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Review Article

A Multidimensional Investigation of Diastasis Recti Abdominis Treatment and Assessment in Postpartum Women: A Systematic Review and Meta-Analysis

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ABSTRACT

Introduction: Diastasis recti abdominis (DRA) is prevalent among postpartum women, with various physiotherapy treatments utilized. Despite the effectiveness of diverse DRA treatment methods and the importance of evaluating its levels and methods, limited attention has been given to this aspect. This study comprehensively investigates DRA, examining evaluation levels and methods, and assessing the efficacy of diverse physiotherapy interventions.

Materials and Methods: Online search was conducted in Cochrane, ProQuest, PubMed, Embase, Scopus, Web of Science, Google Scholar, and Magiran databases until the end of 2022, employing the population, intervention, comparison, and outcome framework (population = DRA, intervention = physiotherapy, comparison = control, and outcome = inter-rectus-distance [IRD]). The JBI checklist and Cochrane Collaboration RoB 2.0 tool evaluated critical appraisal and bias risk. Meta-analysis was performed using the RevMan software.

Results: The study included 16 articles with 650 postpartum women. The findings revealed no significant differences in various measurement methods (P=0.25) and levels (P=0.10). Combination therapy demonstrated greater effectiveness than exercise alone in reducing IRD (P=0.04), with tape being particularly impactful (P=0.009).

Conclusion: Although sonography evaluation of IRD above the umbilicus is recommended, the study highlights the limitation of diverse measurement methods and levels in determining the optimal physiotherapy intervention. Despite the preference for combined interventions, especially tape alongside exercise for women with DRA, further research is essential due to limited evidence, aiming to provide greater insights into this issue.

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Introduction

Diastasis recti abdominis (DRA) is defined as the separation of two bellies of the rectus abdominis muscle (RAM) along the linea alba. This disorder is prevalent in pregnant women due to the effect of hormones on connective tissues and biomechanical changes in pregnancy [1]. Some conditions, such as maternal age, frequent deliveries, maternal weight gain, overweight infants, multiple pregnancies, and cesarean section can increase the risk of DRA [2]. The prevalence of DRA in the last trimester of pregnancy and 12 months after delivery was reported to be 66% to 100% and above 36%, respectively [1]. DRA can lead to a range of consequences during and after pregnancy including back and pelvic pain, decreased strength and endurance of abdominal muscles, urinary and fecal incontinence, pelvic organ prolapses, and decreased quality of life [3-6].

There is a significant negative relationship between the strength of abdominal muscles and the presence of DRA in postpartum women [7, 8]. Strengthening the abdominal muscles is likely to affect DRA and its consequences, such as low back pain [9]. Various exercises in physiotherapy are usually prescribed to patients for this purpose. In addition to exercise therapy, other interventions, such as tape, corsets, and neuromuscular electrical stimulation (NMES) may be effective in accelerating the healing process [10]. Combining exercise with other interventions may likely cause higher intensities of force on abdominal muscles and lead to better results in improving DRA. Furthermore, in some cases, the patient may not be able to do exercise and adjunct interventions are demanded.

To evaluate DRA, the inter rectus distance (IRD) index is used, which is the distance between the two bulks of the RAM. There are various methods to evaluate the severity of these disorders. Clinical methods, such as finger width (FW), caliper, and imaging methods including sonography, computed tomography-scan, and magnetic resonance imaging are used to measure IRD [11]. Among these methods, sonography and caliper have good to excellent reliability in IRD measurement [12]. However, even though sonography has no side effects, this method is time-consuming, depends on the operator, and interpreting its results requires skill [11]. On the other hand, other clinical methods like employing a caliper are cheap and easy to use [11]. So far, these two methods have not been compared to evaluate the extent of IRD changes after treatment. Diverse measurement methods may lead to differences in the study results and confusion among therapists. In addition to the measurement method, the measurement site is also an important factor in the interpretation of the results. In the previous studies, IRD was measured above, below, and at the level of the umbilicus [13]. However, in most studies, the level of above umbilicus has been used; however, the amount of improvement at different levels is still unclear. According to different amounts of IRD along the linea alba, it may not be correct to compare the results of studies without considering the evaluation levels. Therefore, the comparison of different levels shows therapists which level is more responsive for treatment, helping them choose the best level for the assessment of IRD.

In 2023, a systematic review study was conducted by Weingerl et al. to determine the best conservative treatment of DRA [14]. According to the study, tape causes a significant reduction in IRD. Also, combining NMES with exercise has beneficial effects in reducing IRD and there are conflicting results regarding the effects of the corset or abdominal belt. In the study, it has been mentioned that using different measurement methods and sites is the limitation in determining the best conjunct intervention in these patients. Although there are review studies about combination therapy in women with DRA [14, 15], the results concerning which intervention in physiotherapy can lead to improving this disease are still unknown, and it seems necessary to perform a new review study in this field to clarify the treatment strategy in patients considering measurement method and assessment location.

Accordingly, an ideal and specific physiotherapy treatment protocol for postpartum women with DRA has not been provided, and some aspects of the treatment of these patients have not been assessed yet. Therefore, this systematic review study aimed at a multidimensional investigation of DRA, including the comparison of different measurement methods and levels, and the comparison of different types of physiotherapy interventions, as well as the effects of physiotherapy on secondary complications of this disease in postpartum women.

Materials and Methods

This systematic review with meta-analysis adhered to the guidelines outlined in the Cochrane Collaboration Handbook and the preferred reporting items for systematic reviews and meta-analysis statements. Approval for this study was obtained from the Ethics Committee of Tabriz University of Medical Sciences. The study protocol was registered in the PROSPERO database and assigned the registration number CRD42022382998.

The protocol has also been published [16]. The literature search encompassed electronic databases, including Cochrane, ProQuest, PubMed, Embase, Scopus, Web of Science, Google Scholar, and Magiran, covering clinical trial studies in this domain until the conclusion of 2022. Additionally, a manual search of references and related studies was conducted to ensure comprehensive coverage.

Search strategy

The search strategy based on the population, intervention, comparison, and outcome framework with MeSH and entry keywords included the following items:

"Diastasis recti" OR "Diastasis recti abdominis" OR "Rectus diastasis" OR "Pregnancy" OR "Postnatal women" AND "Exercise Therapy" OR "Abdominal Exercises" OR "Transverse Exercises" OR "Core stability exercises" OR "Pelvic floor exercises" OR "Noble technique" OR "Strength training" OR "Resistance training" OR "Endurance training" OR "Physiotherapy" OR "Rehabilitation" AND "Taping" OR "Neuromuscular electrical stimulation" OR "Manual therapy" OR "Postural training" OR "Physical activity" OR "Splint" OR "Corset" OR "Brace" OR "Adjunct intervention" AND "Diastasis recti width" OR "Inter rectus distance" OR "Pelvic floor dysfunction" OR "Quality of life" OR "Pain" OR "Caliper" OR "Ultrasonography" OR "Sonography" OR "Magnetic resonance imaging " OR "Finger width" OR "CT-scan."

Study selection

This systematic review specifically focused on randomized controlled trial (RCT) studies assessing the impact of physiotherapy on diastasis recti abdominis (DRA). RCTs were chosen due to their elevated position in the evidence pyramid. The study population comprised women with DRA, and inclusion criteria encompassed studies incorporating at least one physiotherapy intervention within the study groups. Meanwhile, the exclusion criteria comprised studies involving cadavers and non-human subjects, those solely involving male participants, and studies lacking full-text availability in English or Persian.

To ensure rigor, a meticulous process was followed. Initially, duplicate studies were removed, and the remaining articles underwent a two-stage review. The first and second evaluators independently assessed titles and abstracts, followed by a comprehensive review of full texts for eligibility. Any uncertainties were clarified by contacting the respective article authors. Discrepancies between evaluators were resolved through discussion, resulting in the final selection of studies. Furthermore, the references of the chosen studies were scrutinized to identify and include pertinent studies in the analysis

Data extraction and quality assessment

The data from the included studies, such as sample size, intervention type, duration of intervention, IRD measurement method and level, outcome measurements such as IRD, pain, pelvic floor disability index (PFDI), Oswestry disability index (ODI), abdominal muscle's function and quality of life, and results were extracted (Table 1).

The quality of the selected studies was obtained using the JBI evaluation checklist for RCT studies in two stages by the first and second evaluators to prevent the risk of bias. Disagreements were resolved through discussion. Studies with less than 50% of positive answers were considered low quality. Meanwhile, 50% to 75% of positive answers were medium quality, and above 75% of positive answers had high quality [17]. After the quality assessment conclusion, the articles with a minimum score of 6 out of 12 were included in this study[1]. The JBI checklist has been approved by the JBI International Scientific Committee and is a reliable tool (kappa = 0.713 between evaluators) to assess the methodological quality of studies [18]. In the JBI checklist, various items, such as using the correct randomization method, allocation concealment, baseline similar groups, participants, delivering treatment and assessor blinding, receiving the same basic intervention, completing the follow-up, intentions to treat, same measurement method in treatment groups, reliable measurement method, appropriate statistical analysis, and parallel groups are checked. The risk of bias was assessed by two independent reviewers using the revised Cochrane Collaboration Risk of Bias 2.0 tool [19]. This tool evaluates six domains, including sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other types of bias. In this checklist, a high risk was considered when the analyzed studies showed a high risk of bias in at least one domain or had some concerns for multiple domains; uncertain risk was considered for studies with some concerns in at least one domain, but not at high risk of bias for any domain. A low risk was considered when studies showed a low risk of bias for all domains. After selecting the final studies, the preferred reporting items for systematic reviews and meta-analysis diagrams were drawn.

1. The JBI checklist consists of 13 questions; the fifth question was not applicable in this study and the final score was calculated from 12.

Table 1. Study characteristics

Author/ Year	Sample Size	Age (y)	Quality Score	Outcomes	●Measurement Method ●Measurement Level (cm)	Intervention	Duration	Results IRD (mm)
El-Kosery et al., 2007 [23]	G1=10 G2=10 G3=10	20-28	6/12	P= IRD S= -	● Caliper ● +4.5 U	G1: Static abdominal exercise, trunk curl up, posterior pelvic tilt, SLR, tupler technique; G2: NMES (faradic for abdominal muscles, frequency: 50-100 Hz, 30 min); G3: G1+ G2 interventions	3 × week 10 rep. 8 weeks	G1=-19.43 G2=-16.3 G3=-21.2
El-Mekawy et al., 2013 [24]	G1=15 G2=15	25-35	6/12	P= IRD S= Abd power	● Caliper ● Above U	G1: Abdominal corset; G2: Static abdominal exercise, posterior pelvic tilt, trunk twist, reverse trunk twist, reverse sit-up	3 × week 20 rep. 6 weeks	G1=-5.6 G2=-10.50
Walton et al., 2016 [32]	G1=5 G2=4	32.88	9/12	P= IRD S= ODI, PFDI	● Caliper/Sonography ● At U	G1: Core stability (posterior pelvic tilt, kegel) + plank exercise; G2: Core stability (posterior pelvic tilt, kegel) + crunch exercise	3 × week 3 sets 10 rep. 6 weeks	G1=-1.17 G2=-4.34
Kamel & Yousif, 2017 [34]	G1=30 G2=30	29±3	11/12	S= IRD P= Abd strength, power	● Sonography ● Above U	G1: Reverse trunk twist, sit up, reverse sit up, U-seat + NMES (for RAM, frequency: 80 Hz, duration: 0.1-0.5µs, on/off: 5/10, 30 min) G2: Reverse trunk twist, sit up, reverse sit up, U-seat	3 × week 20 rep. 8 weeks	G1=-1.43 G2=-0.73
Izadi et al., 2018 [21]	G1=16 G2=16	18-45	10/12	P= IRD S= -	● Sonography ● +2 U/ -2 U	G1: Oblique abdominal muscles exercise G2: No intervention	7 × week 20 rep. 6 weeks	G1=-7 G2=0
Tuttle et al., 2018 [30]	G1=10 G2=8 G3=5 G4=7	32.03± 4.33	10/12	P= IRD S= PFDI	● Sonography ● +4.5 U	G1: TrA exercise G2: Tape (4-7 × week X pattern above and below U) G3: TrA exercise + tape G4: No intervention	4-5 × week 12 weeks	G1=-9.4 G2=-1.9 G3=-8.8 G4=-3.9
Bobowik & Dabek, 2018 [26]	G1=20 G2=20	20-45	8/12	P= IRD S= -	● FW ● -	G1: Positioning, head lifting lower limb flexion and extension, 1 week tape G2: No intervention	1 × daily 6 weeks	G1=-1.865 G2=-2.876
Gluppe et al., 2018 [35]	G1=87 G2=88	29.8±1.4	10/12	P= presence of DRA S= -	● FW ● +4.5 U/at U/ -4.5 U	G1: Pelvic floor muscles exercise, abdominal exercises, plank, sit up, straight sit up G2: No intervention	1 × week 4 months	G1= (n=-10) G2= (n=-9)
Keshwani et al., 2019 [29]	G1=8 G2=8 G3=8 G4=8	18-35	10/12	P= IRD S= PFDI, ODI, abd strength, endurance	● Sonography ● +5 U/+3 U/ -3 U	G1: TrA exercise, bent knee leg lift in crook lying, eccentric trunk flexion, and progressive side plank exercise G2: Abdominal corset (continuous) G3: Exercises of G1+ abdominal corset G4: No intervention	1 × week 12 weeks	G1=-5.90 G2=-9.2 G3=-8.1 G4=-10.1

Author/ Year	Sample Size	Age (y)	Quality Score	Outcomes	●Measurement Method ●Measurement Level (cm)	Intervention	Duration	Results IRD (mm)
Thabet & Alshehri, 2019 [31]	G1=20 G2=20	23-33	10/12	P= IRD S= HRQL	● Caliper ● +4.5 U	G1: Core exercise (abdominal bracing, plank, pelvic floor, diaphragmatic and isometric abdominal exercises) + traditional abdominal exercise (static abdominal contraction, posterior pelvic tilt, reverse sit up, trunk twist, reverse trunk twist) G2: Traditional abdominal exercise	3 × week 8 weeks	G1=-8.30 G2=-4.85
Dave & AratiMahishale, 2019 [36]	G1=15 G2=15	25-40	9/12	P= IRD S= MMT	● Caliper/FW ● +2.5 U/at U/ -2.5 U	G1: Static abdominal exercise, head lifting, bridging, SLR, superman exercise + abdominal corset G2: Static abdominal exercise, head lifting, bridging, SLR, superman exercise	4-5 × week 2-3 sets 8-12 rep 4 weeks	G1=-5.75 G2=-3.16
Yalfani et al., 2019 [42]	G1=12 G2=12	20-40	10/12	P= IRD S= VAS, ODI	● Caliper ● -4 U	G1: Drawing in, kegel, plank, crunch, dog bird, balance G2: No intervention	3 × week 8 weeks	G1=-22.63 G2=-2.89
Mohamed et al., 2020 [27]	G1=20 G2=20	28.47± 2.12	10/12	P= IRD S= -	● Sonography ● Above U/ below U	G1: Static abdominal, crunch, bridging pelvic floor and oblique abdominal muscles exercise G2: Exercises of G1 + tape (3 × week on cesarean section, RAM, and external oblique muscles,)	2 × week 3 sets 3-15 rep 8 weeks	G1=-1.40 G2=-4.5
Saleem et al., 2021 [33]	G1=20 G2=20	30±4.15	11/12	P= IRD S= ODI	● Caliper/ FW ● +4.5U/+2 U/ at U -2 U/ -4.5 U	G1: Abdominal crunch + kegel, gluteal exercise, back strengthening G2: Double SLR + kegel, gluteal exercise, back strengthening	3 × week 6 weeks	G1=-4.06 G2=-1.20
Awad et al., 2021 [28]	G1=25 G2=25	23-35	11/12	P= IRD S= -	● Sonography ● +4.5 U/ -4.5 U	G1: Progressive prone plank exercise + abdominal corset, advice to the patient G2: Abdominal corset, advice to the patient	3 × week 8 weeks	G1=-8.85 G2=-3.53
Laframboise et al., 2021 [25]	8	35.6±3.2	7/12	P= IRD S= -	● Caliper ● +2 (inch) U/ at U/ -2 (inch) U	G1: Core exercise (bridging, plank, dead bug,), breathing, and awareness training G2: No intervention	3 × week 12 weeks	G1=-4.30 G2=+0.2

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Abbreviations: G: Group; P: Primary; S: Secondary; IRD: Inter rectus distance; U: Umbilicus; NMES: Neuromuscular electrical stimulation; rep: Repetition; ODI: Oswestry disability index; PFDI: Pelvic floor disability inventory; TrA: Transverse abdominis; FW: Finger width; DRA: Diastasis rectus abdominis; n: Number; VAS: Visual analog scale; HRQL: Health-related quality of life; MMT: Manual muscle testing; SLR: Straight leg rising; Abd: Abdominal.

Statistical analysis

A statistical meta-analysis was conducted for studies employing similar interventions and outcomes, using Review Manager (RevMan) 5.4 statistical software (Cochrane Collaboration, London, UK). The mean difference between the two groups served as the effect size and was presented with 95% confidence intervals (CI) in the forest plot. Heterogeneity between studies was examined using the I^2 index, with values exceeding 50% indicating heterogeneity. The random-effects model was applied in cases of heterogeneity, while the fixed-effects model was used for homogeneous studies. Publication bias was assessed through a funnel plot, and a significance level of <0.05 was considered.

The meta-analysis specifically focused on studies incorporating exercise therapy alone in at least one trial arm. Comparisons were made between exercise therapy alone and exercise therapy combined with adjunct interventions. Subgroups were defined based on the type of adjunct interventions. Additionally, a meta-analysis was conducted for the comparison between the effects of exercise therapy and non-intervention on IRD, with subgroups based on the measurement method. Within-group meta-analysis was employed to investigate the effect of the measurement level in this study. Furthermore, a within-group meta-analysis was conducted to assess the impact of exercise therapy on ODI.

Results

Search results

The initial database search yielded 4152 studies, and after eliminating duplicates, the number was reduced to 2896. An additional 5 relevant articles were identified through manual searches, bringing the final number of articles from both manual and electronic searches to 2901. Upon scrutinizing titles and abstracts, 2884 studies were excluded from further consideration. Subsequently, 17 studies, comprising 15 in English and 2 in Persian, met all the inclusion criteria. Following a thorough examination of the full-text articles, one study was excluded due to a low-quality score [20]. Consequently, the final analysis included 16 articles, with 14 in English and 2 in Persian authored by Izadi and Yalfani [21, 22] (Figure 1).

Quality assessment

The quality score of the selected studies assessed by the JBI checklist and the score of articles have been reported in Table 1. Four studies had moderate methodological quality [23-26], and other studies had high methodological quality based on the JBI checklist [21, 22, 27-36]. The risk of bias in studies included in the meta-analysis is shown in Figure 1 and Figure 2. According to the findings, the studies were characterized by a high risk of bias, with the color coding indicating a high risk as red (-), an unclear risk as yellow (?), and a low risk as green (+). Importantly, there were no discrepancies among assessors in making these determinations.

Characteristics of the studies

Sixteen articles, totaling 650 postpartum women, were from 2007 to 2021. The age range of patients in the studies varied from 20 to 45 years. The type of delivery was vaginal in 7 studies [22-24, 28, 29, 34, 35], cesarean in 1 study [27], cesarean and vaginal in 3 studies [32, 33, 36], and unknown in 5 studies [21, 25, 26, 30, 31]. The participants' parity was 1 in 4 studies [24, 27, 29, 35], 1-3 in 7 studies [21-23, 25, 30, 34, 36], and unknown in 5 studies [26, 28, 31-33]. The primary outcome in all studies except that of Gluppe et al.'s study was IRD. In Gluppe et al.'s study, the prevalence of DRA has been reported [35]. The ODI was assessed in 3 studies [22, 32, 33], pain in 4 studies [22, 30, 32, 33], abdominal muscle strength in 2 [29, 36], endurance in 1 [29], and power in 2 studies [24, 34], pelvic floor dysfunction based on PFDI in 2 studies [30, 31], and quality of life in 2 studies [31, 32]. The start time of intervention was varied in different studies, but in all studies it was postpartum. The measurement method was FW in 2 studies, caliper in 5 studies, sonography in 6 studies, caliper and FW in 2 studies, and caliper and sonography in 1 study (Table 1). The applied intervention was one of the types of abdominal, pelvic floor, or core stability exercises, as well as interventions such as NMES, tape, and corset (Table 1). The duration of the intervention varied between 4 to 12 weeks. The data from the selected studies are summarized in Table 1.

Data synthesis and analysis

To maintain homogeneity for meta-analysis and consider exercise therapy as a primary intervention for these patients, only studies incorporating exercise therapy alone in one of the study groups were included. The study by Gluppe et al. [35] was excluded from the meta-analysis due to the absence of IRD evaluation. Additionally, the studies by Awad et al. [28] and Bobowik and Dabek [26] were not included in the meta-analysis as they lacked an exercise therapy alone group. Gluppe et al.'s study demonstrated a significant decrease in the number of patients after treatment (60%); however, the difference between the

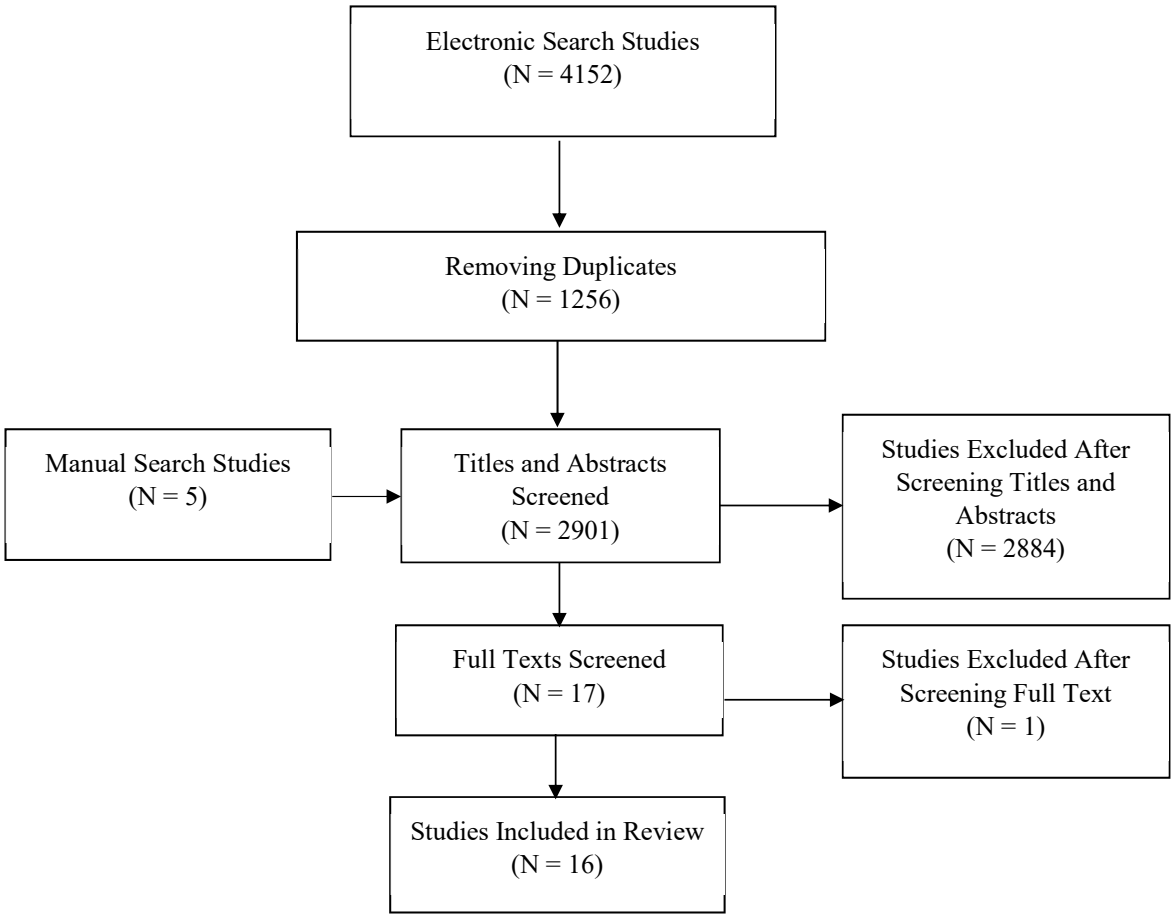

Figure 1. Preferred reporting items for systematic reviews and meta-analyses diagram

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intervention and non-intervention groups after treatment was not statistically significant [35]. Awad et al.'s study indicated that exercise therapy with a corset significantly reduced IRD compared to using a corset alone (P=0.001) [26]. Bobowik and Dabek's study also showed that the combination of exercise therapy and tape significantly reduced IRD compared to non-intervention (P<0.001) [26]. In all meta-analyses conducted in this study, there was significant heterogeneity between studies (P<0.05), leading to the utilization of the random-effects model.

Differences among measurement methods of inter rectus distance following physiotherapy

Five studies were included in this analysis and the exercise therapy group was compared with the control (non-intervention) group. The forest plot is shown in Figure 2. Based on the random effects model, the mean of IRD in the exercise group was 6.95 mm lower than the control group (no intervention), implying that it was statistically significant (mean deviation [MD]=-6.95 mm; 95% CI, -13.98 to 0.07; Z=1.94; P=0.05).

In the sonography subgroup decrease in IRD was observed (MD=-3.89 mm; 95% CI, -9.14 to 1.36). This decrease was more in the caliper subgroup (MD=-13.04 mm; 95% CI, -27.87 to 1.79). There was no significant difference between the sonography and caliper subgroups (χ^2=1.30, df=1; P=0.25, I^2=23.0%).

Differences among measurement levels of inter rectus distance following physiotherapy

Six studies were included in this meta-analysis [21, 25, 27, 30, 32, 34]. The studies were divided into three subgroups, each including three studies. In the above, below, and level of the umbilicus, IRD was decreased significantly after treatment (MD=-3.66 mm; 95% CI, -5.25 to -2.07; Z=4.52; P<0.00001).

The highest decrease was observed above the umbilicus (MD=-5.03 mm; 95% CI, -9.85 to -0.21), and the lowest decrease was observed below the umbilicus (MD=-1.11 mm; 95% CI, -1.39 to -0.83). The decrease in the level of the umbilicus was -4.05 mm (MD=-4.05 mm; 95% CI, -7.96 to -0.14). There was no significant difference

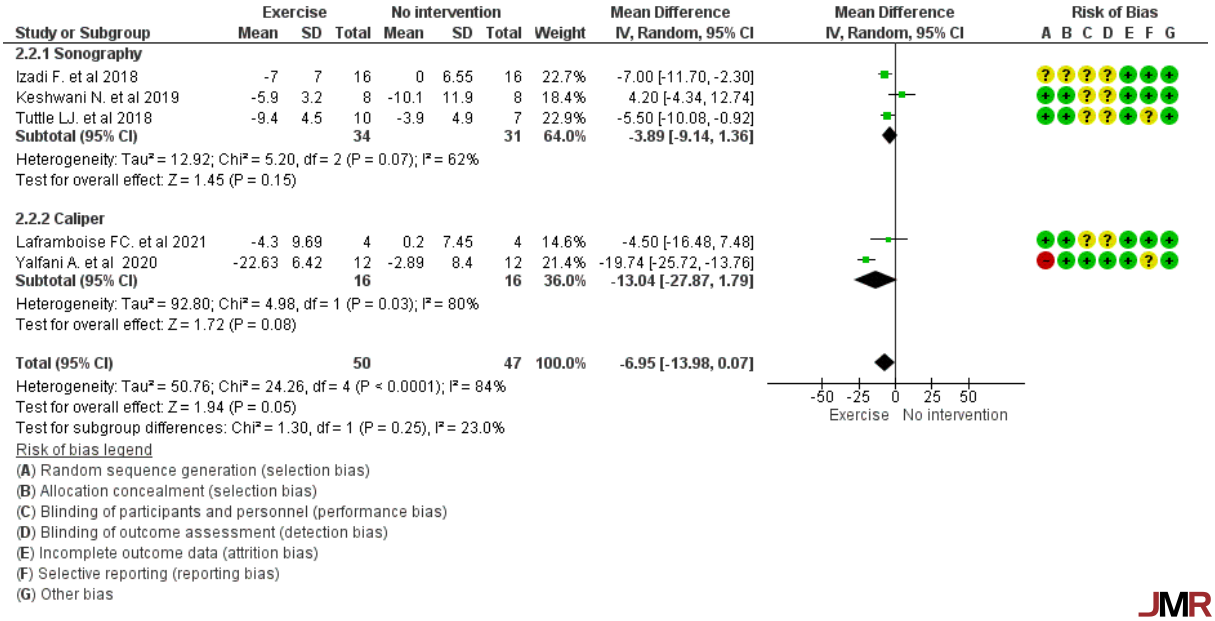

Figure 2. Forest plot: Differences in measurement methods of inter rectus distance in women with diastasis recti abdominis

in the reduction of IRD after treatment at different levels (χ^2=4.68; df=2; P=0.10; I^2=57.3%).

The effectiveness of combination therapy (exercise therapy + Neuromuscular electrical stimulation/taping/corset)

In this analysis, exercise therapy was compared with combination therapy. The forest plot is shown in Figure 3. After treatment, the mean of IRD in the combination therapy group was significantly lower than the exercise therapy group (MD=-1.89 mm; 95% CI, -3.69 to -0.08; Z=2.05; P=0.04).

In all subgroups of the corset, NMES, and tape, the amount of IRD in the combination group was significantly lower than in the exercise therapy alone group. The more decrease was in the tape subgroup (MD=-2.91 mm; 95% CI, -4.50 to -1.33), then the corset subgroup (MD=-2.55 mm; 95% CI, -5.07 to -0.02), and finally the NMES subgroup (MD=-0.70 mm; 95% CI, -0.87 to -0.53). There was a significant difference between the corset, NMES, and tape subgroups (χ^2=9.36; df=2; P=0.009; I^2=78.6%).

The effect of physiotherapy on oswestry disability index in postpartum women with diastasis recti abdominis

Three studies were included in this meta-analysis [22, 32, 33]. Based on the random effects model, the mean of ODI in the exercise therapy group after treatment was 3.25 units lower than before treatment, showing that this value was statistically significant (MD=-3.25; 95% CI, -5.93 to -0.58; Z=2.38; P=0.02).

Publication bias

The publication bias assessment was performed using the funnel plot (Figure 4), Begg's, and Egger's tests. According to the results, no publication bias was found by Egger's and Begg's tests (P=0.531; 95% CI, -5.83383 to 9.49984).

Secondary outcomes

Pain

Pain intensity was assessed in 4 studies. The results of the Yalfani et al. study showed that exercise therapy after 8 weeks reduced pain intensity by 3.08 units based on a visual analog scale, which was statistically significant [22]. In the study by Saleem et al., the severity of low back pain was assessed based on ODI and decreased by 3 to 5 units after treatment, which was statistically significant [33]. Also, according to Walton et al.'s study, pain intensity was assessed based on ODI and pain was decreased after treatment but the reduction was not statistically significant [32]. According to Tuttle et al.'s study, pain intensity was evaluated based on Roland-Morris disability questionnaire and pain was reduced by 1.6 units, but the changes in this study were not statistically significant [30].

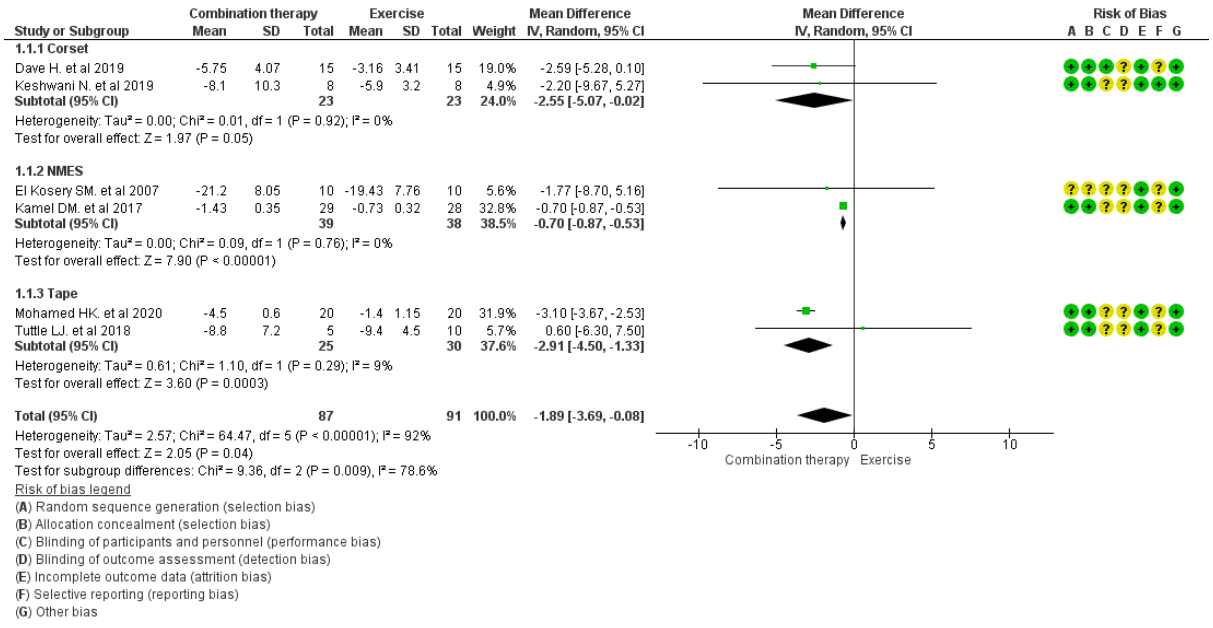

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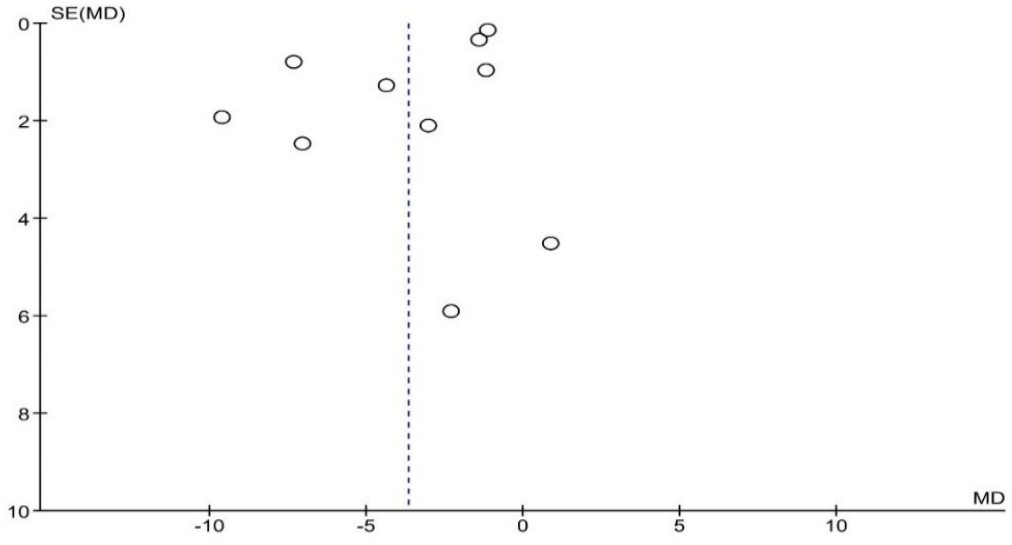
Figure 3. Forest plot: Effectiveness of combination therapy on inter rectus distnace in women with diastasis recti abdominis

Abdominal muscles strength, endurance, and power

Muscle function was also examined in 4 studies. According to El-Mekawy et al.'s study, exercise therapy significantly increases the power of abdominal muscles (8.48 watts) [24]. The findings of Keshwani et al.'s study showed that exercise therapy increased muscle strength and endurance, but these changes were not statistically significant [29]. In the study by Dave and Arati Mahishale, one unit of improvement in abdominal muscle strength based on manual muscle testing was seen after exercise therapy [36]. In the study by Kamel and Yousif, the average abdominal muscle power increased by about 6 watts after exercise therapy, but the rate of the increase in power in the exercise-therapy group with electrical stimulation was 13 watts higher than in the exercise-therapy alone group [34].

Pelvic floor dysfunctions

The effect of exercise therapy on pelvic floor dysfunctions has been investigated in studies by Keshwani et al. [29] and Walton et al. [32]; in the study by Keshwani et



JMR

Figure 4. Funnel plot

al., the PFDI increased by 2.3 units [29]. Meanwhile, in this study, the highest amount of improvement in pelvic floor dysfunctions was observed in the group that received corsets (19.3 units). In Walton et al.'s study, no significant effect of exercise therapy was observed on urinary distress inventory (P=0.111) and pelvic organ prolapse distress inventory (P=0.138), but the effect of exercise on the colorectal anal distress inventory was significant in women with DRA (P=0.042) [32].

Quality of life

Quality of life was examined in studies by Walton et al. [32] and Thabet and Alshehri [31]. The findings of Walton et al.'s study showed that exercise therapy increased the quality of life of women with DRA based on ODI but the amount of change was not significant (P=0.383) [32]. The study by Thabet and Alshehri showed that core stability exercises combined with traditional abdominal exercises significantly increased quality of life (5.25 units) based on the physical functioning scale, but traditional abdominal exercises alone did not cause a significant change in the quality of life of women with DRA (0.25 units) [31].

Discussion

This systematic review study aimed at a multidimensional investigation of DRA in terms of comparing different measurement methods and levels of IRD, and the effectiveness of various physiotherapy interventions in postpartum women with DRA.

Assessing the severity of IRD in women with DRA with different measurement methods and at different locations is one of the main limitations of studies to draw a single conclusion, making the task of comparing the results difficult. In this study, the effect of exercise therapy on IRD with the measurement method (sonography and caliper) subgroups was assessed (Figure 1). The results of the five included studies [21, 22, 25, 29, 30], in the meta-analysis revealed that the IRD decreased significantly after treatment and the caliper showed a further reduction of IRD (9.15 mm) compared to the sonography, but the difference between them was not significant. Previous studies have demonstrated that both sonography and caliper have good reliability in assessing IRD [11, 12]. Although there is no significant difference between the two methods, sonography is recommended over caliper due to its greater accuracy and use in all people. Sonography is the golden standard of IRD measurement [37] and is a real-time, precise, objective, and safe tool to measure IRD [11]. On the other hand, the caliper is dependent on the person's ability to contract and may not be usable in obese people. Therefore, the use of sonography as a more accurate and objective tool is recommended. Since all of the studies included in this analysis had a high risk of bias (Figure 1), this result should be considered with caution. Furthermore, there was no significant difference in the amount of IRD after treatment among different levels in the patients. The highest amount of improvement was observed at the above umbilicus (-5.03 mm), which might be related to less subcutaneous fat and more reliable measurements in this area [38]. The amount of improvement at the level of the umbilicus was -4.05 mm and below the umbilicus was -1.11 mm. In fact, due to the presence of less fat above the umbilicus, the RAM bulks are easier to palpate and the measurement is more accurate. The effect of the measurement level of IRD has not been investigated in previous systematic review studies. This meta-analysis was performed for the first time to make more confident decisions about the treatment protocol of these patients, but because of small sample size (n=6), we could not determine definite conclusions and it is suggested that more studies be conducted in this field. Nevertheless, since the observation of bulks of RAM is easier and measurement is more reliable at the level above the umbilicus, it may be better for therapists to perform their assessment of IRD at this level.

The results of previous studies showed that regardless of the type of exercise, exercise reduces IRD. During exercises, the activation of the abdominal muscles causes a mechanical load on the linea alba [39]. This mechanical load may stimulate the formation of collagen and its alignment and then increase the ability of linea alba to transfer load in the midline and reduce the stress on it [29, 40]. Another cause of IRD reduction can be hypertrophy of abdominal muscles following exercise therapy [34].

Although exercise therapy is one of the main physiotherapy interventions in these patients, the use of other conservative interventions may also facilitate the treatment. In this study, exercise therapy was compared with combination therapy (exercise therapy + adjunct intervention) [23, 27, 29, 30, 34, 36]. Adjunct interventions included tape, corset, and NMES, and it was found that if exercise is combined with other non-invasive interventions, it will lead to a greater reduction in IRD (MD= -1.89 mm).

Additionally, in this analysis, studies were divided into three subgroups based on the type of second intervention: Tape, NMES, and corset. The amount of improvement was significant in all subgroups. The difference between the subgroups was also significant and the highest

rate of reduction of IRD was in the tape subgroup (-2.91 mm), then the corset subgroup (-2.55 mm), and finally the NMES subgroup (-0.70 mm). The recent systematic review study by Weingerl et al. [14], also confirms these results and shows that combining exercise with tape or NMES has better results in patients with DRA; however, their study showed that there was conflicting evidence about the effectiveness of corsets [30]. In Weingerl et al.' study, the comparison between the effectiveness of tape, NMES, and the corset was not performed. Adjunct interventions may improve muscle function and proprioception, and act as a biofeedback for the transverse abdominis muscle. Significant improvement following combination intervention compared to exercise therapy alone may be due to higher intensities of force exerted on the muscles, which leads to further strengthening [27]. The motor units are activated by the stimulation of the skin receptors by the tape which affects the excitability of the central nervous system [27]. The alteration of muscle strength by tactile input through the skin is widely known [27]. In addition, tape probably increases the recruitment of motor units and increases bioelectrical activity and muscle strength [27]. The use of NMES also increases the motor signals from the central nervous system to muscles and causes the muscles to contract [23]. The corset also acts as a biofeedback and may cause coactivation of the flexor and extensor muscles of the trunk thus increasing the stability of the spine [24]. Based on the findings of our study, using tape along with exercise can reduce IRD more. Due to the small number of studies (n=6), and considering that all the included studies were at a high risk of bias (Figure 2), this conclusion should be considered with caution. Further high-quality studies are demanded to be conducted to take into account the importance of this issue in facilitating the healing process in these patients.

The results of the present study manifested that physiotherapy reduces low back pain, and disability, improving the function of abdominal muscles and quality of life in postpartum women with DRA, nevertheless, pelvic floor dysfunctions were not improved in these women.

As mentioned earlier, following the occurrence of DRA, the function of the abdominal muscles was disrupted [3-6]. The results of the included studies showed that physiotherapy may improve the strength, endurance, and power of the abdominal muscles in women with DRA. Findings from a systematic review by Gluppe et al. also confirm that exercise therapy improves abdominal muscle strength in these patients [15]. Physiotherapy, especially exercise therapy, improves neuromuscular control and increases coordination between muscles, activating the slow and fast fibers in the skeletal muscle, therefore improving muscle function [22].

According to the results of this review, the intensity of disability based on the ODI score significantly was reduced after physiotherapy. The ODI measures pain, disability, and quality of life, has good to excellent reliability, and internal agreement [41], and has not been studied in previous systematic reviews of women with DRA. An increase in lumbopelvic stability and activation of sensory inputs and nerve receptors following physiotherapy improves an individual's performance in daily activities and reduces pain and disability, thus reducing the ODI score [32, 42].

Pelvic floor dysfunction may occur in these patients due to the disruption of synergy between abdominal muscles and pelvic floor muscles. Meanwhile, the findings of our systematic review indicate that physiotherapy has no significant effect on pelvic floor dysfunctions in women with DRA. The systematic review study by Gluppe et al. also confirmed this result [15]. For the treatment of pelvic floor dysfunctions in women with DRA, it may be necessary for the physiotherapy directly to focus on strengthening and retraining the pelvic floor muscles, while most studies in this review have focused on the abdominal muscles in these patients.

According to the findings of the present study, physiotherapy is likely to increase the quality of life of women with DRA. Physiotherapy can play an effective role in reducing back and pelvic pain due to increasing the stability of these areas. Following the improvement of function and reduction of pain and disability, an increase in quality of life is expected. The systematic review of Benjamin et al. also showed that exercise therapy resulted in a 79% physical and a 48% psychological improvement in the quality of life according to the 36-item short-form health survey questionnaire [43]. Therefore, physiotherapy, especially exercise therapy seems to be beneficial in improving the quality of life of women with DRA, but the type of exercise is also important. The results of some studies included in our systematic review show that exercises, such as plank and core stability exercises are more effective than traditional abdominal exercises in improving the quality of life [31, 32]. The reason for this difference is not clear properly and future studies need to investigate this factor.

Conclusion

Due to the high prevalence of DRA and its effect on the quality of life in women, it is necessary to have a specific

protocol for its evaluation and treatment. Although there was no significant difference between the different assessment levels and methods of IRD, it might be better for therapists and researchers to use sonography as the golden standard of assessment, as well as the level of the above umbilicus as a more reliable level in the evaluation. Also, according to the evidence of available publications, in the physiotherapy of these patients, the use of adjunct interventions, especially the tape along with exercise, may increase the recovery of postpartum women with DRA, but due to the high risk of bias of the included studies, these conclusions should be considered with more caution.

Study limitations

This study faced some limitations and its results should be used with caution. No blinding of the patient or examiner, small sample size, low quality, and no intention to treat in some of the studies were the limitations of the included studies in the present study. The heterogeneity of the studies in terms of the type of delivery, parity, type of exercise, and language limitation (English and Persian studies only) makes it difficult to achieve a single protocol in these patients. Also, due to the small number of RCT studies to compare exercise therapy with non-intervention and combination therapy, thorough conclusions cannot be drawn. Therefore, it is necessary to overcome these limitations in future studies.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Tabriz University of Medical Sciences (Code: IR.TBZMED.REC.1400.241).

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Authors' contributions

Conception and design: Elham Soleimanzadeh and Hakimeh Adigozali; Searching the databases: Morteza Ghojazadeh and Fariba Ghaderi; Study selection: Elham Soleimanzadeh and Hakimeh Adigozali; Data extraction: Elham Soleimanzadeh; Quality assessment: Elham Soleimanzadeh, Hakimeh Adigozali, and Hanieh Salehi-Pourmehr; Meta-analysis: Hanieh Salehi-Pourmehr; Drafting of the Article: Elham Soleimanzadeh and Hakimeh Adigozali; Final Approval of Article: Hakimeh Adigozali.

Conflict of interest

The authors declared no conflict of interest.

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