded 16 trials for inclusion (Ķ = 0.94, 95% CI 0.82–1.00) (Fig. 1). Three full-text trials were translated into English. No additional information on these trials was available following requests to the three authors.

Characteristics of the included trials

The 16 trials included 698 postnatal women (Table 2). No trials were focused on antenatal management of DRAM. Women were aged between 18 and 40 years, were of mixed parity, and predominantly had birthed vaginally where birth history was recorded (Table 1).

Twleve trials examined abdominal strengthening exercise as an intervention, four trials examined abdominal exercise as a cointervention, two trials evaluated the effect of binders and a single trial evaluated the effect of electrical stimulation and kinesiotape. Two trials involved three intervention groups (Table 3). The interventions were compared to usual care in nine trials, and a comparison intervention in seven trials. The inter-recti distance was measured by ultrasound in six trials, by calipers in eight trials and by number of finger widths in two trials (Table 2).

Risk of bias

Eight trials were judged to have an overall high risk of bias [16–24], three trials had a low risk of bias [25–27] and the remaining five had some concerns [19,28–31] (Fig. 2). Most trials scored a high risk of bias in domain 1 (risk of bias in the randomisation process) which related to lack of concealment. Three trials had concerns in domain 4 (risk of bias in measurement of the outcome) and two had some concerns and one high risk of bias in domain 5 (risk of bias in the selection of the reported results).

Secondary outcomes

Secondary outcomes were reported in 12 trials (Table 2). Body mass index was examined in four trials [16,17,19,26]; waist-hip ratio in three trials [16,17,19]; abdominal strength in two trials (power and torque) [17,19]; low back pain and pelvic floor dysfunction in three trials each [24,26,27]. Body image, perceived function in five domains (household responsibilities, social and community activities, baby care, self-care, and work) [26] and quality of life [23] were each examined in a single trial.

Adherence

Adherence to prescribed exercise was reported as monitored in five trials [18,24–27], actually monitored in two [18,26], and was found to be poor with 30% average adherence to prescribed sessions completed among the intervention groups (Fig. 1a Online Supplementary information) and 20% among the comparison group (Fig. 1b Online Supplementary information).

Adverse events

Presence or absence of adverse events were not reported in 15 of the 16 trials. A reaction to kinesiotape was reported in one trial [27].

Reporting of Interventions

More than half of all included trials reported information on each of the TIDieR intervention characteristics. Information relating to materials used, who provided

Table 2
Study Characteristics.

Study First Author	Quality Risk rating (ROB2 Fig. 3)	Int: Con ratio	Age -mean years (SD)	Parity	Delivery mode	Intervention	Comparison	Primary Outcome	Secondary Outcome/s
Awad, 2021 (Egypt)	Some Concerns	25:25	Range 23–35 years	Parity – NR Postnatal (3–6 months)	Vaginal	Plank exercises + abdominal binding + education	Abdominal binding + education	IRD (mm) with US	-
Bobowik, 2018 (Poland)	High	20:20	Intervention: 28.9 (6.93) Control: 34.75 (5.95)	Parity – NR Postnatal (0–3 days)	NR	Prone positioning, abdominal sit-ups, education and kinesiotape	No intervention	IRD (cm) no. of fingers where 1 finger width = 1.3 cm	BMI WHR
El-Mekeway, 2013 (Egypt)	High	15:15	Range 25–30 years	Parity – NR Postnatal (2 days)	Vaginal	Abdominal exercises	Abdominal binder	IRD (cm) caliper	BMI WHR Abdominal strength
Gluppe, 2018 (Norway)	High	87:88	29.48 (4.1)	Parity – primiparous Postnatal (6 wk)	Vaginal	PF strengthening, Abdominal/ back/ arm/ thigh strengthening (16-wk duration)	No intervention	IRD (no. of fingers width): < 2 = normal; 2–3 = mild; 3–4 = moderate; ≥4 = severe	DRAM Presence/ Absence
Himani, 2019 (India)	Some Concerns	15:15	Range 25–40 years	Parity – mixed Postnatal (1–3 years)	Vaginal = 8 LUSC = 22	Abdominal exercises	Abdominal exercises + binder	IRD (no of finger width) IRD (mm) caliper	Abdominal strength
Izardi, 2018 (Iran)	Low	16:16	Intervention: 32.45 (0.3) Control: 34.7 (4.1)	Parity = 2 (0.61) Postnatal (6 months)	Vaginal	Oblique abdominal exercises	No intervention	IRD (cm) with US	Rectus abdominis muscle thickness (cm); Oblique muscle thickness (cm)
Kamel, 2017 (Egypt)	Some Concerns	29:28	Intervention: 29.33 (2.98) Comparison: 29.50 (3.00)	Parity: Intervention group 3 (0.63) Comparison group 3 (0.63) Postnatal 2 months	Vaginal	NMES stimulation + abdominal exercises	Abdominal exercises only	IRD (cm) with US	BMI WHR Abdominal strength
Keshwani, 2021 (Canada)	Low	Int 1 = 8 Int 2 = 8 Int 3 = 8 Con = 8	Range: 18–35 years. Exercise:31 (3) Binding: 32 (2) Combination: 31 (3) Control: 32 (2)	Parity: Primiparous Postnatal 3 wk	Vaginal	Three intervention groups: 1. Abdominal exercise 2. Binding 3. Abdominal exercise + binding	No intervention	IRD (cm) with US	BMI PF complaints Body image Perceived function Trunk function strength and endurance
LaFramboise, 2021 (USA)	Some Concerns	4:4	> 18 years	Parity: NR Postnatal 6–24 months (singleton)	Vaginal	Blooms's method (isometric abdominal variations i.e. in plank, in bridge in dead bug position)	No intervention	IRD (mm) caliper	Unilaterall hip bridge endurance (UHBE) Physical Activity Questionnaire (IPAQ)
Mesquita, 1999 (Brazil)	High	25:25	Range: 18–40 years.	Parity ≤4 children Postpartum 6 h	Vaginal	Abdominal and PF regimen exs	No intervention	IRD (cm) caliper	-

Table 2 (*Continued*)

Study First Author	Quality Risk rating (ROB2 Fig. 3)	Int: Con ratio	Age -mean years (SD)	Parity	Delivery mode	Intervention	Comparison	Primary Outcome	Secondary Outcome/s
Pampolim, 2021 (Brazil)	High	25:25	22.6 (3.28) years	Parity ≤4 children 96% primiparous Postpartum 6 h	Vaginal	Isometric PF and TA Isotonic abdominal oblique	No intervention	IRD (mm) caliper	-
Saleem, 2021 (Pakistan)	High	20:20	Intervention 1: 29.8 (4.1) years Intervention 2: 30.2 (4.3) years Combined: 30 (4.20) years	Parity -NR	Vaginal or Caesarean	Abdominal crunch exercise protocol (incl gluteal, PF, isometric lumbar strengthening)	Double SLR exercise protocol (incl gluteal, PF, isometric lumbar strengthening)	IRD (cm) caliper IRD (cm) finger palpation	
Thabet, 2019 (Saudi Arabia)	High	20:20	Range 22–35 years	Parity – NR Postpartum 3–6 months	Vaginal	Deep core stability and strengthening exs plus abdominal exercises 3 × 20 reps 3 times/ wk for 8/52 in formal setting, and daily as HEP	Abdominal exercises 3 × 20 reps 3 times/ wk for 8/52 in formall setting, and daily as HEP	IRD (mm) caliper	Health-related QoL (physical function 1–10)
Tuttle, 2018 (U.S.A)	Low	Int1: 10 Int2: 8 Int3: 5 Con: 7	32.03 (4.33)	Parity = 2 (1.34) Postpartum 6–12 wk	NR	Three intervention groups: 1. TA exercise 2. Kinesiotape 3. TA exercise + kinesiotape	Control – no intervention	IRD (cm) with US	LBP (Roland Morris Questionnaire) PF dysfunction (PF Distress Inventory – PFDI)
Walton, 2016 (U.S.A)	High	5: 4	Range 18–45 years	Parity NR Postpartum 3 months-3 years	Vaginal (8) Caesarean (1)	Dynamic core stabilisation program with plank exercises	Control - abdominal supine strengthening exercises	IRD (cm) with US	Pain LBP (Oswestry Disability Index) PF dysfunction (PF Distress Inventory – PFDI)
Yalfani, 2020 (Iran)	Some Concerns	12:12	Intervention: 29.66 (4.97) Control: 28.25 (4.55)	Parity >2 (multiparous)	Vaginal	Abdominal, PF and gluteal isometric/ isotonic exercises	No intervention	IRD (cm) caliper	Lumbopelvic control Pain Disability

ROB2 -Risk of Bias 2; Int = intervention; Con = control; sd = standard deviation; IRD = inter-recti distance; BMI = body mass index; WHR = waist-hip ratio; LUSC = lower uterine segment cesarean section; NMES = neuromuscular electrical stimulation; LBP = low back pain; PF = pelvic floor; wk = weeks; NR = not reported; QoL = quality of life; TA = transversus abdominis; SLR = straight leg raise

Table 3
Summary of Findings Table.

Number of Trials included	Study Design	Risk of Bias	Certainty Assessment: Inconsistency	Certainty Assessment: Imprecision	Intervention	Comparison	Number of patients: Exp	Number of patients: Control/ Exp 2	Effect (95% CI)	Grade Certainty
Abdominal Exercise compared to usual care (natural recovery) for DRAM reduction post- natal (follow up: range 6 weeks to 12 weeks)										
6	Randomised Controlled Trial	Very Serious	*Not Serious*	Not Serious	Abdominal & pelvic floor strengthening	Usual care (natural recovery)	82	79	MD -0.43 (-0.82 to -0.05)	⊕⊕⊕◯ MODERATE
Abdominal Exercise compared to usual care (natural recovery) for DRAM reduction – with sensitivity analysis (follow up: range 6 to 12 weeks)										
5	Randomised Controlled Trial (with sensitivity analysis)	Not Serious	Not Serious	Not Serious	Abdominal & pelvic floor strengthening	Usual care (natural recovery)	62	59	MD -0.29 (-0.51 to -0.06)	⊕⊕⊕⊕ HIGH
Abdominal Exercise compared to natural recovery in the immediate post-partum period for DRAM reduction										
2	Randomised Controlled Trial	Very Serious	Serious	Not Serious	Abdominal & pelvic floor strengthening	Usual care (natural recovery)	25	25	MD **-0.20** (-0.47 to 0.07)	⊕◯◯◯ VERY LOW
Deep core strengthening plus abdominal exercises compared to abdominal exercises alone for DRAM (follow up: range 6 weeks to 8 weeks)										
3	Randomised Controlled Trial	Serious [a]	Serious [b]	Not Serious	Abdominal & pelvic floor strengthening plus plank exercise	Abdominal & pelvic floor strengthening	45	44	MD -0.02 (-0.47 to 0.44)	⊕⊕◯◯ LOW
Abdominal exercise compared to binder for DRAM reduction (follow up: median 6 weeks)										
2	Randomised Controlled Trial	Serious [a]	Serious [b]	Very Serious [c]	Abdominal & pelvic floor strengthening	Binder	22	23	MD **-1.02** (-2.35 to 0.3)	⊕◯◯◯ VERY LOW
Abdominal exercise compared to natural recovery (control) (follow up: median 6 weeks)										
2	Randomised Controlled Trial	Very Serious [a,d]	Serious [b]	Serious [c]	Abdominal & pelvic floor strengthening	No intervention	107	108	OR 0.47 (0.05 to 4.51)	⊕◯◯◯ VERY LOW

DEFINITIONS OF LEVELS OF CERTAINITY

Level of Certainty	Definition
HIGH	Authors have a lot of confidence that the true effect is similar to the estimated effect
MODERATE	The authors believe that the true effect is close to the estimated effect
LOW	The true effect might be markedly different from estimated effect
VERY LOW	The true effect is probably markedly different from the estimated effect.

CI = Confidence Intervals; MD = Mean Difference; OR =Odds Ratio

Explanations: [a.] Increased risk of bias in randomisation process; [b]. Increased statistical heterogeneity; [c.] Wide confidence interval - lack of precision, [d.] Increased bias in measurement of outcome in 1 study.

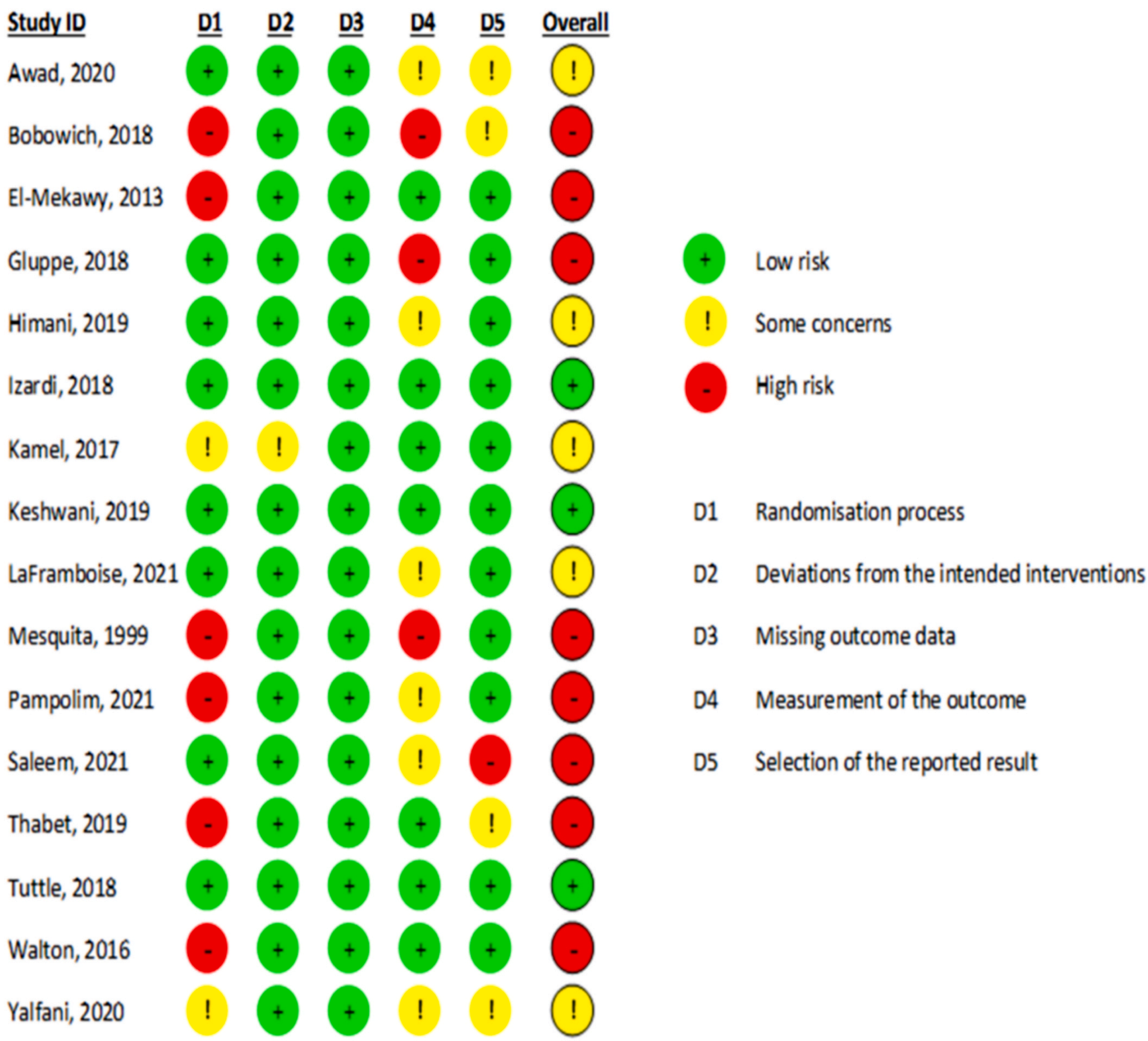


Fig. 2. Methodological quality assessment – Risk of bias 2.

intervention tailoring, adherence, intervention fidelity and intensity were poorly reported and no trial described modifications to the intervention (Fig. 1a Online Supplementary and Table 4). Among the control interventions, details on materials accessed, who provided the intervention, mode of delivery and modifications were not reported (Fig. 1b Online Supplementary and Table 4).

Effect of conservative interventions

There is moderate certainty evidence from two trials (n = 100) that abdominal exercise in the immediate postnatal period (6 h post-partum) had no effect on inter-recti distance (−0.2 cm 95%CI −0.47 to 0.07, I^2 = 77%) (Fig. 3c and Table 3). However, beyond two days and up to two years postnatal, there was moderate certainty evidence from six trials (n = 161) [16,25–28,30] that abdominal exercise reduced inter-recti distance in postnatal women compared to usual care (MD −0.43 cm, 95% CI −0.82 to −0.05, I^2 = 86%) (Fig. 3a and Table 3). A sensitivity analysis excluding one trial [16] with a high risk of bias demonstrated high certainty evidence that abdominal exercise reduced inter-recti-distance in postnatal women (MD −0.29 cm, 95% CI −0.51 to −0.06, I^2 = 46%) (Fig. 3b and Table 3).

There was very low certainty evidence from two trials (n = 215) that there was no reduction in the risk of having DRAM with abdominal exercise in postnatal women compared to usual care (OR 0.47, 95% CI 0.05–4.51) (Fig. 4 and Table 3).

Table 4
TIDierR: Description of experimental group interventions according to TIDieR (template for intervention description and replication).

Study First Author	Why: DRAM reduction techniques	What Material/s	What Procedure	Who provided (training required)	How	Where	When/ How much -dose	Modifications	Fidelity Adherence
Awad (2021)	**Group 1:** Progressive plank exercise, abdominal binder and education Group 2: Abdominal binder and education	DRAM Abdominal binder, Swiss ball	**Treatment group**: Progressive prone plank exercise program + abdominal binder +advice. **Control:** Advice + abdominal binder	Physiotherapist (training NR)	FTF	Physiotherapy outpatients clinic	3 × 20 reps, 3 times/wk for 5/52 with moderately hard effort in clinic. HEP: perform exs as in clinic regularly (dosage NR)	NR	NR
Bobowik (2018)	**Treatment group**: 1. Postural lying 2. Abdominal exercises 3. Ergonomic education 4. Kinesiotape **Control group**: No intervention	Mat + Kinesiotap-e	Exercise program	Physiotherapist (training NR)	FTF initial training + tape, then HEP independently	Initial hospital, then HEP (6/52)	1. Postural lying 2. Abdominal crunch variations x 10 3. Ergonomic adherence daily 4. Kinesiotape wkly (6/52)	NR	NR
El-Mekawy (2013)	**Everyone**: 1800 calories/day **Group 1**: Abdominal binder **Group 2:** Abdominal exercise program	Abdominal binder	**Group 1:** Binder during day **Group 2:** Supervised abdominal exercise 3x/ wk for 6/52. Same program for HEP on other days.	Health Professional (specifics and training NR)	Initial application of binder FTF. Formalised exercise 3x/wk. FTF. HEP on other days for 6/52	Initial binder application and formalised exercise at hospital. Then independently at home	**Group 1:** Wear binder all day. Removal for sleeping and bathing **Group 2:** Abdominal Exercise Program 30 mins – 3 sessions/wk every other day in formalised setting. Program to be repeated independently on alternate day	NR	NR
Gluppe (2018)	**Treatment group**: Exercise class focus PF strengthening. Plus, HEP. **Control group**: No intervention	Mats, music (for PF) Exercise equipment for other areas NR.	**Treatment group**: Wkly 45 min supervised PF exercise class for 16/52 + daily PF HEP.	3 experienced physical therapists	Formal supervised classes FTF. HEP independently.	Formal supervised classes held in University Hospital and private institute	**Treatment group:** 1 Wkly 45 min supervised exercise class for 16/52. Focus on strengthening PF + exercises for global strengthening set to music. HEP: Three sets of 8–10 maximal pelvic floor contractions daily.	NR	Adherence: Supervised class via registry and HEP via diary.
Himani (2019)	**Treatment group:** Progressive abdominal exercise program + Corset **Control group:** Corset	Corset for DRAM (both groups)	**Treatment group:** Progressive abdominal exercise program + Corset **Control group**: Corset Corset specific use NR	NR	NR	NR	**Treatment group:** 8–12 reps, 2–3sets, 4–5 sessions/ wk at mild to moderate intensity. Corset specific use NR **Control group**: Corset Corset specific use NR	NR	NR

Table 4 (*Continued*)

Study First Author	Why: DRAM reduction techniques	What Material/s	What Procedure	Who provided (training required)	How	Where	When/ How much -dose	Modifications	Fidelity Adherence
Izardi (2018)	**Treatment group:** Internal and external oblique muscles strengthening program. **Control group:** No intervention	NR	**Treatment group**: Strengthening of internal and external oblique abdominal muscles for 6/52.	Researcher (training NR)	Initial exercise FTF + HEP independently. Optional review follow-ups every 2/52 to check performance.	Initial session held in Physiotherapy Dept. with supervision of researcher	**Treatment group**: Internal and external oblique abdominal muscles x 20 reps for 6/52. Increase workload by 10% in first 1/52 and thereafter by 20% Wkly	NR	Adherence: Phone call and review follow-ups 2/52.
Kamel (2017)	**Treatment group**: Neuromuscular stims (NMES) and abdominal strengthening regimen **Control group**: Abdominal strengthening exs. regimen only	Scarf around abdomen for bracing with exs. For NMES *Phyaction* E NMES machine. Illustrations of exercises provided.	**Treatment group**: Application of stims (E NMES) to RA plus abdominal strengthening exs for 8/52, **Control group**: Abdominal strengthening exs as in treatment group.	NR	Control and treatment groups received interventions FTF 3 x/ week for 8/52 at Cairo University hospital. HEP carried out independently on the 4 other days.	3 sessions / wk for 8/52 at Cairo University Hospital and 4 sessions/wk at home	**Treatment group**: NMES Dose: 80 pulses/min – strengthening pulse width = 0.1–0.5 ms (with 5 s on 10 s off) for 30 mins. Abdominal strengthening regimen followed (20 reps each, ↑ 4 reps per wk for 6/52). **Control group:** Abdominal strengthening exs <u>only</u> as for treatment group. Dosage: 3 times a wk for 8/52	Stims intensity increased till contraction seen and felt.	Adherence to program specifics NR. NMES attrition = 1 subject; Abdominal strength exs (only) attrition = 2 subjects.
Keshwani (2021)	**Treatment group 1**: Individualised abdominal exercise + progressive HEP **Treatment group 2**: Fitted abdominal binder **Treatment group 3**: As per group 1 + abdominal binder. **Control group**: No intervention	**Groups 1 and 3:** Sheet/ towel around abdominal wall with eccentric trunk flexion exs. **Group 2 and 3:** An abdominal binder.	**Groups 1 and 3:** Received wkly abdominal progressive exercise sessions and HEP. **Group 2 and 3:** Fitted with binder and instructions of use. **Control group** No intervention	A registered physiotherapist with postgrad training and experience in women's health.	**Treatments groups 1 and 3:** Wkly FTF exercise sessions + HEP independently. **Group 2:** 1x binder application instructional session FTF. 12/52 application independently	Initial assessment at Toronto University Laboratory. FTF setting for exs sessions and initial binder application NR; Continued binder use at home.	**Treatment Group 1 and 3**: Weekly individualised FTF exercise sessions. Wk 1 crook lying with TA; Wk2: TA in sitting and standing; Wk3 – TA in crook lying with unilateral leg lift and TA with ADLs in sitting and standing; Wk4 – TA with eccentric RA. Wk 5**:** Eccentric RA with TA activation. Side plank added. **HEP:** Bent knee side planks daily. **Sessions 6–12** s hold, Side plank progressed to straight leg. **Treatment groups 2 and 3**: Abdominal binder worn waking hours except for bathing for 12/52	Groups 1 and 3 exercise groups received weekly individualised exercise sessions.	Exercise and abdominal binder monitored with online self-reported logs. Daily email reminders to complete logs.

Table 4 (*Continued*)

Study First Author	Why: DRAM reduction techniques	What Material/s	What Procedure	Who provided (training required)	How	Where	When/ How much -dose	Modifications	Fidelity Adherence
LaFramboise (2021)	**Treatment group:** Bloom Method exercise program **Control:** No intervention	**Treatment group:** Access to Bloom Method online studio program	**Treatment group:** Bloom Method program =core exercise, breathing techniques and mindfulness. **Control:** No intervention	NR	Provided via online video	At home	Specifics NR	NR	NR
Mesquita (1999)	**Treatment group:** Hip adduction with PF contraction; isometric PF with pelvic tilt; isometric TA; abdominal oblique activation with trunk rotation. **Control group:** No intervention	NR	**Treatment group:** Instruction of PF exercises in first session (6/24 postnatal) and abdominal exercises in second session (18/24 postnatal). **Control group:** No intervention	NR	Interventions delivered individually FTF in hospital.	Assessments and interventions took place at Maternity School Hilda Brandao da Santa Casa de Belo Horizonte Hospital.	**Treatment group**: Exercises in crook lying. (i) Hip adduction with pillow between knees and isometric contraction of PF x10; (ii) Isometric TA x 10; and (iii) abdominal obliques in crook lying with hand behind head x 10. After 18 h, repeat the 3 exs 20 reps each. **Control group**: No intervention	NR	NR
Pampolim (2021)	**Treatment group**: Hip adduction with PF contraction; isometric PF with pelvic tilt; isometric TA; abdominal oblique activation with trunk rotation. **Control group**: No intervention	NR	**Treatment group:** Instruction of PF exercises in first session (6/24 postnatal) and abdominal exercises in second session (18/24 postnatal). **Control group:** No intervention	NR	Interventions delivered individually FTF in hospital.	Assessments and interventions took place at Maternity hospital Pro-Matre of Vitoria, Espiroto Santo-Brazil	**Treatment group**: Exercises in crook lying. (i) Hip adduction with pillow between knees and isometric contraction of PF x10; (ii) Isometric TA x 10; and (iii) abdominal obliques in crook lying with hand behind head x 10. After 18 h, repeat the 3 exs 20 reps each. **Control group**: No intervention	NR	NR
Saleem (2021)	**Treatment group 1**: Abdominal crunch training protocol **Treatment group 2**: Double leg SLR protocol	NR	**Treatment group 1:** Abdominal crunch **Treatment group 2:** DSLR **Treatment groups 1 and 2:** Static gluteal exs, Kegel exs and back strengthening exs.	Physiotherapist (training NR)	Interventions delivered FTF	NR	**Treatment group 1:** Abdominal crunch, Static gluteal exs, Kegel exs and back strengthening exs. **Treatment group 2:** DSLR, Static gluteal exs, Kegel exs and back strengthening exs. **Dosage for both groups**: 3 sets x 10 reps each, on alternate days for 6/52	NR	NR

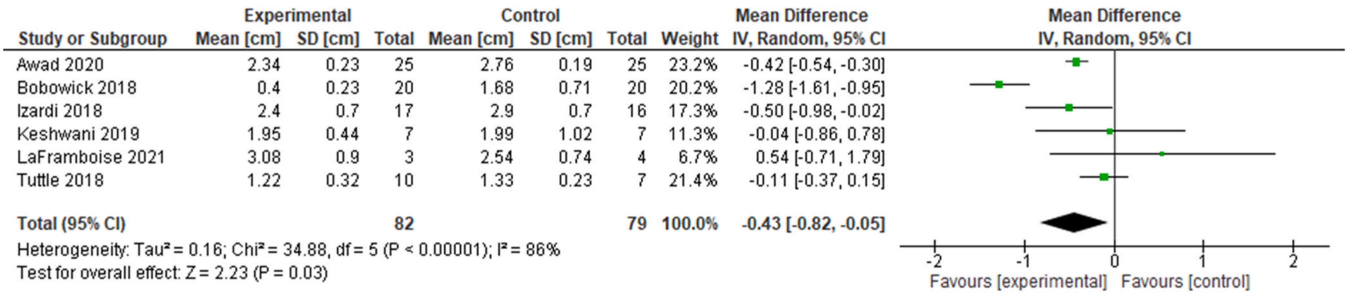
Table 4 (*Continued*)

Study First Author	Why: DRAM reduction techniques	What Material/s	What Procedure	Who provided (training required)	How	Where	When/ How much -dose	Modifications	Fidelity Adherence
Thabet (2019)	**Treatment group**: Deep core stabilising routine **Control group**: abdominal exs.	Sheet/ towel to provide abdominal brace to enhance TA activation.	**Treatment group**: Deep core stabilising with: Abdominal and PF contraction, and plank exs. Program repeated as HEP. **Control group:** abdominal exs: static abdominal contractions, posterior pelvic tilting, reverse sit up, trunk twist and reverse trunk twist	Primary researcher – training NR	Exercise teaching FTF by primary researcher 3x/ week for 8/52. Plus, same program (as FTF) done as HEP.	NR	**Treatment group**: Deep core stabilising: 1. Abdominal bracing (with large sheet/ towel around abdomen 2. PF contraction hold 3. Plank position 4. Isometric TA – 5 abdominal exs as for control group below. **Control group**: abdominal exs: 1. Static abdominal contractions 2. Posterior pelvic tilting 3. Reverse sit up 4. Trunk twist 5. Reverse trunk twist **Dosage** (both groups): Hold contraction for 5 s. Rest for 10 s 20 reps x 3 sets, 3x /week for 8/52 in clinic. Repeat program as HEP with same dosage	NR	NR
Tuttle (2018)	**Treatment group 1**: TA exs **Treatment group 2**: Kinesiotape **Treatment group 3**: Combination of TA exs + Kinesiotape. **Control group**: No intervention	Kinesiotape (pre-cut). Written instructions for continuity and precision.	**Treatment group 1** TA activation with expiration in supine/ side-lie/ 4-point/ sitting **Treatment group 2**: Kinesiotape – to be placed in 'X' pattern over umbilicus from rib to pelvis. Worn 4–7 days and 2–4 days off for 12/52 **Treatment group 3**: Treatment as for groups 1 and 2 - **Control group (7)**: No intervention Normal level activity.	Physiotherapist with women's health specialisation	All Assessments and training sessions FTF in participant's home.	Assessment and training undertaken at participant's home.	**Treatment group 1**: TA in: supine, side-lie, 4 point and sitting (10 reps in each position 4–5 times /week for 12/52) **Treatment group 2**: Kinesiotape –To be worn 4–7 days on and 2–4 days off for 12/52 **Treatment group 3**: To carry out treatment as for groups 1 and 2 - **Control group**: No intervention. To maintain their normal level activity and assessments.	NR	Participant self-adherence log and weekly check ins by research assistant via phone/ email / texts based on participant preference.

Table 4 (*Continued*)

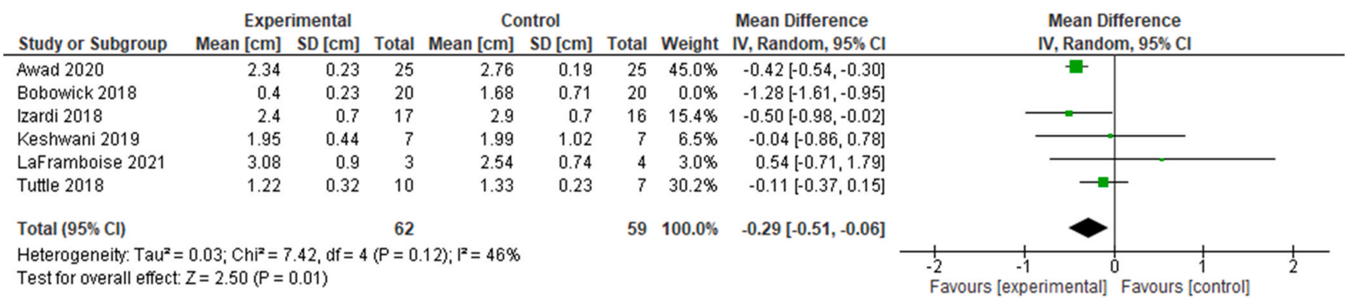
Study First Author	Why: DRAM reduction techniques	What Material/s	What Procedure	Who provided (training required)	How	Where	When/ How much -dose	Modifications	Fidelity Adherence
Walton (2016)	**Treatment group**: 1. Plank 2. Post pelvic tilt 3. Kegels 4. Russian Twist **Control group (4)**: 1. Abdominal crunch 2. Post pelvic tilt 3. Kegels 4. Russian Twist All exs with abdominal bracing	-Floor space -Sheet/ towel for abdominal bracing. -Subjects given booklet with exs instructions, pictures and recording sheet	All exercises 3 sets x 10 reps, 3x/ week for 6/52 (exc. Plank) Progression: increase repetitions to fatigue. Plank 10 × 10 s hold	Researcher (training NR)	Initial measurements and exercise teaching FTF with researcher. HEP independently.	Initial measurements and exercise teaching in physical therapy facility. Then HEP independently.	Towel/ sheet around abdomen to enhance abdominal bracing in both groups prior to exercise. **Control and Treatment group**: Posterior pelvic tilt in supine with bracing; Kegel with abdominal bracing; Russian twist- abdominal contraction with abdominal crunch and twist. **Control group:** Abdominal crunch lifting head-shoulders off the mat. **Treatment group**: In prone stabilizing on forearms and feet or knees.	Subjects to increase their repetitions to personal fatigue level.	Monitored HEP adherence by phone call from researcher every 2/52.
Yalfani (2020)	**Treatment group**: Isometric- isotonic exercises in 3 training phases. (transition from local to global strengthening with focus on core and increasing aerobic capacity.) **Control group:** No intervention	weights, bosu ball	**Treatment group**: Phase 1 – low torque exercise -isometric TA, PF, marching, supine bridge and SLR with focus on breathing: Phase 2: TA, PF, Clam shell, curl up, hip extension, squat, plank, bird dog Phase 3: Walking, jogging, lunging, weights, high level core with, Bosu ball, clamshell obliques and gluts and obliques in standing	Sports rehab and movement specialist	Interventions delivered individually FTF in hospital	Sports Rehabilitation Laboratory of Bu Ali Sina University Hospital	**Treatment group**: 3 sessions/ wk for 8/52. 10 min aerobic warm up 50 min isometric aerobic exercise 10 min cool down Control: No intervention	NR	NR

NR = not reported; RA = rectus abdominis; electrical stimulation, exs = exercises; FTF = face to face; PF = pelvic floor; PFM = pelvic floor muscles; HEP = home exercise program; wk = week; NMES = neuromuscular; RA = rectus abdominis; TA = transversus abdominis; PF = pelvic floor; DSLR = double straight leg raise



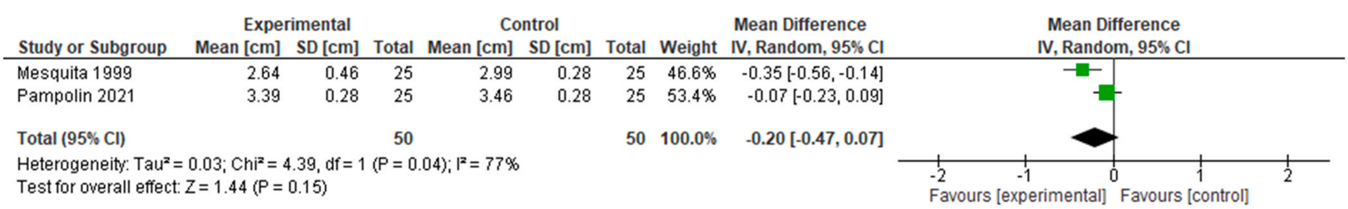
a

Fig. 3a. Mean difference (cm) in inter-recti difference between abdominal exercise and control. GRADE Moderate certainty evidence, downgraded due to high levels of heterogeneity.



b

Fig. 3b. Sensitivity analysis. Mean difference (cm) in inter-recti difference between abdominal exercise and control excluding 1 study with a high risk of bias. High certainty evidence (no downgrades).



c

Fig. 3c. Mean difference (cm) in inter-recti difference between abdominal exercise and control in immediate post-natal period (6 h post-natal). Moderate certainty evidence (heterogeneity).

There was low certainty evidence from three trials (n = 89) that deep core abdominal exercise (plank exercises in addition to a regimen of abdominal strengthening) had no effect on inter-recti distance in postnatal women when compared to abdominal exercise (MD −0.02 cm, 95% CI −0.47 to 0.44, I^2 = 99%) (Fig. 5 and Table 3).

There was very low certainty evidence from two trials that abdominal exercises (n = 45) did not reduce inter-recti distance compared to using a belt /binder (MD −1.02 cm, 95% CI −2.35 to 0.30, I^2 = 91%) (Fig. 6 and Table 3).

A single trial not included in the meta-analysis demonstrated that neuromuscular electrical stimulation with abdominal exercises applied at eight weeks postnatal for eight weeks, was more effective in reducing inter-recti distance (50%) compared to abdominal exercises alone (26%) [21].

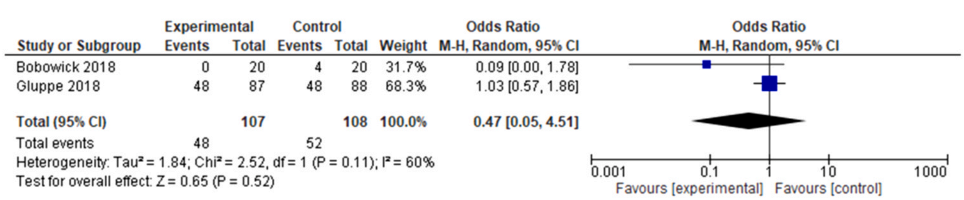


Fig. 4. Odds ratio of diastasis recti with abdominal exercises compared with control (Note Gluppe 2018 data at 6 weeks). Very low certainty evidence: 1 study with high risk of bias, heterogeneity, imprecision.

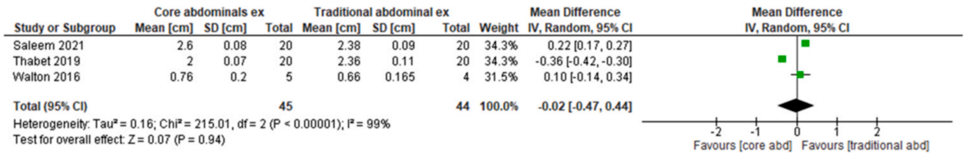


Fig. 5. Mean difference (cm) in inter-recti-distance between core abdominal exercise and abdominal exercise. Low certainty evidence. Downgraded for high risk of bias and heterogeneity.

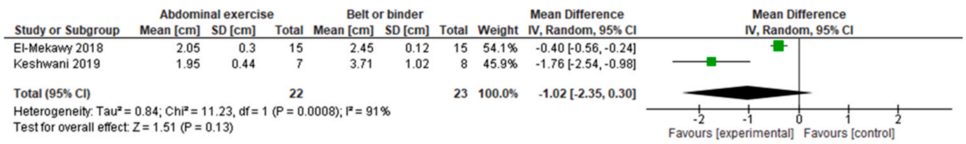


Fig. 6. Mean difference (cm) in inter-recti-distance between abdominal exercise and binder. Very low certainty evidence: Downgraded for 1 study with high risk of bias, heterogeneity, and imprecision.

Secondary outcomes

Three trials [17,19,29] reported improved torque and power outcomes with abdominal strengthening. Four trials [16,17,19,26] found abdominal strengthening programs alone reduced body mass index more than adjunct and combination therapies. One trial [24] found reduced low back pain in both intervention (abdominal exercise) and comparison (dynamic core plank exercise) groups. One trial [27] found no effect from incorporating kinesiotape into interventions.

Discussion

This systematic review of 16 randomised controlled trials with 698 participants found moderate certainty evidence that abdominal exercise has a small effect on reducing inter-recti distance. Compared to usual care, postnatal abdominal exercises reduced inter-recti distance by a mean of 0.4 cm, which relative to DRAM (greater than 2.2 cm) is unlikely to be clinically significant. Gluppe et al. [18] identified similar findings, concluding abdominal and pelvic floor muscle training to be ineffective in DRAM reduction. Low certainty evidence with similar non-significant clinical findings was seen with adjunct conservative interventions such as abdominal binders or corsets, neuromuscular stimulation, and other exercise regimens.

These results cast doubt on the biological rationale for using strengthening exercises to reduce the inter-recti distance of impaired and altered connective tissue. The linea alba is formed by fascia and connective tissue. The role of fascia is to provide tensile support in all directions, enabling loading of the connective tissue, due to the irregular arrangement of collagen [32] without disruption. DRAM occurs when connective tissue is stretched, weakened and separates. Muscle strengthening increases cross-sectional muscle area and contractile activity [33]. Although a wide variety of connective tissue can display contractile behaviour [34], the effects are likely to be considerably smaller than for muscle [35].

Our results can be compared to other conditions where strengthening exercise has not altered connective tissue defects. Just as weakened connective tissue can lead to DRAM, weakening of bands of connective tissue that form the supportive ligaments and fascia of the pelvic floor can lead to incontinence and pelvic organ prolapse [36,37], and may sometimes require surgical repair. Although exercising the pelvic floor strengthens the pelvic floor muscles muscles [37], it may not always compensate for fascial disruption due to collagen connective tissue defects [36,37]. Less collagen has been identified in women with more severe pelvic organ prolapse [40] and DRAM [38]. Connective tissue alterations also occur in Achilles tendinopathy where there is similar breakdown in extracellular matrix and disorganised collagen [39]. Exercise that stresses the Achilles tendon with loading, and not strengthening contractile muscle— reduces pain, enables adaption, and is critical for cell function and matrix integrity [39]. Timeframes and the amount of loading with exercise required for collagen synthesis and significant modification of mechanical properties, is more prologed with connective tissue (> 12 weeks) than with contractile skeletal muscle[40]. The length and amount of training in most studies in this review may improve contractile muscle, but is unlikely to be sufficient to change connective tissue in DRAM.

Although abdominal exercise has a small, non-clinically significant effect on inter-recti distance, women are encouraged to exercise in the postnatal period for its essential physiological and psychological benefits. Research has demonstrated that increased inter-recti distance has an impact beyond the gap and is correlated with distress, fear/ avoidance of movement, increased BMI and lumbopelvic pain which lead to disability and difficulties with daily activity [41,42]. DRAM can lead to poorer physical perception, body image, functioning and quality of life. Therefore it is possible that strengthening exercises may influence biopsychosocial well-being by altering this perception by improving mood and feeling good in oneself as well as improving physical health, decreasing fear of movement and enabling improved function [1,5,41–43].

Surgical interventions or implementing other types of exercise targeted at connective tissue may reduce inter-recti distance [44]. However, surgery plicates the tissue and does not change the connective tissue properties and therefore, the intrinsic tensile strength remains unchanged. Additionally, surgery is not accessible to all, involves restrictions post-operatively and potential harms. There may be other forms of exercises that could be more conducive to connective tissue strengthening such as myofascial anatomy slings. Sling exercises involve muscle, fascia and ligaments all working together to enable both stability and mobility and could be beneficial for DRAM as it has proposed benefits of contractile strengthening with improved fascial loading [32,45]. Further research should explore the efficacy of these exercises in reducing DRAM.

In clinical practice, natural resolution may give clinicians the impression that exercises instituted in the first six weeks are effective, and why they value and persist with these exercises and DRAM-targeted interventions. Although the the types of exercises in these studies reviewed displayed a small reduction, it is important to consider if this gapping is indeed bothersome for women. Further qualitative analysis of new mothers' perspectives would provide insights into this. Additionally it is important to consider if variation in the type, dosage and timeframes of when exercise is instituted may more be amenable to collagen repair and strengthening.

Strengths and limitations

This review followed the PRISMA guidelines on high quality reporting on systematic reviews and meta-analysis. There was no restriction on language or search date reducing the likelihood of relevant studies being missed. Robust methods were employed to extract, assess, and analyse the data, and most trials employed validated methods to assess DRAM (ultrasound, calipers and finger-width measured prior to assessment). One trial in this review [18] used number of fingers to measure effectiveness of treatment over time. It is difficult to compare this study's participants, assessment methods including definition of DRAM and intervention effectiveness with the others which have used the more responsive and sensitive ultrasound or caliper DRAM measurements in post-natal women in active or resting states at different measurement locations [46]. It must be noted that finger-width measurements can be reliable if the assessor's finger width is measured in cm/ mm prior to DRAM measurement [47]. Fourteen studies measured DRAM in contraction with head lift where the borders of rectus abdominis and distortion of the linea alba are more easily palpable [48] for measurement, capturing clinically relevant change. A single study [19] measured DRAM at rest only with ultrasound.

Although, TIDieR analysis found DRAM interventions were generally reported sufficiently to enable replication in commencing exercise, details relating to modifications, monitoring adherence and intervention fidelity, progression and the level of instructor training were deficient. These results could be influenced by poor exercise prescription including lack of dosage progression, training intensity and poor monitoring of adherence [49] seen in some trials. Reporting on fidelity is important to ensure interventions have been delivered as intended and is often better in a controlled clinical setting as compared to the home environment [50]. Other limitations include that seven of the 16 trials had a high risk of bias related to the randomisation process, lack of concealment and or reporting of concealment. As no trials have examined DRAM intervention effectiveness in the antenatal period, our results cannot be generalised to this group.

Implications

Strengthening exercises may assist in improvements in self-perception, physical health and functioning and should be encouraged for these reasons. However, physiotherapists should not prescribe abdominal exercises to women postnatally for the purpose of reducing inter-recti distance only compared to usual care. Further investigation is needed to investigate if exercise may stop inter-recti distance worsening. Current conservative interventions, including abdominal strengthening exercises, do not lead to clinically significant reductions in DRAM in the postnatal period but may have other important physical and psychosocial benefits.

Conclusions

Current conservative interventions, including abdominal strengthening exercises, do not lead to clinically significant reductions in DRAM in the postnatal period but have other physical and psychosocial benefits.

Ethics Approval

None required.

Conflict of interest: None declared.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.physio.2023.02.002.

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