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Research

Curl-up exercises improve abdominal muscle strength without worsening inter-recti distance in women with diastasis recti abdominis postpartum: a randomised controlled trial

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KEY WORDS

Curl-up
Diastasis recti abdominis
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ABSTRACT

Question: What is the effect of a 12-week, home-based, abdominal exercise program containing head lifts and abdominal curl-ups on inter-recti distance (IRD) in women with diastasis recti abdominis (DRA) 6 to 12 months postpartum? What is the effect of the program on: observed abdominal movement during a curl-up; global perceived change; rectus abdominis thickness; abdominal muscle strength and endurance; pelvic floor disorders; and low back, pelvic girdle and abdominal pain? **Design**: This was a two-arm, parallel-group, randomised controlled trial with concealed allocation, assessor blinding and intention-to-treat analysis. **Participants**: Seventy primiparous or multiparous women 6 to 12 months postpartum, having a single or multiple pregnancy following any mode of delivery, with a diagnosis of DRA (IRD > 28 mm at rest or > 25 mm during a curl-up). **Intervention**: The experimental group was prescribed a 12-week standardised exercise program including head lifts, abdominal curl-ups and twisted abdominal curl-ups 5 days a week. The control group received no intervention. **Outcome measures**: The primary outcome measure was change in IRD measured with ultrasonography. Secondary outcomes were: observed abdominal movement during a curl-up; global perceived change; rectus abdominis thickness; abdominal muscle strength and endurance; pelvic floor disorders; and low back, pelvic girdle and abdominal pain. **Results**: The exercise program did not improve or worsen IRD (eg, MD 1 mm at rest 2 cm above the umbilicus, 95% CI –1 to 4). The program improved rectus abdominis thickness (MD 0.7 mm, 95% CI 0.1 to 1.3) and strength (MD 9 Nm, 95% CI 3 to 16) at 10 deg; its effects on other secondary outcomes were trivial or unclear. **Conclusion**: An exercise program containing curl-ups for women with DRA did not worsen IRD or change the severity of pelvic floor disorders or low back, pelvic girdle or abdominal pain, but it did increase abdominal muscle strength and thickness. **Registration**: NCT04122924. **[Gluppe SB, Ellström Engh M, Bø K (2023) Curl-up exercises improve abdominal muscle strength without worsening inter-recti distance in women with diastasis recti abdominis postpartum: a randomised controlled trial. *Journal of Physiotherapy* 69:160–167]**

Introduction

Diastasis recti abdominis (DRA) is defined as midline separation of the two rectus abdominis muscles along the linea alba.[1] To diagnose DRA, the inter-recti distance (IRD) is measured,[2] but there is no consensus on the cut-off point.[3] Ultrasound is the recommended method to measure IRD, with intra-rater and inter-rater intraclass correlation coefficients > 0.9.[4]

The condition has been reported to be highly prevalent in the postpartum period, with prevalence rates up to 45% at 6 months and 30% at 12 months postpartum.[5] To date, two systematic reviews[6,7] have evaluated the consequences of DRA, and DRA has been associated with weaker abdominal muscles[7–9] and more abdominal pain.[6,8] Associations with low back pain, pelvic girdle pain and pelvic floor disorders (such as urinary incontinence, anal incontinence and pelvic organ prolapse) have been suggested but not substantiated in studies of women with mild or moderate DRA.[6–8,10] Keeler et al[11] reported that 89% of women's health physiotherapists used pelvic floor muscle training and 87% used transversus abdominis training in the treatment of DRA. These results were confirmed in a recent study by Gluppe et al.[12] Three systematic reviews have evaluated the effect of different exercise programs in the treatment of DRA, concluding that due to poor methodological quality and small samples sizes of the included trials, the evidence is insufficient to recommend any specific exercise protocol.[13–15] Curl-ups have traditionally been discouraged in the treatment of women with DRA, but a short-term experimental study found that head-lift and abdominal curl-ups reduced the IRD during the exercises.[16]

Therefore, the research questions for this trial were:

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1. What is the effect of a 12-week, home-based, abdominal exercise program containing head lifts and abdominal curl-ups on IRD in women with DRA 6 to 12 months postpartum?
2. What is the effect of the exercise program on observed abdominal movement during a curl-up, global perceived change, abdominal muscle strength, abdominal muscle endurance, rectus abdominis thickness, pelvic floor disorders, low back pain, pelvic girdle pain and abdominal pain?

Method

Design

This was an assessor-blinded, two-arm, parallel-group randomised controlled trial. After baseline testing, all participants were randomly allocated equally to either the experimental or control group by a person not involved in the assessments. Randomisation was computer-generated in blocks of four. Concealed allocation was used.

One trained physiotherapist who had undergone specific training in ultrasound imaging of the abdominal muscles prior to data collection performed all assessments. Images taken at baseline testing were transferred from the hard disk to a software program[a] and analysed offline. The same physiotherapist, blinded for group allocation, performed both the ultrasound assessments and the offline analyses. All participants were thoroughly informed at the start of the post-test to not reveal group allocation.

Participants

Participants were recruited through women's health physiotherapists, personal trainers, midwives, gynaecologists/obstetricians, friends and acquaintances and by advertising on social media. The numbers of women screened and excluded with reasons for exclusion are presented in Figure 1. The trial was performed mainly at the Norwegian School of Sport Sciences in Oslo and at two physiotherapy centres in Norway from January 2020 to December 2022. Post-test assessment was conducted after 12 weeks of the intervention period by one physiotherapist blinded to group allocation.

Inclusion criteria were being a primiparous or multiparous woman with a diagnosis of DRA 6 to 12 months postpartum, having a single or multiple pregnancy following any mode of delivery, and being able to understand a Scandinavian language. The diagnosis of DRA was based on previous studies, and IRD cut-off was set to $\geq$ 2.8 cm at rest or $\geq$ 2.5 cm during a curl-up 2 cm above or 2 cm below the umbilicus.[17,18] Diagnosis of DRA was confirmed with ultrasound prior to baseline testing or when signing up for screening. In addition, if a protrusion along the linea alba was observed, women were included even if the IRD was less than the cut-off values.

Prior to baseline testing, the participants responded to an electronic questionnaire gathering information about background variables and comorbidities such as neurological and systemic musculoskeletal diseases or psychiatric diagnoses (Table 1). Height, weight and waist circumference were measured at the clinical assessment, and body mass index was calculated for all participants.

Intervention

The focus of the exercise protocol was to strengthen the abdominal muscles, based on findings from a short-term experimental study.[16] The specific exercises and progression of the program are shown in Figure 2. The standardised, individual exercise program was prescribed for 10 minutes/day, 5 days/week for 12 weeks. Due to the COVID-19 pandemic, the instructions on how to perform the exercises were described by a physiotherapist by telephone or demonstrated on FaceTime[b]. In addition, the exercises were captured and described in detail in a document sent to all participants in the experimental group (Figure 2). The experimental group was also provided with a smartphone app[c] where adherence to training could be registered. Furthermore, a daily reminder to exercise and a weekly SMS was given to encourage participants in the experimental group to adhere to the program. The physiotherapist providing the training program was not involved in any assessments.

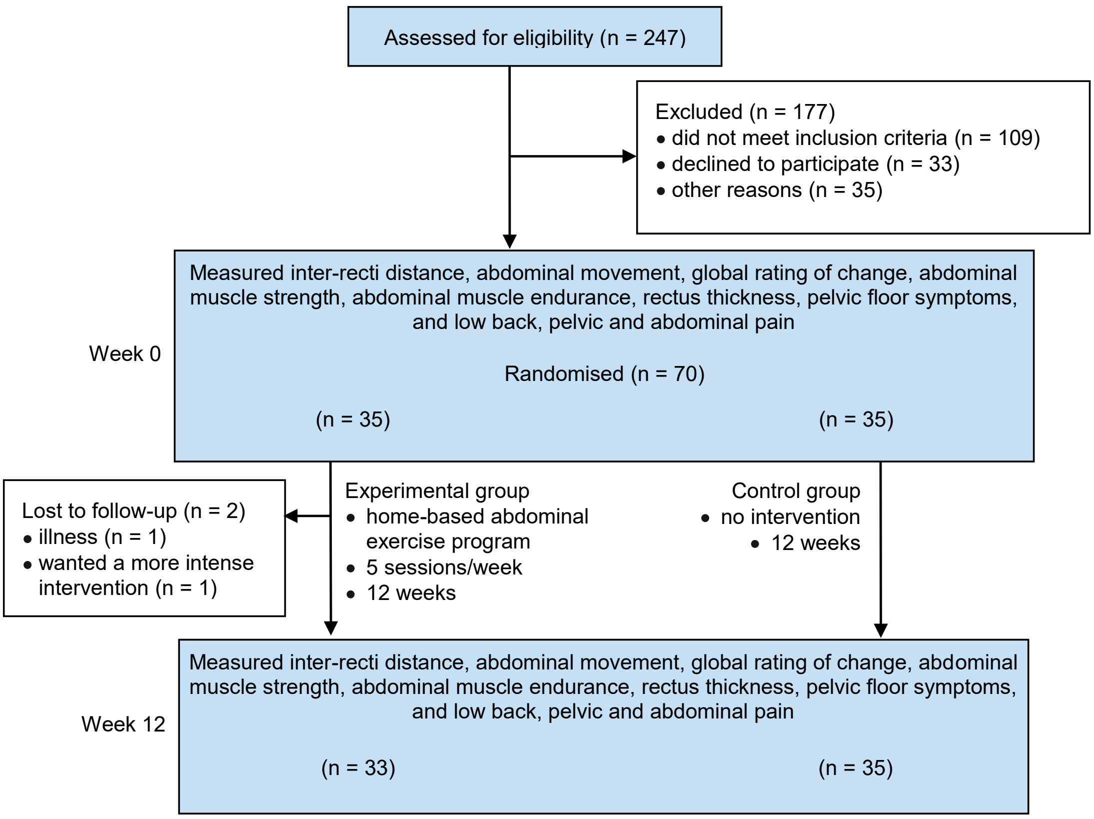

Figure 1. Flow of participants through the trial.

Table 1
Baseline characteristics of the participants.

Variable	Total sample (n = 70)	Exp group (n = 35)	Con group (n = 35)
Age *(y)*, mean (SD)	34 (3)	35 (4)	33 (3)
Height *(m)*, mean (SD)	1.67 (0.10)	1.68 (0.10)	1.66 (0.10)
Weight *(kg)*, (SD)	69.4 (15.4)[a]	69.7 (15.6)	69.1 (15.4)
Body mass index *(kg/m^2)*, mean (SD)	24.9 (5.6)[a]	24.8 (5.4)	25.0 (5.8)
Waist circumference *(cm)*, mean (SD)	85.2 (13.9)	85.3 (13.0)	85.1 (14.9)
Weight gain last pregnancy *(kg)*, mean (SD)	15.5 (5.6)	15.9 (6.1)	15.1 (5.2)
Heavy lifting at work, n yes (%)[b]	6 (24)	3 (23)	3 (25)
Singleton parity, n (%)[c]			
1	14 (22)	5 (16)	9 (27)
2	41 (64)	21 (68)	20 (61)
3	9 (14)	5 (16)	4 (12)
Mode of delivery, n (%)			
vaginal	44 (69)	25 (81)	19 (58)
caesarean	9 (14)	1 (3)	8 (24)
both vaginal and caesarean	11 (17)	5 (16)	6 (18)
Use of contraceptives, n yes (%)	25 (36)	13 (37)	12 (34)
Breastfeeding ≥ 1 time/day, n (%)	57 (81)	27 (77)	27 (77)
Striae, n (%)			
during teenage	30 (43)	12 (34)	18 (51)
during pregnancy	39 (56)	23 (66)	16 (46)
postpartum	14 (20)	7 (20)	7 (20)
Menstruating, n (%)			
yes	38 (54)	17 (49)	21 (60)
no	24 (34)	14 (40)	10 (29)
uncertain	8 (11)	4 (11)	4 (11)
Physical activity *(minutes/wk)*, mean (SD)	136 (118)	150 (115)	120 (121)

Con = control group, Exp = experimental group.
Percentages may not sum to 100% due to the effects of rounding.
[a] N = 69; missing data for one woman who did not want to measure weight from control group (valid percent reported).
[b] N = 25; 25 women reported to be back to work and therefore responded to this question.
[c] N = 64; missing data on six women had a twin delivery (valid percent reported).

The control group received no intervention and was discouraged from conducting specific abdominal training/exercises. However, general physical activity and training of other muscle groups was not restricted.

Outcome measures

Primary outcome

Change in inter-recti distance: One physiotherapist performed the clinical examinations of all participants at baseline and at the end of the 12-week intervention period. To diagnose DRA, the IRD was assessed with transabdominal ultrasound, a portable two-dimensional ultrasound machine with a linear transducer[d]. The ultrasound imaging protocol has been described in detail elsewhere.[16]

To standardise the measurement locations, two marks were made on the skin: one 2 cm above and one 2 cm below the centre of the umbilicus (Figure 3).[4] Images were captured at rest and during a curl-up at both measurement locations. During the curl-up, the participants were in a standardised supine position with arms crossed over the chest and the curl-up was performed until the shoulder blades were off the bench. The end position of the ultrasound assessment of IRD during the curl-up is illustrated in Figure 4.

Secondary outcomes

Clinical observation of diastasis recti abdominis: The assessor observed the abdomen while the participants performed a curl-up and registered if the following was seen at baseline and Week 12: protrusion, sink-in, no movement, or uncertain.

Perceived change of the condition with the Global Rating of Change scale: At Week 12, participants in both groups were asked to report whether they perceived improvement in their DRA compared with baseline on a Global Rating of Change scale. This scale includes classifications from very much worse to fully healed in a numerical 11-point scale; the instrument has shown good intra-test reliability (ICC = 0.9).[19]

Abdominal muscle strength and endurance: An isokinetic dynamometer[e] was used to assess maximal isometric abdominal wall strength, limited to trunk flexion. Isometric trunk flexion assessment with dynamometers in a sitting position has shown excellent test–retest reliability with ICC $>$ 0.9[20,21] and strong correlation with the width of the IRD.[9,20] Abdominal muscle endurance was assessed as number of repetitions of a standardised abdominal curl-up to exhaustion test following the protocol of the American College of Sports Medicine (ACSM) curl-up test.[22,23] The protocol for these two strength tests is described in detail elsewhere.[8]

Rectus abdominis thickness: Muscle thickness was defined as the distance between the inside edges of the superior and inferior fascial borders.[2] Participants rested in a standardised supine position with arms alongside and knees bent with the feet on the bench. Three ultrasound images were taken at rest 2 cm above the umbilicus. The transducer was moved transversely over the midpoint of the right rectus abdominis and the average was calculated. This protocol was modified from a published protocol.[2]

Pelvic floor disorders, low back pain, pelvic girdle pain and abdominal pain: Prior to testing at baseline and Week 12, all participants responded to the following questions in the electronic questionnaire: 'Do you have symptoms from your bowel, bladder or pelvic region that bother you (eg, urinary leakage, bowel leaks or feeling of bulge in the vagina)?', 'Do you have low back pain?', 'Do you have pelvic girdle pain?' and 'Do you have pain in your abdomen?'. If participants responded yes to these questions, they were asked to respond to the following: the Pelvic Floor Distress Inventory-short form 20,[24] the Oswestry Disability Index[25] and the Pelvic Girdle Questionnaire,[26] respectively. If participants responded yes to having abdominal pain, they were asked to indicate the location of the pain and to what degree (from 0 = not at all to 10 = a lot) the pain affected their activities of daily living. Each scale score of the Pelvic Floor Distress Inventory-short form 20 ranges from 0 (no disability) to 100 (maximum disability) and the sum score from the three scales together range from 0 to 300. The sum score in the Oswestry Disability Index is calculated in percent from 0 (not disabled) to 100 (disabled) and the Pelvic Girdle Questionnaire is calculated in percent from 0 (not at all) to 100 (to a large extent). All three instruments have been validated and are recommended for assessment of symptoms of PFD, functional measure of disability due to low back pain, and limitation in activities/participation due to pelvic girdle pain.[24–26]

Data analysis

An a priori power calculation was conducted based on a conservative approach. The effect size for the experimental group was set to 0.8 cm with SD of 0.8, for the control group the effect size was set to 0.2 and SD 0.8. These numbers are based on results from a previously published randomised trial,[27] but the effect size was slightly adjusted upwards due to that study's low power. In addition, the adjustment was based on other relevant studies.[28,29] Therefore, we planned to include 58 participants with 29 in each group. To allow for some loss to follow-up, the final estimation was increased to 70 participants with 35 in each group.

Data were analysed using SPSS 28. Background variables were reported as means with standard deviations (SD) or numbers with percentages. Within-group and between-group comparisons of continuous and categorical data were analysed by the independent sample t-test and chi-square test for independence, respectively. For continuous variables, an ANCOVA was used as a linear regression with Week 12 value as the dependent variable and group and the baseline variable as the independent variables. Difference in change between groups from baseline to Week 12 are reported with 95% CI. *P*-values $<$ 0.05 were considered statistically significant. Analyses were based on intention to treat.

Exercise program

Weeks 1 to 4: Perform one set of exercises 1, 2 and 3 in the order described below.
Weeks 5 to 8: Perform two sets of exercises 1, 2 and 3 in the order described below with a 1-minute pause between sets.
Weeks 9 to 12: Perform three sets of exercises 1, 2 and 3 in the order described below with a 1-minute pause between sets.

*Perform all exercises **slowly** and check that the exercises are performed correctly without causing a significant protrusion (please observe your abdomen while doing the exercises). You may conduct the exercises while lying on the floor with your child.*

Exercises with explanation			
	1) Head lift *Lie on your back with your legs bent and arms alongside* • *Slowly inhale and exhale* • *After exhaling, lift your head up with your chin towards your chest* • *Lower slowly* 	**2) Oblique curl-up (both right and left side)** *Lie on your back with your legs bent and one arm alongside, the other hand behind your head* • *Slowly inhale and exhale* • *After exhaling, lift your head and bend the upper part of your back obliquely up until one shoulder blade is free from the floor* • *Lower slowly* 	**3) Curl-up** *Lie on your back with your arms crossed over your chest* • *Slowly inhale and exhale* • *After exhaling, lift your head and bend the upper part of your back up until both shoulder blades are free from the floor* • *Lower slowly*   Progression for weeks 11 and 12
Progression			
Weeks 1 and 2	1 × 8 repetitions	1 × 8 repetitions	1 × 8 repetitions
Weeks 3 and 4	1 × 10 repetitions	1 × 10 repetitions	1 × 10 repetitions
Weeks 5 and 6	2 × 10 repetitions	2 × 10 repetitions; Holding time 1 second	2 × 10 repetitions; Holding time 1 second
Weeks 7 and 8	2 × 12 repetitions	2 × 12 repetitions; Holding time 2 seconds	2 × 12 repetitions; Holding time 2 seconds
Weeks 9 and 10	3 × 10 repetitions	3 × 10 repetitions; Holding time 2 seconds	3 × 10 repetitions; Holding time 2 seconds
Weeks 11 and 12	3 × 12 repetitions	3 × 12 repetitions; At the top, tilt forward three times	3 × 12 repetitions; Place your hands in a grip behind your neck (avoid picking up speed with your arms on the way up!)

Figure 2. Details of the experimental intervention.

Results

Flow of participants through the study

A total of 247 women were screened with ultrasound for DRA, with 177 (72%) excluded mostly due to not meeting the IRD inclusion criteria. Of the 70 women who met the eligibility criteria, 35 women were randomised to the experimental group and 35 to the control group (Figure 1). Two participants (4%) dropped out of the experimental group and none dropped out of the control group. The reasons for drop-out are described in Figure 1. Women in the experimental group completed 74% (SD 26) of their prescribed exercise sessions. Twenty-one participants (66%) in the experimental group adhered to ≥ 80% of their prescribed exercise sessions.

Compliance with the trial protocol

Extra exercise sessions were added for three participants where the Week 12 assessment was delayed due to lockdown during the pandemic. Eighteen participants did not perform the maximal isometric strength with the dynamometer due to the lockdown.

Figure 3. Inter-recti distance measurement locations during ultrasound assessment.

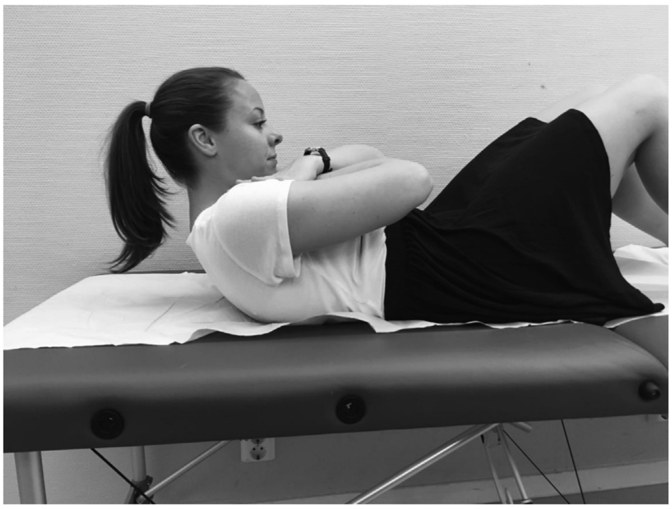

Figure 4. The end position during curl-up in the ultrasound assessment of IRD. Reproduced with permission of Kristina L Skaug.

Baseline characteristics of the participants

The baseline characteristics of the participants are shown in Table 1 and in the first two columns of data in Tables 2 to 8. Individual participant data are available in Table 9 on the eAddenda. Among the total sample, 97% of the participants had a college/university education, 97% were of Caucasian genetic origin, 99% were married/cohabitating and 99% were non-smokers. Six (9%) participants had one twin delivery each: four participants in the experimental group and two in the control group.

Change in inter-recti distance

For all participants, the widest IRD was measured at rest 2 cm above the umbilicus (Table 2). Mean IRD decreased from baseline to week 12 for all IRD measurements in both groups, except from a minor increase in IRD measured below the umbilicus at rest in the control group. Little to no difference in change occurred between the two groups from baseline to week 12, with the estimates of mean difference and their 95% CIs below the smallest worthwhile effect thresholds of 5 mm for above the umbilicus and 8 mm for below the umbilicus[30] (Table 2). One minor exception was the effect below the umbilicus during a curl-up, where one end of the 95% CI just reached the smallest worthwhile effect, indicating a slight possibility that the experimental intervention might have a worthwhile benefit on IRD there. Certainly, the curl-ups did not worsen DRA to any clinically important extent.

Observed movement of the abdomen

The estimates of the effect of the experimental intervention on observed movement of the abdomen during a curl-up were very imprecise (Table 3); therefore, the effect of the curl-ups on movement of the abdomen remains uncertain.

Global rating of change

At week 12, 20 of 33 participants (61%) in the experimental group and 15 of 35 participants (43%) in the control group reported improvement in DRA (RR 1.41, 95% CI 0.88 to 2.27). None of the participants in either group reported worsening of the condition.

Rectus abdominis thickness

The experimental group improved the thickness of their rectus abdominis more than the control group by a mean difference of 0.7 mm. However, the confidence interval spanned worthwhile and trivial effects (95% CI 0.1 to 1.3) as shown in Table 4.

Abdominal muscle strength and endurance

The experimental group improved their maximal isometric strength more than the control group (Table 5). However, the confidence intervals spanned worthwhile and trivial effects: MD 8 nM (95% CI 1 to 14) at 30 deg and MD 9 nM (95% CI 3 to 16) at 10 deg.

At baseline, 76% of all participants were unable to perform one curl-up according to the ACSM curl-up test procedure; therefore, the data on number of curl-ups were strongly skewed in both groups. Although the few participants in each group who could perform ACSM curl-ups generally showed a small increase in their number of curl-ups by week 12, there was no between-group difference in the amount of improvement: Hodges–Lehmann MD 0 curl-ups, 95% CI 0 to 0 (Table 6).

Pelvic floor disorders, low back pain, pelvic girdle pain, and abdominal pain

When participants were questioned about the presence of any pelvic floor disorders or low back, pelvic girdle or abdominal pain, very imprecise estimates of effect were elicited. This is evident in the wide confidence intervals that included the possibility of clinically worthwhile effects in either direction (Table 7). However, when questioned about the severity of pelvic floor disorders or low back, pelvic girdle or abdominal pain, more precise estimates of effect could be obtained (Table 8). The effects were all so small as to be clearly clinically trivial because the confidence limits were all $<$ 10% of the outcome measure's scale.

Discussion

The effect of the exercise program on the primary outcome, IRD, was measured above and below the umbilicus and at rest and during a curl-up. The mean between-group differences and most of their 95% CIs were below the smallest worthwhile effect thresholds of 5 mm for above the umbilicus and 8 mm for below the umbilicus.[30] One exception was the effect below the umbilicus during a curl-up, where one end of the 95% CI just reached the smallest worthwhile effect (8 mm), indicating a slight possibility that the experimental intervention might have a worthwhile benefit on IRD there. Certainly, the curl-ups did not worsen DRA to any clinically important extent. The exercise program clearly improved abdominal muscle strength and thickness, although it is unclear whether these effects were large enough to be worthwhile. The exercise program clearly did not change abdominal muscle endurance or the severity of pelvic floor disorders or low back, pelvic or abdominal pain to any worthwhile extent. The effects on the other secondary outcomes were unclear due to wide confidence intervals.

The choice of intervention was based on a short-term experimental study showing an immediate IRD reduction during head-lift and abdominal curl-ups.[16] This effect was not found when the participants were performing the same exercise for 12 weeks in this trial. The reason for a negligible effect on IRD may be due to the choice of exercises, that only 66% of participants in the experimental group adhered to $\geq$ 80% of the prescribed exercise and that the exercises were home-based and unsupervised. It was difficult to make direct comparisons between other randomised trials applying abdominal training to reduce IRD. The studies differ in measurement methods to assess IRD (palpation, calliper, ultrasound), choice of cut-off value for diagnosing DRA, and inclusion of primiparous and/or multiparous women. In addition, onset of the training intervention, type of

Table 2
Mean (SD) of groups, mean (SD) within-group difference and mean (95% CI) between-group difference for width of inter-recti distance under various conditions.

Inter-recti distance *(mm)*	Groups				Within-group difference		Between-group difference
	Week 0		Week 12		Week 12 minus Week 0		Week 12 minus Week 0
	Exp (n = 35)	Con (n = 35)	Exp (n = 32)	Con (n = 35)	Exp	Con	Exp minus Con
At rest 2 cm above umbilicus	37 (8)	40 (10)	36 (9)	38 (10)	–1 (5)	–2 (4)	1 (–1 to 4)
At rest 2 cm below umbilicus	29 (10)	28 (10)	27 (12)	30 (11)	–1 (6)	2 (7)	–3 (–6 to 0)
During a curl-up 2 cm above umbilicus	27 (10)	30 (13)	26 (12)	28 (12)	–2 (7)	–2 (6)	0 (–3 to 3)
During a curl-up 2 cm below umbilicus	23 (12)	24[a] (13)	21 (13)	24 (13)	–2 (8)	1 (12)	–3 (–8 to 2)

Con = control group, Exp = experimental group.
[a] n = 34.

Table 3
Number (%) of participants with specific observed movements of the abdomen during a curl-up, with relative risk (95% CI) for between-group difference in prevalence at 12 weeks.

Observed movement of abdomen	Week 0		Week 12		Relative risk (95% CI) at week 12
	Exp (n = 35)	Con (n = 35)	Exp (n = 32)	Con (n = 33)	Exp relative to Con
Protrusion	14 (40)	12 (34)	6 (19)	5 (15)	1.23 (0.42 to 3.65)
Sink in	5 (14)	2 (6)	5 (16)	3 (9)	1.72 (0.45 to 6.61)
No movement	15 (40)	19 (54)	19 (59)	22 (67)	0.89 (0.61 to 1.30)
Uncertain	2 (6)	2 (6)	2 (6)	3 (9)	0.69 (0.12 to 3.85)

Con = control group, Exp = experimental group.

Table 4
Mean (SD) of groups, mean (SD) within-group difference and mean (95% CI) between-group difference for rectus abdominis thickness.

Outcome	Groups				Within-group difference		Between-group difference
	Week 0		Week 12		Week 12 minus Week 0		Week 12 minus Week 0
	Exp (n = 34)	Con (n = 34)	Exp (n = 31)	Con (n = 32)	Exp	Con	Exp minus Con
Rectus abdominis thickness *(mm)*	8.3 (2.1)	8.5 (1.5)	9.5 (2.1)	8.7 (1.8)	1.0 (1.2)	0.3 (1.3)	0.7 (0.1 to 1.3)

Con = control group, Exp = experimental group.

Table 5
Mean (SD) of groups, mean (SD) within-group difference and mean (95% CI) between-group difference for abdominal strength.

Maximal isometric strength *(Nm)*	Groups				Within-group difference		Between-group difference
	Week 0		Week 12		Week 12 minus Week 0		Week 12 minus Week 0
	Exp (n = 24)	Con (n = 27)	Exp (n = 20)	Con (n = 24)	Exp	Con	Exp minus Con
At 30 deg	119 (27)	114 (28)	128 (28)	116 (23)	9 (11)	1 (11)	8 (1 to 14)
At 10 deg	91 (27)	88 (24)	100 (26)	89 (25)	10 (11)	1 (10)	9 (3 to 16)

Con = control group, Exp = experimental group.

Table 6
Median (IQR) of groups, median within-group difference (95% CI) and Hodges–Lehmann median (95% CI) between-group difference for abdominal muscle endurance.

Outcome	Groups				Within-group difference		Between-group difference
	Week 0		Week 12		Week 12 minus Week 0		Week 12 minus Week 0
	Exp (n = 31)	Con (n = 34)	Exp (n = 31)	Con (n = 34)	Exp	Con	Exp minus Con
ACSM curl-ups *(n)*	0 (0 to 7.5)	0 (0 to 0)	0 (0 to 11.5)	0 (0 to 9)	0 (0 to 1.5)	0 (0 to 1)	0 (0 to 0)

ACSM = American College of Sport Medicine, Con = control group, Exp = experimental group.

Table 7
Number (%) of participants reporting the presence of pelvic floor disorders, low back pain, pelvic girdle pain and abdominal pain, and relative risk (95% CI) between groups.

Reported symptoms, n (%)	Week 0		Week 12		Relative risk (95% CI) at Week 12
	Exp (n = 35)	Con (n = 35)	Exp (n = 32)	Con (n = 34)	Exp relative to Con
Pelvic floor disorders	18 (51)	12 (34)	13 (41)	9 (26)	1.53 (0.76 to 3.09)
Low back pain	18 (51)	16 (46)	15 (47)	13 (38)	1.22 (0.70 to 2.16)
Pelvic girdle pain	12 (34)	13 (37)	15 (47)	13 (38)	0.71 (0.28 to 1.77)
Abdominal pain	6 (17)	4 (11)	6 (19)	3 (9)	2.13 (0.58 to 7.79)

Con = control group, Exp = experimental group.

Table 8
Mean (SD) of groups, mean (SD) within-group difference and mean (95% CI) between-group difference for reported symptom severity.

Symptom severity	Groups				Within-group difference		Between-group difference
	Week 0		Week 12		Week 12 minus Week 0		Week 12 minus Week 0
	Exp (n = 35)	Con (n = 35)	Exp (n = 32)	Con (n = 34)	Exp	Con	Exp minus Con
PFDI – short form 20 *(0 to 300)*	28[a] (43)	10[b] (25)	17[b] (29)	16[c] (38)	–5 (28)	4 (27)	–9 (–25 to 8)
Oswestry Disability Index *(0 to 100)*	6 (9)	5 (9)	6 (10)	5 (9)	–1 (6)	–1 (8)	0 (–3 to 3)
Pelvic Girdle Questionnaire *(0 to 100)*	11 (19)	10 (19)	4 (10)	8 (15)	–6 (14)	–3 (16)	–4 (–11 to 4)
Abdominal pain severity *(0 to 10)*	1 (2)	0 (1)	1 (2)	0 (1)	0 (2)	0 (1)	0 (–1 to 1)

Con = control group, Exp = experimental group, PFDI = Pelvic Floor Distress Inventory.
[a] n = 26.
[b] n = 27.
[c] n = 31.

exercises and training programs, training dosage, supervision of the exercise interventions and methodological quality of the studies[13-15] made comparison between studies challenging. As there is a natural remission of DRA in the postpartum period,[5] the effect of interventions should be compared with untreated controls. Seven randomised trials have compared abdominal training with an untreated control group. Two randomised trials[28,29] found no clear effect of their exercise intervention: Keshwani et al[28] included exercises for isolated activation of transversus abdominis; and Gluppe et al[29] evaluated the effect of pelvic floor muscle training including weekly group training involving abdominal exercises. The latter study measured IRD with palpation. Hence, comparison with the present results was difficult. Five randomised trials have found a beneficial effect on IRD over untreated controls.[27,31–34] The participants in these studies were comparable with this study regarding parity and onset of training postpartum. However, the studies were hampered with sample sizes (eg, n = 10)[27] and the cut-off values for DRA in some studies indicated no DRA.[34] Only one of the randomised trials[27] measured IRD with ultrasound and this study was a pilot trial.[27]

The present study found beneficial effects on maximal isometric muscle strength and muscle thickness. Only one other randomised trial has compared an exercise group with an untreated control group measuring trunk flexion strength and endurance.[28] Although the test was different, their results correspond with the current findings. A limitation of the measurement method used in the present study (Humac NORM) is lack of reliability data. However, reliability studies with comparable dynamometers to measure maximal trunk flexion have shown good to excellent intra-tester reliability.[20,21] The present study also found that the program increased rectus abdominis thickness. This corresponds with increased rectus abdominis thickness in both intervention arms (exercise delivered in person or via ZOOM) in the study by Kim et al.[35] Participants' characteristics, time since last birth and the ultrasound protocol were comparable with the present study.

The negligible effect of the experimental intervention on abdominal muscle endurance assessed with the ACSM curl-up test in the present study did not correspond with the positive effect found with dynamometry. Interestingly, > 70% of the participants were unable to perform a single curl-up according to this test. Hence, the ACSM curl-up test might be too difficult for women with DRA postpartum.[8] In addition, there is no reliability data on this test and the results should therefore be interpreted with caution. In contradiction to this study group, Botla and Saleh[36] found that their participants were able to perform 24 curl-ups, but the mean IRD values were smaller in their participants compared with our study's participants and below the normal IRD values in postpartum women according to Mota et al.[17]

Despite the finding that our participants did not reduce the IRD, they were able to increase maximal abdominal muscle strength and rectus abdominis thickness, with no widening of the IRD. Performing crunches and sit-ups were discouraged for a long time because these exercises were believed to worsen DRA. However, several short-term experimental studies have now found that contracting the transversus abdominis and pelvic floor muscles widens the IRD, while crunches narrow the IRD.[16,37,38] Our results of no negative effect on IRD by conducting head-lift, crunch and twisted crunches regularly for 3 months indicate that women with mild to moderate diastases can perform these exercises safely; furthermore, these exercises improve abdominal strength.

A postulated association between DRA and pelvic floor disorders, low back pain, pelvic girdle pain and abdominal pain has not been substantiated in many studies.[6,10] The present study did not find any effect of curl-up training on any of these conditions, and the results support the findings in a systematic review of randomised trials.[14] A recent study by Yalfani et al[31] found a positive effect of abdominal training on low back pain and disability in women with DRA. Further studies are needed to explore the effects of abdominal training on these conditions in women with DRA.

An interesting finding of the present study was that 72% of women screened for participation believed they had a DRA but were excluded due to not meeting our IRD inclusion criteria. This may reflect the huge focus on DRA in social media and young mothers' concerns about their abdomen postpartum.[12] Even small and possible negligible DRAs may result in fair avoidance and drop-out from physical activities both during pregnancy and following childbirth. The World Health Organization recommends that all women start or continue a regular exercise program during pregnancy and in the postpartum period.[39] Mota et al[17] suggested that the upper limit for normal IRD during pregnancy and postpartum needs to be re-evaluated. The current results indicate that women with mild to moderate diastasis can perform abdominal crunches with no risk of worsening DRA. However, the effect on abdominal exercises in women with severe DRA needs further investigations.

Strengths of the present study were the randomised design, a priori power calculation, low loss to follow-up, blinding of the assessor and the use of an exercise program including three exercises shown to give an immediate reduction of IRD in a short-term experimental study.[8] The exercise program also included progression in load and volume every second week. The same assessor performed all assessments, ultrasound was used to assess IRD, the assessment procedures were standardised with the aim of minimising inaccuracy, and a homogeneous group of parous women 6 to 12 months postpartum was included. Limitations were that unsupervised training may have reduced adherence and intensity of the training, and that the abdominal muscle strength tests have not been tested for reliability. In addition, this sample consisted of a limited number of participants with severe diastasis, and the results might therefore not be generalisable to women with severe DRA.

A 10-minute, standardised, abdominal exercise program conducted 5 days a week for 12 weeks is unlikely to decrease IRD. Furthermore, the exercise program was effective in increasing abdominal muscle strength and rectus abdominis thickness. The program, which included head-lift, curl-up and twisted curl-up, did not worsen DRA, so parous women with mild to moderate DRA should not be discouraged from performing such exercises. Further high-quality randomised trials of exercise programs including women with severe DRA are warranted.

What was already known on this topic: Diastasis recti abdominis is common in the postpartum period. Literature reviews have not found conclusive evidence about the effects of abdominal exercises on the inter-recti distance, but curl-ups have traditionally been discouraged in the treatment of women with diastasis recti abdominis.
What this study adds: Although an exercise program with head lifts and curl-ups is unlikely to reduce the inter-recti distance, it definitely does not worsen it. Furthermore, the exercise program increases abdominal muscle thickness and strength. Parous women should not be discouraged from performing head lifts and curl-up exercises.

Footnotes: [a] MicroDicom software, MicroDicom, Sofia, Bulgaria.
[b] FaceTime, Apple, Cupertino, USA.
[c] Athlete Monitoring, Fitstats Technologies Inc, Honiton, UK.
[d] Logic e R7, GE Healthcare, Chalfont St Giles, UK.
[e] Humac NORM isokinetic dynamometer, CSMi, Soughton, USA.

Ethics approval: The Regional Medical Ethics Committee (REK South-East 2018/2312) and the Norwegian Centre for Research Data (440860) approved this study. All participants gave written informed consent before data collection began.

Competing interests: Nil.

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