Outcomes of operative versus non-operative interventions on rectus abdominis diastasis: a combination of a retrospective analysis and a systematic review

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Abstract

Background There is no current consensus on the treatment of Rectus abdominis diastasis (RAD). This study aimed to assess the recurrence rates and adverse events after operative or non-operative intervention. **Methods** We performed a retrospective study and a systematic review. Patients with a diagnosis of RAD who underwent the mesh placement procedure were eligible. Data were collected from The Research Patient Data Registry. Then, a systematic literature search of Pubmed, Embase, and The Cochrane Library databases was performed. A modified Downs and Black checklist for randomized and non-randomized studies of healthcare interventions (DB) was used to evaluate the methodological quality of the studies. **Results** Data of 82 patients was collected. The 5-year cumulative incidence of recurrence of abdominal hernia was high (females 37.0% vs males 43.4%, $P = 0.557$). Of 3908 citations, 27 studies describing 2,372 patients were included into the systematic review. In non-operative group, seven studies (25.93%) with a total of 603 subjects reported no patient relapsed after a follow-up of 12 months; a 40% recurrence rate was reported after a follow-up of 5 years in one study, the adverse events associated with operation mainly included seroma (5.13%), a sensibility disorder of the abdominal skin (2.26%), and minor scarring (1.56%). Muscle strength training, such as training of the pelvic floor muscles, abdominal muscles, rectus abdominis, internal/external oblique, or transverse abdominal muscles, was performed in all included non-surgery studies, neither adverse events nor recurrence was reported. **Conclusion** Operative intervention may be effective at restoring the functions of the rectus muscles and at improving the stability of abdominal wall in the short-term, while non-operative intervention has a limited effect, especially for those RAD combined with hernia.

Background

Rectus abdominis diastasis (RAD) is characterized by widening of the *linea alba* and usually presenting with a “bulge” in the midline when intra-abdominal pressure is increased. This phenomenon at present was well-recognized as the laxity of the ventral abdominal musculature^{1,2}. RAD is a common disorder among women during the third trimester of pregnancy with a high prevalence (66% to 100%), approximately 50% of individuals who underwent abdominal hysterectomies or hernia repair were diagnosed with RAD as well³⁻⁷. It is increasingly recognized as it may be associated with symptomatic umbilical and/or epigastric hernia, aneurysmal disease, low back pain and muscular imbalance⁸⁻¹⁸.

There is no current consensus on the treatment of RAD, nor is there unity on the repair techniques among the surgical and physical and rehabilitative communities¹⁹⁻²¹, although a large body of literature has been generated on the restoration of some degree of strength of the midline in the postpartum setting, and many different innovative methods for surgical treatment to repair the defeat are available: vertical incision from the xiphoid process to the umbilicus or a low transverse skin incision, the repair of diastasis recti combined with liposuction, with or without using mesh to repair the rectus abdominis diastasis as well, etc. Based on the current literature, the promising results of new procedures with mesh placement and recurrent rate after long-term follow-up have not been clearly reported yet^{22,23}.

Therefore, evaluating the effect of both physical therapy and repair surgery interventions is important, because RAD is wide-spread, significantly downgrading the quality-of-life (QoL) and increasing the costs of health care burden as well.

To better understand what is about the therapy and its outcomes of RAD, we conducted a retrospective study concerning the mesh placement and the systematic review summarizing operative-interventions and non-operative interventions in patients with RAD. Our result possibly may aid our understanding of RAD and help physiotherapists, surgeons and patients with RAD to make intervention strategy decision when encountering RAD patients.

Methods

This study followed a two-step procedure: (1) a retrospective analysis summarizing the outcomes of repairing of abdominal wall and hernia with mesh based on the data extracted from the Research Patient Data Registry (RPDR) in Massachusetts, USA; (2) a systematic literature review of intervention studies evaluating the effects of operative versus non-operative strategies on patients with RAD. The current review was registered on PROSPERO and can be accessed at [www.crd.york.ac.uk/PROSPERO/display_record.asp? \(CRD42018115608\)](http://www.crd.york.ac.uk/PROSPERO/display_record.asp?CRD42018115608). We applied the PRISMA reporting guidelines for this review.

Retrospective study

Materials and Methods

This retrospective study analyzed the outcomes of patients with RAD who underwent mesh placement from six hospitals within the Partners Healthcare System in Massachusetts, United States. The review board of RPDR approved this study protocol (#2018P003056). Patients with a diagnosis of RAD who underwent the mesh placement procedure were eligible. RAD was defined as an inter-rectus distance (IRD) of or more than 22 mm, three centimeters above the umbilicus measured in a relaxed state²⁴. Exclusion criteria were the implantation of mesh was not used for the repairing of abdominal wall and hernia. Identified individual-level data of eligible patients from January 2011 to November 2018 was obtained from RPDR. Data including demographic information (age, body mass index (BMI), race or ethnic group), social history (smoking status, alcohol abuse, depressive disorder), diagnosis (including contaminant conditions possibly associated with RAD: hernia, low back pain, pelvic and perineal pain, incontinence, strain of muscle, fascial and tendon (SMFT), the history of open abdominal surgery, operative notes, imaging reports and procedures were collected. The diagnoses above were as defined by the International Classification of Diseases, Ninth Revision Clinical Modification ICD-9-CM and International Statistical Classification of Diseases and Related Health Problems, Tenth Revision ICD-10-CM diagnoses codes.

The outcome indexes

The primary outcome was the recurrence of RAD and hernia, and the second outcome was a composite of concomitant conditions (hernia, low back pain, pelvic and perineal pain, incontinence, strain of muscle, fascial and tendon (SMFT), depressive disorder and the peri-operative characteristics (operation type, anesthesia type, mesh type, skin closed method and adhesions in abdominal cavity noted on operate notes).

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics, version 20. Data were summarized as mean and standard deviation or frequencies and percentages where applicable. Chi-square test or Fisher's exact test were used to analyze categorical variables and Independent-Samples T test was used for continuous variables. binary logistic regression analysis to determine the association between the potential factors and the primary outcome, and the odds ratio and 95% confidence interval were estimated from BLRA. To reduce confounding bias, we adopted a forward stepwise regression analysis (α entry = 0.10, α removal = 0.10). A P -value <0.05 was considered statistically significant.

Results

Characteristics of the patients

Of 82 patients who were reviewed at the 6 clinical settings from January 2011 through November 2018, 45 were female who received 54 mesh placement procedures totally and 37 were male who received 53 procedures. These patients were all diagnosed with RAD combined with one or more hernia. The mean age undergoing first time hernia repair in males was significantly older than that of females (mean 61.2 years old vs. 49.2 years old, $t = 4.654$, $P = 0.000$). The mean BMI values were greater than 30 kg/m² in both groups (mean 31.8 vs. 31.6, $\chi^2 = 0.147$, $P = 0.883$). The number of individuals smoking at index repair and using alcohol were high in both groups (37.8% vs. 31.1%, 54.1% vs. 48.9%, respectively) (Table 1).

The outcomes

The 5-year cumulative incidence of recurrence of and RAD and hernia was 37.0% in female group compared with 43.4% in male group ($\chi^2 0.450$, $P = 0.557$, Figure 1). While the recurrence after a one-year follow-up in male group was higher than in female group (24.53% vs. 5.56%, $\chi^2 0.7571$, $P = 0.007$, Figure 1). We failed to identify risk factors contributing to recurrence after the repair with mesh when practicing binary logistic regression analysis by using 17 independent variables including age, race, concomitant conditions, mesh type, suture type, etc. As for the composite second outcomes, ventral hernia was most common type (27.8% vs.

40.7%, $P = 0.104$) and there was no difference in hernia number and type between two groups ($P = 0.176$). The rate of concomitant low back pain were higher than 30% as well in both groups (35.1% vs. 33.3%, $P = 1.000$), whereas depressive disorder and major depressive disorder in female group were significantly higher than that in male groups (51.1% vs. 27.0%, $P = 0.041$; 46.7% vs. 21.6%, $P = 0.022$, respectively). Over one-quarter cases had noted adhesion in abdominal cavity and there was no significant difference between two groups (29.7% vs. 35.6%, $P = 0.641$). Of 37 cases in male group, 20 (62.5%) had the history of open abdominal surgery compared to 33 of 45 cases (76.7%) in female group ($P = 0.207$) (Table 1). The most common anesthesia type was general anesthesia and the suture was used to close skin commonly in both groups (79.2% vs. 85.2%, 86.8% vs. 88.9%, respectively). In female group, risk of coexisting with low back pain in patients with pelvic and perineal pain was 27 times greater than that of those without pelvic and perineal pain (OR 28.653; 95% CI 2.924, 280.753; $P = 0.004$); and patients with concomitant SMFT were more likely to have low back pain than those without SMFT as well (OR 9.604; 95% CI 0.763, 120.858; $P = 0.08$).

Systematic review

Materials and Methods

This study was conducted according to the Modified Downs and Black checklist for randomized and non-randomized studies of healthcare interventions (DB) ²⁵.

Search strategy

Systematic searches were conducted using Pubmed, Embase, and The Cochrane Library databases from the earliest data available to November 2018. The search terms used were “diastasis recti abdominis”, “diastasis recti”, “diastasis rectus abdominus”, “abdominal rectus diastasis”, “diastasis of the rectus abdominis muscle”, “linea alba”, “diastasis recti and weakness of the linea alba”, and their combinations with Boolean “AND” and “OR” intervention terms, including “surgery”, “surgical intervention”, “reconstructive surgery”, “surgical treatment”, “prolotherapy”, “regeneration injection therapy”, “operative repair”, “abdominal wall repair”, “non-surgical intervention”, “conservative treatment”, “physiotherapy”, “physical therapy”, “conservative management”, “conservative therapy”, “exercise”, “recommendation”, “counsel”, “manual therapy”, “strengthening”, “movement”, “fitness program”, “external support”, “band”, “tape”, “belt”, “tubigrip”, “drills”. There were no restrictions placed on study design, but only full texts in English were included. We performed also manually searched the included references of relevant papers to ensure full coverage.

Study selection

Titles and abstracts were reviewed independently by three reviewers (Li YX, Fan L and Li Q) to determine the eligibility of the papers for inclusion. The research team discussed and resolved issues together if there were any disagreements. Studies meeting all the following criteria were included: 1) the study included at least one intervention that aimed to improve RAD; 2) the study was designed as a prospective, retrospective, clinical trial, or case report; 3) Full-text journal articles in English. Cadaver studies and animal studies were excluded.

Data extraction and outcome measures

Outcomes of the systematic review were overall presence/absence of RAD, RAD size/width, patient satisfaction, recurrence rate, physical activity levels, back pain, functional impairments, quality of life, follow-up information, and adverse events. Data on the type of study and sample size, the nationality of the enrolled patients, and the patients' age, sex, BMI (Kg/m^2), the types of anesthesia used during the surgical operation were also extracted.

Quality assessment

All included papers were evaluated for methodological quality using DB, which has a total maximum modified DB score of 28 and consists of four factors: external validity, confounders, bias, and power²⁵. Articles with a DB score were grouped into the following quality levels: strong (≥ 21), moderate (14-20), limited (7-13), or poor (7 or less)²⁶. The final set of papers varied in outcome reporting; therefore, a meta-analysis was not possible.

Results

Study identification

The initial database search yielded 3906 articles, and two were obtained by tracking the references. After removing 739 duplicates, 3169 studies were screened for further analysis. Since 3102 did not match the review criteria, 67 full-text articles were screened for eligibility; of these, 40 were excluded later. Therefore, 37 studies were included in this systematic review. The flow diagram and reasons for study exclusion are shown in Fig. 2.

Characteristics of the included studies

The characteristics of all 2372 patients from the 37 included studies are presented in Tables 1 and 2^{11,12,17,20,22,27-58}. 1341 (69.02%) patients in the surgery group and 422 (98.37%) patients in the non-surgery group were female; the gender of 607 patients was not reported. BMI was reported in 20 studies (the average BMI was $> 23 \text{ kg/m}^2$ in each reported study). There are four randomized controlled trials in the non-surgery group and three prospective clinical trials in the surgery group.

Quality assessment

Of the studies examining surgery intervention, 11 were of moderate quality, 13 were of limited quality, and three were of poor quality; of the studies examining non-surgery intervention, four were of strong quality, four were of moderate quality, and two were of limited quality. The average modified DB score of the included studies for the surgery intervention group was 11.7 (range 6-20), and that for the non-surgery group was 18.4 (range 12-26).

Type of anesthesia

Fifteen studies described the type of anesthesia, ten used general anesthesia, two used local anesthesia, and three used general anesthesia combined with epidural anesthesia. There were no complications due to anesthesia reported in any of the included studies.

Operative intervention

Eight studies (29.63%) reported the use of endoscopy during abdominoplasty surgery; the remaining studies (70.37%) were performed using a vertical skin incision from the xiphoid process to the umbilicus or a low transverse skin incision. The mesh augmentation technique was used to reinforce the linea alba with or without associated hernias in nine studies (33.33%), and the type of mesh used included polypropylene, self-adhesive synthetic, composite, and resorbable vinyl mesh.

In eight studies (29.63%), liposuction was combined with traditional abdominoplasty and repair of the rectus sheath defect to reduce complications and provide fast recovery; the volume of abdominal lipoaspirate ranged from 50 to 2800 ml, and the maximum volume reported in these studies was 7800 ml. Five studies (18.52%) reduced recurrence by adopting a special suture

method, such as the triangular mattress suture, continuous suture, the Venetian blinds application technique, braided suture, buried suture, and figure-of-eight suture combined with the wearing of self-adherent silicone strips.

Non-operative intervention

Muscle strength training, such as training of the pelvic floor muscles, abdominal muscles, rectus abdominis, internal/external oblique, or transverse abdominal muscles, was performed in all included non-surgery studies. Physical interventions including head lift, pelvic lock or tilt, plank, superman, and double leg raise were induced into the intervention program in two studies. The frequency was from one to 14 times per week, and the period of intervention was from 8 weeks to 15 months unequally.

Outcomes

The conclusions from six studies (60%) in the non-surgery group were positive, and the remainder (40%) were negative. The indexed outcomes included one or more of the following: inter recti distance (IRD), BMI, abdominal strength, pain, quality-of-life (QOL), pelvic floor distress index (PFDI), and activation endurance (hold seconds). In the surgery group, 26 studies (96.30%) obtained positive results over the short-term, and just one study (3.70%) reported negative results over the long-term. The indexed outcomes in this group included one or more of the following: the width of the diastasis of the recti abdominis muscles, ventral hernia pain, quality-of-life, Oswestry Disability Index, abdominal wall function, cosmetic outcome, satisfaction, Aponeurosis Shortening Index (ASI), back pain after surgery, and recurrence rate. None of the included studies demonstrated that physical training can be effective in improving the abdominal wall function of patients suffering RAD combined with hernia.

Recurrence rates

In the surgery group, there were seven studies (25.93%) including a total of 603 subjects with a reported follow up of 12 months; no patient relapsed; after a follow up of 24 months, the three remaining studies (11.11%) reported a 0% recurrence in a total of 268 subjects. Van reported a 40% recurrence rate of standard plication of the abdominal wall with absorbable material after a follow up of 5 years in a retrospective study of 40 patients attending a follow-up ultrasound investigation and with a total sample size of 70 women. No residual or recurrent diastasis was reported among 228 subjects receiving experimental training in the non-surgery group.

Adverse events

Twenty-four studies (85.19%) including a total of 1989 patients described adverse events associated with the surgery, which included: seroma (102 cases, 5.13%), sensibility disorder of the abdominal skin (45 cases, 2.26%), minor scar (31 cases, 1.56%), necrosis (umbilical/skin/sterile/infected fat) (19 cases, 0.96%), pain (13 cases, 0.65%), wound infection (13 cases, 0.65%), dog-ears (9 cases, 0.45%), hematoma (8 cases, 0.40%), sensibility disorder of the thigh (6 cases, 0.30%), epigastric fullness (4 cases, 0.20%), full-thickness skin loss (3 cases, 0.15%), prolonged neuralgia (3 cases, 0.15%), thrombosis (3 cases, 0.15%), discrete wound (3 cases, 0.15%), subcutaneous emphysema (2 cases, 0.10%), transient scalp alopecia (1 case, 0.05%), pulmonary embolism (1 case, 0.05%), pneumonia (1 case, 0.05%), subdermal burn (1 case, 0.05%), epidermolysis (1 case, 0.05%), and postoperative ileus (1 case, 0.05%). There were no adverse events reported in patients with physical training.

Discussion

Summary of results

This systematic review found a limited strength of evidence that abdominoplasty and diastasis recti repair with or without mesh and/or liposuction may be effective at restoring the function of the rectus muscles, improving the stability of the abdominal wall

and upgrading the quality of life in the short-term. However, the post-operative recurrence rate in patients who underwent either traditional standard vertical plication or modern endoscopic surgery increased rapidly with the time, a rate of up to 40 percent was reported in one study, and this high recurrence rate also has been confirmed in our retrospective study.

Our study also found a moderate strength of evidence that physical training including strength training of the pelvic floor muscles, transverse abdominal muscle, core stabilization, and rehabilitation therapy have limited effectiveness for the rehabilitation of diastasis rectus muscles, especially for patients suffering from RAD combined with hernia.

Among all twenty-one types of complications reported in the included studies, the rate of seroma was the highest at five percent, which was higher than other reported ⁵⁹. A large body of evidence shows that the use of drains in abdominoplasty may increase the seroma rate, while surgeons are unwilling to change their clinical practice of using drains ⁶⁰. Meanwhile, thrombosis and pulmonary embolism were reported in these studies, but their final outcomes and the reason leading to the severe adverse events were not reported. Therefore, an understanding of how to prevent these adverse events due to diastasis rectus abdominus repair surgery is also needed and will require further, in-depth research.

Therefore, the problems of how to reduce the recurrence rate and adverse events related to procedure remains although surgeons have tried innovative suture techniques or materials, such as triangular mattress suture, smooth running absorbable polydioxanone suture, nylon, or polydioxanone and/or different meshes, or in combination with liposuction abdominoplasty, etc. In this retrospective study, we found that, obesity was an important characteristic in both male and female patients with RAD. In addition, the rate of noted adhesion in abdominal cavity was high, similar to previous study ⁶¹. These adhesions played an important role in increasing the difficulty of operation performing due to extensive adhesions. Whether the adhesion in abdominal cavity was related to the recurrence of RAD and hernia was unknown. In the field of fascia research, researchers found that a previously unknown feature of human anatomy, termed a newfound "organ", exists in numerous tissues, including the submucosae of the entire gastrointestinal tract and urinary bladder, the dermis, the peribrochial and peri-arterial soft tissues, and the fascia; this may play an important role in the mechanical functioning of many or all tissues and organs, cancer metastasis, edema, and fibrosis ⁶². Other researchers found that telocytes exist in human fascia, which may contribute to some common diseases such as stiffening of limbs, inflammatory diseases, sclerotic and the progression of fibrotic, etc ⁶³, but the exact role of these cells is unknown ⁶⁴. It was also reported that fascia lesions were closely related with chronic pain ⁶⁵. We confirmed that women with SMFT were also more likely to coexisting with LBP than those without SMFT, which is consistent with myofascial pain theory as well ²⁶. We demonstrated that RAD is most common among obesity population and more than 33 percent of them were coexisting with low back pain. In addition, women with SMFT had more than 9 times of risk of coexisting with low back pain than those without SMFT; we also found that the volume of intra-abdominal and superficial fat being removed during abdominoplasty surgery is closely associated with the outcome. Is there a close relationship between the fat removed by surgeons and the newfound "organ" with telocytes? The authors want to boldly make a hypothesis here, and further study is warranted to examine this most possibly association.

In conclusion, this systematic review found a moderate strength of evidence that physical training has limited effectiveness for the rehabilitation of diastasis rectus muscles, especially for those patients suffering from RAD combined with hernia, and abdominoplasty and diastasis recti repair with or without mesh and/or liposuction may be effective at restoring the functions of the rectus muscles and improving the stability of the abdominal wall and quality of life in the short-term; however, up to now, the long-term durability and the adverse events are unsatisfactorily, these all need further, in-depth research.

Limitations

Several limitations existed in this study. Firstly, the methodological quality, especially in the surgery group, was weak. Secondly, a meta-analysis of the studies was not performed given the lack of consistency in the interventions. Thirdly, the results of the review may be influenced by publication bias because we did not contact the authors about other possibly existing unpublished analyses, nor did we search for unpublished studies.

Recommendations for future research

RAD is common and may be associated with low back pain and impaired health-related quality of life. Fortunately, mounting evidence indicates that surgery repair and physical training have helped many patients in improving their quality of life. However, why is RAD very common among people with high BMI, why does the diffuse fusiform bulge reappear to a large extent even when mesh is used, and why is the outcome possibly better when abdominoplasty combined with liposuction is used rather than the standard method? Whether or not there is a closely relationship between surface and deep fascia lesions? Many puzzles remain to be explored. Therefore, future research should pay more attention to the pathogenesis of RAD based on a multidisciplinary co-operative team of experts, including at least the departments of plastic surgery, radiology, ultrasound imaging, and pathology as well as the fascia research center.

Conclusion

This review found a limited strength of evidence that abdominoplasty and diastasis recti repair with or without mesh and/or liposuction may be effective at restoring the functions of the rectus muscles and improving the stability of the abdominal wall and quality of life in the short-term; a moderate strength of evidence was found that strength training has a limited effect, especially for those patients suffering RAD combined with hernia. To maximize long-term efficacy, a multidisciplinary cooperative team including experts from at least the departments of plastic surgery, radiology, ultrasound imaging, and pathology as well as the fascia research center is urgently needed because abdominoplasty represents the fourth most-common aesthetic surgery procedure according to the reports published by American Society for Aesthetic Plastic Surgery in 2014 ⁶⁶.

Abbreviations

RAD: rectus abdominis diastasis; DB: Downs and Black checklist; QoL: quality-of-life; RPDR: IRD: inter-rectus distance; BMI: body mass index; SMFT: strain of muscle, fascial and tendon; ICD: International Classification of Diseases; OR: odds ratio; CI: confidence interval; BLRA: binary logistic regression analysis; ASI: Aponeurosis Shortening Index.

Declarations

Ethics approval and consent to participate

The review board of the Research Patient Data Registry (RPDR) approved this retrospective study protocol (#2018P003056). As for the systematic review, the ethics approval is not required.

Consent for publication

Not applicable.

Availability of data and materials

As a review study, the data were extracted from the Research Patient Data Registry (RPDR) in Massachusetts, USA; as for the systematic review, the data were extracted from Pubmed and The Cochrane Library databases. The data supporting our findings can be obtained by emailing the corresponding author.

Competing interests

The authors declare that they have no competing interests.

Funding

Not applicable.

Authors' contributions

Sue Yuan: This author helped develop ideas for study, design the study, collect data, analyze data, and prepare the manuscript for publication. Yunxia Li, Qi Li, Lu Fan: This author helped developed ideas for study and review the manuscript. Jie Zhou: This author contributed to the developing of ideas, the study design, manuscript preparation for publication.

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Tables

Table 1 Characteristics of the Patients with RAD underwent hernia repair and abdominoplasty with mesh

	Male group (n=37)	Female group (n=45)	χ^2	P
Demographic characteristics				
Age (yr) (underwent first hernia repair)				
Mean (sd) (year)	61.2 ± 12.3	49.2 ± 11.0	4.654	0.000 ^a
Category, n (%)				
<30	1 (2.7)	0 (0.0)	19.139	0
30 to < 40	1 (2.7)	8 (17.8)		
40 to < 50	5 (13.5)	21 (46.7)		
50 to < 60	6 (16.2)	5 (11.1)		
60 to < 70	12 (32.4)	8 (17.8)		
70 to < 80	12 (32.4)	3 (6.7)		
Race or ethnic group, n (%)				
Non-Hispanic black	0 (0.0)	3 (6.7)	2.141	0.143
Hispanic	2 (5.4)	4 (8.9)		
Other	35 (94.6)	38 (84.4)		
Body mass index				
Mean (kg/m ²)	31.8 ± 5.4	31.6 ± 7.9	0.147	0.883 ^a
Category, n (%)				
<18.5	0 (0.0)	1 (2.2)	2.974	0.412
18.5 to <25	5 (13.5)	5 (11.1)		
25 to <30	8 (21.6)	15 (33.3)		
30 to <40	22 (59.5)	19 (42.2)		
≥40	2 (5.4)	5 (11.1)		
Coexisting symptoms, n (%)				
Hernia, n (%)				
Diaphragmatic hernia	5 (6.9)	5 (6.2)	6.323	0.176
Ventral hernia	20 (27.8)	33 (40.7)		
Groin hernia	11 (15.3)	5 (6.2)		
Incisional hernia	16 (22.2)	22 (27.2)		
Umbilical hernia	20 (27.8)	16 (19.8)		
Low back pain, n (%)	13 (35.1)	15 (33.3)	0.029	1
Pelvic and perineal pain, n (%)	4 (10.8)	8 (17.8)	0.789	0.374
Incontinence, n (%)	1 (2.7)	1 (2.2)	0.02	1.000 ^b
Strain of muscle, fascial and tendon, n (%)	2 (5.4)	4 (8.9)	0.363	0.685 ^b
Previous abdominal surgery history, n (%)	20 (62.5)	33 (76.7)	1.796	0.207
Social history, n (%)				
Smoker at index repair, n (%)	14 (37.8)	14 (31.1)	0.409	0.641
Alcohol use, n (%)	20 (54.1)	22 (48.9)	0.217	0.664
Depressive disorder, n (%)	10 (27.0)	23 (51.1)	4.898	0.041
Major depressive disorder, n (%)	8 (21.6)	21 (46.7)	5.572	0.022
Peri-operative characteristics, n (%)				
Operation type, n (%)				
Open abdominal	35 (66.0)	44 (81.5)	3.302	0.081
Laparoscopic	18 (34.0)	10 (18.5)		
Anesthesia type, n (%)				
General	42 (79.2)	46 (85.2)	0.646	0.458
Monitored anesthesia care with local	11 (20.8)	8 (13.0)		
Spinal	0 (0.0)	1 (1.98)		
Mesh type, n (%)				
Polypropylene	29 (54.8)	18 (33.3)	7.177	0.028
Parietex	12 (22.6)	11 (20.4)		
John and Johnson prolene hernia system	12 (22.6)	25 (46.3)		
Skin closed method, n (%)				
Suture	46 (86.8)	48 (88.9)	0.11	0.74
Staples	7 (13.2)	6 (11.1)		
Adhesions in abdominal cavity, n (%)	11 (29.7)	16 (35.6)	0.312	0.641

Notes: a-t value; b – Fisher's Exact Test;

Table 2 Characteristics of included studies with operative intervention.

Study	Country	Design	Sample size (Male, Female)	Age (year)	BMI(Kg/m ²)	Anesthesia	Outcome Index/Tools	Study quality
Juárez Muas DM	Argentina	Case study	50 (3/47)	38 (24-66)	36%>28	General anesthesia	Recurrence of DRAM	13/28
2018[1] Kockerling F	Germany	Prospective cohort study	140 (90/50)	54.7 (25-85)	29.9 (18-50)	NR	DRAM presence, Recurrence of DRAM	13/28
2017[2] Emanuelsson P 2016[3]	Sweden	Prospective randomized clinical 2-armed trial	89 (2/87) Intervention group: 54 Control group: 32	Quil group: 39.6 Mesh group: 42 Control group:	Quil group:23.0 Mesh group:23.0 Control group:	General anesthesia	Recurrence of ARD, width (>3cm), the ventral hernia pain Questionnaire, quality-of-life (SF-36), Abdominal muscle strength	20/28
Gallus KM	SanDiego	Case report	1 (0/1)	24	44.2 22.8 NR	Local anesthesia	Oswestry Disability Index	10/28
2016[4] Kockerling F	Germany	Case series	40 (29/11)	53.6	32.6 (23-50)	NR	Postoperation complications	14/28
2016[5] Privett BJ	Australia	Case series	173 (NR/NR)	NR	NR	NR	Recurrence rate,	6/28
2016[6] Shirah BH	Saudi Arabia	Retrospective cohort study	216 (31/185)	40.9±2.7	26.39 ± 2.8	General anesthesia	Postoperation complications Recurrence rate,	15/28
2016[7] Bellido LJ	Spain	Prospective cohort study	21 (3/18)	37.6[24-50]	27.4 (22-35)	General anesthesia	Postoperation complications, Abdominal wall function, Cosmetic outcome surgical time(min), postoperative stay (days), time of remove drain, postoperative complications,	16/28
2015[8] Verissimo P	Brazil	Prospective clinical trial	31 (0/31) TS:21 CS:10	TS:33.6 CS:37.4	TS :23.2 CS :24.1	General anesthesia combined with epidural	Aponeurosis Shortening Index (ASI)	14/28
2014[9] Kanjoor JR	Canada	Retrospective study	146 (8/138)	43 (29-72)	<30=102 >30=44	General anesthesia or Epidural anesthesia Combined with sedation	Postoperation complications	9/28
2012[10] Tadiparthi S	UK	prospective study	28 (0/28)	36 (23-47)	26 (21-37)	NR	Beer classification	13/28
2012[11] Rosen A	USA	retrospective review	34 (0/34)	43.6 (33-67)	23 (18.7-29.1)	General anesthesia	Recurrence rate,	14/28
2011[12] Pechter EA	New Jersey	review					Postoperation complications	
2010[13] Siddiky AH	USA	retrospective review	35 (0/35)	40.7 (23-63)	25.3 (18.3-37.2)	General anesthesia	Ischemic complications	14/28
2010[14] Brauman D	USA	Case report	1(0/1)	38	NR	NR	Recurrence rate,	14/28
2009[15] Palanivelu C	India	Prospective study Retrospective study	337 (7/330) 18 (5/13)	36 (21-72)	29.3 (19.5-41.7) 28.6 (25-32.2)	Local anesthesia NR	Post-operation Complications. Post-operation complications IRD, Complications	10/28 6/28

Batchvarova Z	France	Retrospective review	52 (0/52)	39 (25-60)	23.5 (20-31.5)	General anesthesia	Post-operation Complications	9/28
2008[17]								
Dabb RW	USA	Case series	32 (NR/NR)	NR	NR	Epidural or General anesthesia	Post-operation Complications	6/28
2004[18]								
Nahas FX		Case series	2 (0/2)	38&59	NR	General anesthesia	Recurrence rate,	9/28
2004[19]	Brazil						Post-operation Complications	
Cardenas Restrepo JC	Columbia	case-report series	42 (0/42)	34 (25-53)	NR	NR	Post-operation Complications	7/28
2002[20]								
Ferreira LM	Brazil	case-report series	56 (NR/NR)	NR	NR	NR		8/28
2001[21]								
Nahas FX	Brazil	Prospective clinical trial	Intervention 10 (NR/NR)	Intervention 38.5	NR	General anesthesia	DRAM width (cm)	16/28
2001[22]			Control 10(NR/NR)	Control 32.5				
Nahas FX	Brazil	Case series	88 (0/88)	18-59	NR	NR	Recurrence rate,	11/28
2001[23]							Post-operation Complications	
van Uchelen JH	Netherlads	Case series	63 (0/63)	39.4	NR	General anesthesia	Recurrence rate,	14/28
2001[24]							Post-operation Complications	
Ramirez OM	Baltimore,Md	Case series	104 (NR/NR)	NR	NR	NR	Post-operation Complications	14/28
2000[25]								
Zukowski ML	USA	Retrospective review		33 (21-50)	NR	General anesthesia	Post-operation Complications	13/28
1998[26]			85 (0/85)					
Asaadi M	USA	Case series	39 (NR/NR)	NR	NR	NR	Post-operation Complications	8/28
1994[27]								

Quality score is based on the Downs and Black criteria. Abbreviations: BMI-Body Mass Index, DRAM-Diastasis rectus abdominus muscel, ELAR-Endoscopic-assisted linea alba reconstruction, ARD-Abdominal rectus diastasis, RD-Rectus abdominus diastasis, IRD-Inter-recti distance, NR-not report.

Table 3 Characteristics of included studies with non-operative intervention.

Study	Country	Design	Sample size (Male, Female)	Age (years)	BMI (Kg/m ²)	Intervention	Frequency	Outcomes Index/Tools	Study quality
Gluppe SL 2018[1]	Norway	RCT	175(0/175) Intervention group: 87 Control group:	Intervention group: 29.5 ± 4.3 Control group: 30.1 ± 4.0	Intervention group: 26.0 ± 4.1 Control group: 25.3 ± 3.9	Strength supervised training of the pelvic floor muscles + pelvic floor muscle training at home	weekly supervised training for four months, daily self-training at home	DRAM presence	26/28
Kamel DM 2017[2]	Egypt	RCT	88 60(0/60) Intervention group: 30 Control group: 30	Intervention group: 29.33 ± 2.98 Control group: 32.5 ± 3.00	Intervention group: 28.02 ± 1.69 Control group: 27.49 ± 1.38	Group A: NMES Group B: abdominal exercises	three times per week for eight weeks	BMI, IRD, Abdominal muscle strength	23/28
Emanuelsson P 2016[3]	Sweden	RCT	89(2/87) Operation with Quill group: 27 Operation with mesh group: 29 Training group: 30	Operation with Quill group: 39.6 Operation with mesh group: 42.0 Training group: 44.2	Operation with Quill group: 23.0 Operation with mesh group: 23.0 Training group: 22.8	Operation with Quill group: double-row plication with Quill technology, Operation with mesh group: retromuscular polypropylene mesh, Training group: a program targeting mainly the rectus, oblique, and transverse abdominal muscles	Training group: 3 times a week over a period of 3 months	Pain, QoL (SF-36), Muscle strength (Biodex 4)	26/28
Khandale SR 2016[4]	India	Self-control trial	40(0/40)	21.7±4.97	23.056 ± 4.425	Head lift, pelvic lock, plank, superman, and double leg raise	30min/day, 5 times/ week for period of 8 weeks.	IRD	15/28
Walton LM 2016[5]	USA	RCT	9(0/9)	32.0	27.4	Traditional group: a supine strengthening program, Experimental group: a dynamic core stabilization program including the addition of plank exercise to approximate the DRA	three times a week for a total of six weeks	IRD, PFDI and ODI Disability scores	23/28
Acharry N 2015[6]	India	Prospective uncontrolled trial	30(0/30)	28.8	NR	Head lift, pelvic tilt, and pelvic clock with bracing	twice daily with a repetition of 5-7 times for 2 weeks duration	IRD	13/28
Balius R 2011[7]	Spain	Case series	5(NR/NR)	NR	NR	Rehabilitation therapy	For 15 months	Posterior and anterior margins at maximum thickness level below the umbilical line (cm)	18/28
Chiarello 2005[8]	Colombia	Quasi-experimental post-test design	18(0/18) Intervention	Intervention group: 32.0 ± 2.2	NR	Prenatal Exercise Program focused on abdominal muscle strengthening, pelvic floor exercises, and	6 classes, 90 minutes per class	DRAM width (cm)	14/28

			group: 8	Control group:	education in prenatal body mechanics				
Hsia M 2000[9]	Australia	Case serious	Control group: 10 2(0/2)	30.4 ± 3.95 Subject A:	Subject A	Antenatal fitness	every Monday, Wednesday	DRAM width (cm)	14/28
			Subject A: 1	33	24.8	classes from week	and Friday over a maximum period of 16 weeks		
			Subject B: 1	Subject B:	Subject B	30/40 to 39/40			
Sheppard 1996[10]	Japan	Case report	1(0/1)	28	23	Education, tubigrip	NR	DRAM presence (>2 finger width)	12/28
				39	NR	and abdominal		DRAM width TA	
						exercises postpartum		activation	
						Postnatal exercise		endurance	
						group at 5/12		(hold seconds)	

Quality score is based on the Downs and Black criteria.

Abbreviations: BMI-Body Mass Index, RCT-Randomized controlled trial, DRAM-Diastasis of recti abdominis muscles, IRD- inter recti distance, NMES- Neuromuscular electrical stimulation, PFDI-Pelvic floor distress index, ODI-Oswestry disability index, QoL- quality of life, NR-not report.

Table 4 Outcomes extracted from included studies with operative intervention

Study	Incision location	Endoscopic/mesh/suction				Follow-up	DRAM presence	Pain and Management	Recurrence	Adverse events	Author conclusion
Juárez Muas DM 2018[1]	In the suprapubic midline.	Y/Y/NR				39 months.	Diastasis recti: <50 mm (55.5%); 51 to 80 mm (29.6%); >81 mm (14.9%).	3/10 with VAS.	0% in 74% patients after 18-months follow up.	Seroma: 12%.	Endoscopic surgery increasing the safety of the repair, without entering the abdominal cavity, with a short hospitalization and no complications or recurrence in 3 years.
Kockerling F 2017[2]	Extending 2–3cm cranially in the midline.	Y/Y/NR				30 days after the operation:125 of the 140 patients; 1-year follow-up: 30 patients.	More than 2 cm.	30 days after the operation: 26 patients (20.8%) complained intermittent pain in the region of the mesh margins, 7 of them (5.6%) took painkillers; 1 year later, 2 patients complained occasional pain, 1 of them complained pain even at rest.	0% after 1-year follow-up.	30 days after the operation: discrete impaired wound healing: 1.6%; seroma with no clinical significance: 4.8%.	ELAR can be implemented via a relatively small open access route for the patient with RAD and concomitant umbilical, trocar, and epigastric hernias, so as to reduce the complication rate.
Emanuelsson P 2016[3]	NR.	NR/Quill:Y/NR				1 year after the operation and 3 months after The training program.	ARD width ≥3 cm.	VHPQ: operated and training group patients were all improved. VAS: sutured group was 7, mesh repair group was 8, training group was 3.	1 early recurrence occurred in the Quill group, 2 encapsulated seromas in the mesh group, and 3 seromas in the suture group.	Seroma: 5 patients (3 with Quill repair, 2 with mesh repair); In the training group, 26 of 32 patients were dissatisfied and discomfort.	There was no difference between the Quill technique and mesh in the effect on abdominal wall stability, with a similar complication rate.
Gallus KM 2016[4]	A low transverse skin	NR/NR/NR	NR	NR	NR		NR	NR	In high functioning military patients with DRA who fail to return to baseline level of activity following a trial of physical therapy, surgical intervention should be considered to obtain the optimal functional ability.		
Kockerling F 2016[5]	On the left side, encircling the umbilicus like a half-loop and extending 2–3 cm upwards.	Y/Y/NR	A 30-days follow-up.	ARD<2 cm (45%).	Patients (7.5%) complained of intermittent pain on exertion, and patients (5%) took painkillers when required.		Low complication rate in the early postoperative after 30-days follow-up.	Umbilical necrosis: 1 (2.5%); Seroma: 1 (2.5%).	ELAR plus is a novel minimally invasive procedure for repair of symptomatic umbilical and/or epigastric hernias with concomitant RAD. Reconstruction of the linea alba via a minimally invasive access route is able to restore the normal anatomy of the abdominal wall.		
Privett BJ 2016[6]	A transverse incision is made 1–2 cm superior to the umbilicus.	N/Y/NR	NR	NR	NR		2(1%).	1 superficial wound infection.	The technique decreased the risk of upper midline recurrence in the at-risk patient group and it has a suitably low rate of recurrence and complications.		

Shirah BH 2016[7]	Through a vertical incision from the xiphoid process to the umbilicus.	N/Y/NR	24 months follow-up.	IRD >1.5 cm, >2 cm, >2.5 cm, and >2 finger widths during a partial sit-up.	Postoperative pain was controlled with intravenous paracetamol 1g every 8 hours for one day, followed by oral analgesics on the second day for one week. 68 (38%) required intramuscular meperidine 75 mg for severe pain in the first 12 hours postoperatively.		0%.	Open repair group: wound infection: 11 (6.1%); seroma: 9 (5%); hematoma: 5 (2.8%); cosmetic (satisfied: 95 (6%); unsatisfied: 4 (4%); foreign body sensation: 3 (1.7%). Laparoscopic repair group: Pain: 4 (10.8%); Cosmetic: satisfied: 91 (2%); unsatisfied: 8 (1%); foreign body sensation: 3 (8.1%).	The technique decreased the risk of upper midline recurrence in an at-risk patient group and it has a suitably low rate of recurrence and complications.
Bellido LJ 2015[8]	A 10 mm incision is made in the suprapubic midline.	Y/Y/NR	20 months.	Midline hernias ≥2 cm.	Preoperative VAS for pain was 4.3 and at 1 year after operation was 2.2.		0%.	Seroma in suprapubic area: 5 (23%); Subcutaneous emphysema: 2 (9%).	Endoscopic approach to diastasis recti associated with midline hernias brings considerable esthetic advantages, allowing the simultaneous correction of both pathologies. The repair of diastasis recti using the Ts suture resulted in vertical shortening of musculoaponeurotic layer.
Verissimo P 2014[9]	NR	N/NR/NR	6-month follow-up.	NR	NR		NR	NR	
Kanjoor JR 2012[10]	The upper line of incision was decided after liposuction and the limited flap dissection in the lower lateral and in the midline.	N/Y/Y			4-year follow-up.	NR	NR	0% after 4-year follow-up. Seroma: 6; sterile fat necrosis: 4; infected fat necrosis: 2; calf vein thrombosis: 1; transient scalp alopecia: 1; Unsatisfied: 4.	Extensive liposuction combined with limited dissection method applied to all abdominoplasty patients yielded insistently safe, reliable and predictable aesthetic results with less complications and faster recovery.
Tadiparthi S 2012[11]	Through a transverse suprapubic incision that was extended laterally to the anterior superior iliac spines.	N/N/NR			Average 28 months (range 12-43 months).	Mean pre-operative /post-operative distance (mm): above umbilicus 32 / 9 at umbilicus 30 / 10 below umbilicus 22 / 6	NR	0% after 12-month follow-up. Major complication: Pulmonary embolism: 1; Minor complication: dog ears, 6; Small area of wound breakdown, 1.	Vertical rectus plication with a non-absorbable suture demonstrated long-term durable results without any suture-related complications.
Rosen A 2011[12]	NR			N/NR/Y(5cases)	Mean of 34 months (27 months barbed, 42 months smooth).	NR	NR	0%. Minor seroma: 2 cases in the barbed suture group, 1 in the smooth group; infected hematoma: 1 in the barbed suture group.	Long-acting absorbable barbed or smooth sutures appeared to be equally effective in maintaining rectus diastasis repair. Barbed sutures held promise as a useful alternative to permanent sutures for the plication of the rectus fascia during abdominoplasty.

Pechter EA 2010[13]	It varied from 5 cm above to 5 cm below the umbilicus, depending on the degree of skin laxity.			N/NR/Y	3 months to 2.5 years.	NR	NR	NR	Umbilical stenosis: 1; MRSA wound infection: 1; interstitial hematoma in the areas treated by liposuction:1.	This modified abdominoplasty technique allows the surgeon to determine the exact pattern of tissue resection at the beginning of the case with a grid marked preoperatively on the patient.	
Siddiky AH 2010[14]	A 10 mm port was placed in the supra-pubic region via a modified Hassan approach and a 5 mm port was placed in each iliac fossa.			N/N/NR	8 weeks following discharge.	NR	Postoperatively difficulties in controlling pain.	0%.	Pain and ileus.	Laparoscopic plication was better than open technique, improved recovery time, and reduced pain and wound infection. Furthermore, avoidance of a mesh negates the risks associated with insertion of a foreign body.	
Brauman D 2009[15]	On the deep abdominal fascia, from one flank to the other and from the inframammary crease down (over the rib cage) to the inguinal/pubic crease.			N/NR/Y	NR	NR	NR	NR	Late infections of seromas: 5(1.4%); marginal necrosis: 6(1.7%).	The enhanced abdominoplasty results and improved safety of the abdominoplasty component enable dramatic body contouring with less morbidity and a fast return to normal activity.	
Palanivelu C 2009[16]	NR	N/Y/NR	Follow up 6–48 months.	NR	2 patients experienced pain that lasted for 3-9days: 1 needed intravenous analgesics, while the other was managed with oral analgesics.		0% after 6-48 months follow up.	Pain: 2; Pneumonia: 1; Chronic pain: 2.	The laparoscopic approach was effective and provided all of the benefits of minimal access in the correction of diastasis. The ‘Venetain blinds’ technique was an effective form of plication, providing additional support and reducing the risk of seroma.		
Batchvarova Z 2008[17]	Horizontal suprapubic incision extending laterally to the anterior iliac crest.	N/Y/Y	Average of 54 months (6 months to 11 years).	NR	NR		NR	Seromas: 2; skin flap necrosis: 1; umbilical necrosis: 1.	The release and plication of the posterior rectus sheath associated with the use of submuscular resorbable mesh was a long-lasting and reliable procedure in multiparous women with severe myo-aponeurotic laxity.		
Dabb RW 2004[18]	NR	N/NR/Y	At least 12 months	NR	NR		NR	Seromas: 5; subdermal burn: 1; limited results: 2.	This technique presented a safe and effective procedure for patients with minimal skin laxity, moderate fatty tissue distribution, musculofascial diastases, and no concern for abdominal stretch marks.		
Nahas FX 2004[19]	NR			N/NR/NR	NR		NR	No pain.	0%.	NR	Advancement of the recti muscles seems to be a reliable method for correcting recurrent rectus diastasis in patients with lateral insertion of the recti muscles.
Cardenas Restrepo JC 2002[20]	Traced an arc-shaped line starting at the upper boarder of the anterosuperior iliac spine on one side, or slightly above it.			N/NR/Y	Average of 15 months (6 months to 2 years).		NR	NR	NR	Seromas: 20; dog-ears: 3; cutaneous ischemia: 1.	The technique offered good results with few complications for patients who have any type of abdominal laxity in the lower hemiabdomen and for those with moderate laxity in the upper hemiabdomen.
Ferreira LM 2001[21]	In the suprapubic region.			N/NR/NR	3-year.		NR	NR	NR	0%.	Triangular mattress suture technique is an effective and easy method to prevent epigastric bulging without increasing operative time and morbidity.
Nahas FX 2001[22]	Through a suprapubic incision extended laterally to the anterior iliac crest.			N/NR/NR	6 months.	NR		NR	NR	Seromas:12.	The correction of rectus diastasis with 2-0 nylon and 0-polydioxanone was achieved and maintained after 6 months.

Nahas FX 2001[23]	NR	N/NR/NR	At least 3 months	NR	NR	Happened (not specify)			Minor scar complication: 31; seromas12.	The classification is a useful tool to help plastic surgeons to diagnose and treat abdominal deformities, emphasizing correction of the myoaponeurotic layer.
van Uchelen JH 2001[24]	A lower abdominal W- incision to the aponeurosis of the external oblique.	N/NR/NR	Mean of 64 months (32 to 109 months).	<45 years old: a separation of the rectus muscles exceeding 10 mm above the umbilicus, and 9mm below the umbilicus; ≥45 years old: the corresponding values were 15mm, 27mm, and 14mm.	NR	40%.			Deep vein thrombosis:1 (1.6%); sensibility disorder of abdominal skin: 45 (71.4%); sensibility disorder of the thigh: 6 (9.5%).	Vertical plication only is not enough to improve the waistline and may eventually lead to epigastric bulging.
Ramirez OM 2000[25]	An incision in a navel is made in a heart shape with a triangular component left in the abdominal flap in a superior or inferior orientation.	N/NR/Y	NR	NR	NR	Back pain was completely relieved postoperatively.			Skin necrosis: 3; seroma: 5.	The new technique: a combination of suction- assisted lipectomy, high lateral tension closure with fascial suspension and external oblique fascial advancement to create a smaller waistline can provide predictable, reproducible, and aesthetically pleasing results.
Zukowski ML 1998[26]	The liposuction was performed through three 1-cm incision located at the umbilicus, in the left lower quadrant of the abdomen 2cm above the anterior superior iliac spine, and in the right upper quadrant of 2 cm below the right coastal margin.			Y/NR/Y	NR	NR	NR	0%.	Intervention group: epidermolysis: 1; full-thickness skin loss: 2; wound infection: 1; prolonged neuralgia: 3; Control group: postoperative ileus: 1; full-thickness skin loss: 1; wound infection: 1; postoperative hematoma: 1. NR	The endoscopic intracorporal abdominoplasty reduced operative scars and effectively pleated the rectus fascia, has a rate of morbidity in a skilled laparoscopist’s hands no greater than with traditional open abdominoplasty.
Asaadi M 1994[27]	NR			N/NR/NR	>25 months.	NR	NR	0%.		Nonabsorbable monofilament sutures have been shown to have a very low tissue reactivity and rate of infection. The repair presented far superior to our previous technique of interrupted suture plication.

Abbreviations: BMI-Body Mass Index, DRAM-Diastasis rectus abdominus muscel, ELAR-Endoscopic-assisted linea alba reconstruction, ARD-Abdominal rectus diastasis,

RD-Rectus abdominus diastasis, IRD-Inter-recti distance, VAS-Visual analogical scale, VHPQ-Ventral hernia pain question-naire, NR-not report.

Table 5. Outcomes extracted from included studies with non-operative intervention

Study	Intervention	Follow-up	DRAM presence	Pain and Manage	Recurrence	Adverse events	Other	Author conclusion
Gluppe SL 2018[1]	Exercise intervention Vs. no intervention	(1) Baseline at 6 weeks postpartum, (2) 6 months postpartum, (3) 12 months postpartum. three times per week	55.2% and 54.5% in two groups at 6 weeks postpartum	NR	NR	NR	The 4-months intervention started 6 weeks postpartum	Supervised exercise program did not reduce the prevalence of diastasis.
Kamel DM 2017[2]	NMES add exercises vs. Exercises alone		>2.5 cm at any point of assessment along the linea alba	NR	NR	NR	The 8-weeks intervention started 8 weeks postpartum	NMES helps reduce DRAM; if combined with exercises, it can augment the effects.
Emanuelsson P 2016[3]	Operative repair (Quill or Mesh) Vs. Exercises	1 year after the operation, 3 months after exercises	3 cm width, abdominal wall discomfort or tenderness	Significant improvements in 2 operative groups, still bodily pain in training group	1 occurred in the Quill group	2 encapsulated seromas in the Mesh group, and 3 in the suture group. 5 midline swelling, discomfort, and pain	5 in each group had undergone other types of abdominal operations, 1 in the Quill group with testicular cancer, 2 in the training group and 2 in the Quill group with gastric bypass	There was no difference between the Quill technique and retromuscular mesh in the effect on abdominal wall stability.
Khandale SR 2016[4]	Exercises no control	Pre-test at 1st week Post-test at 8th week	> 2 finger widths	NR	NR	NR	NR	Exercises were very effective in reducing diastasis and inter recti distance. And support exercises for postnatal women and useful in reducing complications.
Walton LM 2016[5]	Traditional supine core stability strengthening program vs. dynamic core stability plank exercise program	Pre-test at 1st week Post-test at 6th week	With 3 months to 3 years postpartum, pretest at umbilicus from 7.27mm to 13.43 mm	NR	NR	NR	NR	Either Strengthening program, traditional or experimental, could be effective at reducing DRA measurement.
Achary N 2015[6]	Exercises no control	Pre-test at 1st week Post-test at 4th week	Within 1 month postpartum, pretest was found to be 3.5(SD= 0.5085)	NR	NR	NR	Number of offsprings which is another variable used, was listed as 1(Min) and 4(Max) children's	After the exercise regimen and bracing, the DRAM separation was found to be reduced. Non-surgical interventions (Physical Therapy) can prevent or reduce DRAM in the postpartum.
Balius R 2011[7]	Unified rehabilitation protocol vs no intervention	At 15 months postpartum	Fibrillar defect, edema, and hemorrhage	1) Painkiller medication and an ice pack; 2) physical therapy focused on affected soft tissue areas; 3) gradually progressing from passive stretching to active tension to	NR	NR	5 cases of ruptured rectus abdominals, 17 asymptomatic players	The phenomenon of contralateral abdominal hypertrophy in handball appears in the dominant arm as in tennis and volleyball.

prevent the pain due to the formation of scar tissue;

4) set according to levels of discomfort rather than pain threshold;

5) the level of discomfort experienced was qualified as bearable and ranged between 5% and 10% of the visual analog scale

Chiarello 2005[8]	Exercise vs no intervention	Post-test at 6th week	After intervention, 12.5% and 90% of pregnant women exhibited DRA in two groups	NR	NR	NR	The 6-weeks intervention started 16 and 35 weeks gestation	The occurrence and size of DRA is much greater in non-exercising pregnant women than in exercising pregnant women.
Hsia M 2000[9]	No intervention	From 36 weeks of gestation to 12 weeks postpartum: Start of the study, Due date, Immediately postpartum, End of study	IRD at 9.7, above 8.4, below 9 mm with resting; at 8, above 7.6, below 8 mm with active	Epidura pain relief	NR	NR	2 single case studies started 36 and 38 weeks gestation	Despite individual variability, IRD persists in the postpartum period
Sheppard 1996[10]	Physiotherapy no control	At 2 years postpartum	Muscle closure from 125 mm to 60 mm	Non-specific mild-muscular low backache: Lifting and relieved by rest	NR	The author observed the contrary during early postpartum	1 case study started 36 and 38 weeks gestation	

Abbreviations: DRAM-Diastasis rectus abdominus muscel, ELAR-Endoscopic-assisted linea alba reconstruction, ARD-Abdominal rectus diastasis,

RD-Rectus abdominus diastasis, IRD-Inter-recti distance, VAS-Visual analogical scale, VHPQ-Ventral hernia pain question-naire, NR-not report.

Figures

Figure 1

Figure 2
Flow of Literature selection.

Supplementary Files

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