TITLE: Immediate Effect of Abdominal and Pelvic Floor Muscle Exercises on Interrecti Distance in Women With Diastasis Recti Abdominis Who Were Parous

RUNNING HEAD: Immediate Effect of Exercise on Diastasis Recti

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Objective. There is a lack of consensus on which abdominal or pelvic floor muscle (PFM) exercises to recommend for the treatment of diastasis recti abdominis (DRA). The objective of this study is to investigate the immediate effect of abdominal and PFM exercises on interrecti distance (IRD) in women with DRA who are parous.

Methods. In this cross-sectional study, 38 women who were parous, with a mean age of 36.2 years (SD = 5.2), diagnosed with DRA participated. IRD was assessed with 2D real-time ultrasonography during rest and during 8 randomly ordered different exercises. A paired t test was used to compare the IRD at rest with the IRD recorded during each exercise as well as the differences between exercises. Means with 95% CI are reported.

Results. Head lift and twisted curl-up exercises significantly decreased the IRD both above and below the umbilicus. Above the umbilicus, the mean IRD difference from rest during head lift was 10 mm (95% CI = 7 to 13.2), whereas during twisted curl-up, it was 9.4 mm (95% CI = 6.3 to 12.5). Below the umbilicus, the corresponding values were 6.1 mm (95% CI = 3.2 to 8.9) and 3.5 mm (95% CI = 0.5 to 6.4), respectively, but PFM contraction, maximal in-drawing, and PFM contraction+maximal in-drawing increased the IRD (mean difference = -2.8 mm [95% CI = -5.2 to 0.5), -4.7 mm (95% CI = -7.2 to -2.1) and -5.0 mm (95% CI = -7.9 to -2.1), respectively.

Conclusions. Head lift and twisted curl-up exercises decreased the IRD both above and below the umbilicus, whereas maximal in-drawing and PFM contraction exercises only increased the IRD below the umbilicus. A randomized controlled trial is needed to investigate whether head lift and twisted curl-up exercises are effective in permanently narrowing the IRD.

Impact. To date there is scant scientific knowledge of which exercises to recommend in the treatment of DRA. In-drawing and PFM contraction leads to an acute increase in IRD while head lift and twisted curl-up leads to an acute decrease in IRD in postpartum women. There is a need for high quality RCTs to investigate if there is a long-term reduction in IRD by doing these exercises over time. The acute IRD increase and decrease during the different exercises is also present in a sample of women with larger separations.

Diastasis recti abdominis (DRA) is defined as an impairment caused by midline separation of the 2 rectus abdominis muscles along the linea alba.[1] Pregnancy brings several physiological and anatomical changes to the female body.[2] Among these is the increase in girth which stretches, on average, 115 %.[3] DRA affects a significant number of women during the antenatal and postnatal periods, with prevalence rate of 32.6 % at 12 months postpartum.[4] The muscles of the abdominal wall, m. rectus abdominis, m. obliquus externus and internus and m. transversus abdominis (TrA) invest in an aponeurosis to form the rectus sheath, with tendon fibers crossing the midline and intertwining with the linea alba.[5] The linea alba has been described as a "tendinous raphe" running from the symphysis to the xiphoid process.[6] Unlike other tendinous structures in which the collagen fibers are organized in parallel with the line of action of the tendon, *in vitro* studies of linea alba architecture show a more complex structure with arrangements of both longitudinal, transverse and oblique collagen fibers.[7-9] In parous women a higher proportion of transverse collagen fibers has been reported.[7]

While it is a cosmetic concern for many women, DRA has also been postulated to increase low back and pelvic girdle pain and be related to pelvic floor dysfunctions including urinary

incontinence, anal incontinence and pelvic organ prolapse,[10-12] the scientific support for this is, however, sparse.[13]

DRA is diagnosed by measuring the distance between the medial borders of the 2 rectus abdominis muscles, the so-called inter-rectus distance (IRD). Measurement methods include palpation and estimates with finger widths, calipers or ultrasound.[14] Ultrasound has been found to have the best intra- and inter-tester reliability with intraclass correlation coefficients (ICC) having greater values than 0.9.[15] However there is, as yet, no agreement on the definition and cut-off values for DRA or normal IRD values.[14] For example, using palpation Candido et al[12] classified a mild DRA as an IRD > 25 mm while holding a curl-up position immediately after delivery, whereas Mota et al[16] used ultrasonography to report normal IRD values ranging from 17 to 28 mm when measured 2 cm 6 months postpartum.

Over the last decades it has been suggested that certain abdominal and PFM exercises are effective in preventing and treating DRA. For example, Noble suggested that the condition should be treated using a head lift with a simultaneous active manual 'pull together' of the abdomen with the patients hands.[17] Sapsford et al[18] questioned the relevance of the trunk curl and suggested exercises to provide stability of the spine, such as 'in-drawing' via a co-contraction of the PFM. Recently, Tupler suggested a combination of in-drawing and head lift while wearing a splint.[19] Throughout the years, the in-drawing exercise has been commonly recommended to treat low-back pain.[20] However, several researchers have disputed this effect,[21,22] and results from systematic reviews conclude that the effect of in-drawing is not superior to other exercises in the general adult population.[22,23] A systematic review only found low-quality evidence that exercises may reduce pregnancy-related low back pain.[24]

Curl-ups, in-drawing, and PFM exercises are examples of exercises included in randomized controlled trials (RCTs) to investigate the effect of conservative treatment in women with DRA.[25,26] Due to inconsistent results and the use of different training interventions, different cut-off points for DRA as well as outcome measures in the published RCTs,[25-31] there is as yet no consensus on which exercises are the most effective. Keeler et al[32] found that the most common exercises used by physical therapists to treat DRA were in-drawing (89 %) and PFM exercises (87 %). Several studies have shown that a correct PFM contraction causes co-contraction of TrA.[33-36] However, recent experimental studies have found that in-drawing and PFM contraction increase the IRD,[15,37,38] while curl-ups close the diastasis.[37-42]

Different theories have been espoused as to whether treatment for DRA should include exercises that lead to an immediate increase or an immediate decrease in IRD. Some authors have suggested that exercises that narrow the IRD during abdominal maneuvers may cause permanent reduction of IRD.[38,39] Others argue that tension caused by activating the TrA should be maintained on the linea alba during abdominal exercises in order to transfer force between the sides of the abdominal wall and thereby prevent protrusion of the abdominal contents.[41]

Apart from curl-up and in-drawing, the scientific evidence is sparse regarding the effects on IRD of using other commonly used abdominal- and PFM exercises. So, in light of the current lack of evidence, we have included eight exercises in the present study. We do not believe head lift, pelvic tilt and twisted curl-up have been investigated previously.

The objective of the study was to investigate the immediate effect of eight different abdominal and PFM exercises on the IRD in parous women diagnosed with DRA.

METHODS

Study design

This was a cross-sectional study investigating the immediate effect of eight different abdominal and PFM exercises on the IRD in parous women diagnosed with DRA. Written informed consent was obtained from all participants prior to participation, and the study was conducted in accordance with the Helsinki Declaration. The study was approved by the Regional Medical Ethics Committee (REK South-East 2018/2312) and the Norwegian Centre for Research Data (440860).

Setting

This was a university initiated and conducted study. All participants participated in a single visit to the laboratory of the Norwegian School of Sport Sciences for the clinical assessments between February and May 2019.

Participants

A convenience sample of 38 women diagnosed with DRA was recruited through women's health physical therapists, personal trainers, midwives and gynecologists/obstetricians, friends and acquaintances and by advertising in social media. Inclusion criteria were: Primi- and multiparous women > 6 weeks postpartum, > 18 years old, a diagnosis of DRA and being able to understand instructions in Norwegian. Exclusion criteria were any neurological diseases, systemic musculoskeletal diseases or psychiatric diagnoses.

Variables

The main outcome measure is the change in IRD.

Data sources/Measurements

An initial screening of participants using palpation to confirm DRA was performed prior to the ultrasound assessments. DRA was confirmed if the assessor palpated an IRD of 2 finger widths or more during a curl-up, or if there was an observable protrusion during an abdominal curl-up. Following this initial screening, 2D real-time ultrasonography was conducted to ultimately include the participants using a cut-off point of DRA > 25 mm, 2 cm above or 2 cm below the umbilicus.[12] Women with an observable protrusion during a curl-up were included in the analyses, even if IRD was < 25 mm above and below the umbilicus. Ability to perform a correct PFM contraction was also assessed by transabdominal real-time ultrasound imaging.[43] The abdominal and PFM exercises were conducted in random order. One trained physical therapist, who had undergone specific training in ultrasound imaging of the PFM and abdomen prior to data collection, performed all assessments. Twenty images were captured for each participant. To blind the assessor, images were transferred from the hard disk to a software program (MicroDicom) and analyzed offline. The same physical therapist performed both the ultrasound assessments and the off-line analyses.

Electronic questionnaire

Two days before the scheduled clinical assessments, an electronic questionnaire was emailed to all participants to gather information on background variables. This had to be completed prior to the clinical assessment.

Other assessments

Height and weight were measured at the clinical assessment, and BMI was calculated for all participants.

Measurement of ability to perform a correct PFM contraction and the in-drawing exercise

Prior to their assessment, women were instructed verbally on how to perform a correct PFM contraction using an anatomical model. A correct voluntary PFM contraction is defined as an

inward lift and a constriction of the pelvic openings.[44,45] Ability to contract the PFM was assessed by a portable 2D ultrasound machine with a convex transducer (GE Healthcare – Logiq e R7, GE>8C-RS - 2-5 MHz Convex), following a bladder filling protocol.[43] The protocol involved consuming 600-750 ml of water during a 30-minute period, completed half an hour prior to the PFM testing. Participants lay supine with flexed hips and knees with feet resting on a plinth[43] while being assessed for their ability to contract their PFM. The transducer was placed suprapubically in the mid-sagittal plane and confirmation of a correct PFM contraction came from observing a cranioventral displacement of the PFM in the sagittal plane[43]. The ultrasound screen was used to provide biofeedback to the participants during their attempts to contract their PFM. After completing the test of ability to contract the PFM, participants were asked to empty their bladder.

The ability to perform in-drawing, which is mainly conducted by activating TrA, if performed correctly,[15] was tested in all women prior to conducting the eight experimental exercises. A correct in-drawing can be confirmed by observing the change of muscle thickness in TrA via real-time ultrasound imaging of the lateral abdominal wall at the level of the umbilicus.[36,38,46] All other exercises were instructed by the same physical therapist following a standard procedure, and the participants practiced the exercises under supervision before ultrasound assessment of their IRD began.

IRD measurements

A portable 2D ultrasound machine with a linear transducer (GE Healthcare –Logiq e R7, GE>12L-RS - 5-13 MHz Wideband Linear Probe) was used to assess any changes in IRD. Ultrasound imaging has shown to be a reliable method to measure IRD with good intra-rater reliability (ICC > 0.90) and acceptable inter-rater reliability (ICC 0.74-0.90).[15] To standardize the measurement locations 2 marks were made on the skin, one 2 cm above and one 2 cm below the center of the umbilicus.[15,38,40] Ultrasound gel was used during the IRD

measurements, and the transducer was placed transversely and centered over each skin mark. To avoid a reflexive response of the abdominal muscles, the assessor tried not to apply any pressure on the abdomen[15]. Panoramic imaging was used when the investigator was unable to visualize the entire width of the linea alba.[47] Images were taken 2 cm above and 2 cm below[38] the umbilicus during rest and during the following exercises, the order of which were randomized: head lift, curl-up, PFM contraction, PFM contraction + curl-up, maximal in-drawing, PFM contraction + maximal in-drawing, pelvic tilt, and twisted curl-up. For the 2 combined exercises, indicated here with a '+' sign, the subjects contracted in the following order: PFM contraction + curl-up, and PFM contraction + maximal in-drawing. For each image, participants were instructed to first inhale and then exhale so an image could be taken at the end of the exhalation. The participants were instructed to hold each contraction for 3 seconds. Operational definitions of the eight exercises are presented in Table 1. The end position for the ultrasound assessment of IRD during the head lift, curl-up, pelvic tilt, and twisted curl-up exercises are illustrated in Figure 1. Likewise, the position for IRD measurements during rest, maximal in-drawing, PFM contraction, PFM contraction + maximal in-drawing are illustrated in Figure 2.

Bias

To address potential sources of biases, one physical therapist conducted all measurements in blinded fashion, was trained in correct assessments, and followed standardized protocols.

Sample size

Based on a former study[38] reporting IRD change (rest vs. drawing-in) of 2.5 mm (SD 5.2) an *a priory* power calculation was performed. With 80 % power and a 5 % significance level, at least 36 women were needed for the present study.

Quantitative variables

The main outcome measure was change in IRD, and the sample was analyzed as one group.

While IRD during twisted curl-up was assessed for both left and right side, a mean of left and right measurements was used for the analysis.

Statistical methods

All statistical analyses were performed using SPSS statistical software package, version 24 (SPSS Inc., Chicago IL, USA). Background variables are presented as means with SD or numbers with percentages. Checks showed that all the IRD data were normally distributed. Paired t-tests were used to examine the differences between IRD at rest and during all of the eight exercises. Results are presented as means with 95 % confidence intervals (CI) and a P-value of < 0.05 was used.

ROLE OF THE FUNDING SOURCE: The funder of this study, the Norwegian Women`s Public Health Association, played no role in the design, conduct, or reporting of this study.

RESULTS

Forty-five women agreed to participate in the study. Four women were excluded after the initial palpation screening. In addition, 2 women were excluded from the analyses as they did

not meet the cut-off value for mild DRA on ultrasound assessment.[12] One woman was excluded from participation due to neurological disease. Hence, 38 women were finally included in the study. Table 2 presents the background variables of the participants.

Of the total sample, 97.4 % were married/cohabitating, had a college/university education and were of Caucasian genetic origin. Two women had one twin birth each. Mean parity was 2.1 (range 1-4).

An observable protrusion was found in 19 women (50 %). Two of these women had an observable protrusion with an IRD assessed by ultrasound of < 25 mm above and below the umbilicus. According to the cut-off point by Candido et al,[12] 19 women (51.4 %) were classified with mild DRA (< 25 mm), 14 (37.8 %) with moderate DRA (25-50 mm) and four (10.8 %) with severe DRA (> 50 mm). Transabdominal real-time ultrasound revealed that five (13.1 %) were unable to perform a correct PFM contraction. Therefore, the IRD measurements involving a PFM contraction for these women are reported as missing. Table 3 presents the mean IRD at rest and during the eight different exercises.

Mean differences in IRD between rest and during each of the eight exercises are presented in Table 4.

Exercises decreasing the IRD

There was a significant decrease in IRD during head lift and twisted curl-up compared with rest, both at 2 cm above and 2 cm below the umbilicus. Above the umbilicus, a significant decrease in IRD was found during curl-up compared with rest and during PFM contraction + curl-up compared with rest. Other exercises that did not cause statistically significant decreases are shown in Table 3.

Exercises increasing the IRD

A statistically significant increase in IRD, below the umbilicus, was found during PFM contraction compared to rest, maximal in-drawing compared to rest and maximal in-drawing + PFM contraction compared to rest. For measurements above the umbilicus none of the exercises increased the IRD.

DISCUSSION

Key results

Head lift and twisted curl-up were the only exercises that significantly decreased the IRD, both above and below the umbilicus. In addition, curl-up decreased the IRD, above the umbilicus. PFM contraction, maximal in-drawing, and maximal in-drawing + PFM contraction increased the IRD below the umbilicus.

Exercises decreasing the IRD

Head lift led to a statistically significant decrease in IRD above and below the umbilicus. This corroborates a recently study[42] that also used ultrasound imaging and standardized measurements locations and measurements procedures to measure IRD. However, since those authors included women both with and without DRA, only eleven women were classified with DRA and no measurements were included below the umbilicus. Hence, the results might not be comparable.

To the authors` knowledge, this is the first study to investigate the immediate effect of twisted curl-up on IRD in women diagnosed with DRA. The study showed that twisted curl-up decreased IRD significantly both above and below the umbilicus.

When measured above the umbilicus during a curl-up, the decrease in IRD relative to resting IRD values corroborated previously published studies.[37-42] In contrast to the present

study, one of those studies[39] found a significant decrease in IRD during curl-up, for measurements below the umbilicus ($p = .012$).

Above the umbilicus, PFM + curl-up showed a statistically significant decrease in IRD compared to rest. To the authors` knowledge, this combination of exercises has not been investigated in earlier studies. Theodorsen et al[48] reported an increased IRD during PFM contraction. Our results indicate that curl-up may counteract the negative effect of the PFM contraction on the IRD.

Exercises increasing the IRD

In accordance with other ultrasound studies,[37,38,48] the present study found that in-drawing causes a statistically significant increase in IRD for measurements below the umbilicus. Mota et al[38] and Sancho et al[37] also measured above the umbilicus but, as in the present study, they only found a significant increase in measurements below the umbilicus. Time since last birth was greater in the present study compared to that in previous studies (24-26 weeks postpartum[38] and 10-weeks postpartum[37]). However, the population in those studies was similar to our study in the distribution of the mode of delivery. Hence the results may be comparable and show that IRD increases during the in-drawing exercise in women with longer time intervals since their last birth.

For measurements above the umbilicus Lee & Hodges[41] found that a curl-up with pre-activation of TrA via a PFM contraction led to less IRD narrowing than a normal curl-up without the pre-activation. In spite of this, they developed their distortion index and suggested that contraction of TrA may strengthen the linea alba and that this is a key factor in the rehabilitation of DRA. To date, the distortion index has not been validated. The concept of the distortion index is that an intact and unstrained linea alba does not distort during a curl-up due to tension created by contraction of the TrA.[41] However, whether contraction of the

TrA can have this effect on the linea alba is a hypothesis and needs to be further investigated. The relationship between the distortion index, IRD and mean and peak linea alba stiffness was evaluated by Beamish et al.[42] They reported that women with DRA demonstrated a higher distortion index compared to women without DRA. In addition, they reported that ICCs for within-rater reliability for the distortion index ranged from ICC=0.433 to ICC=0.869. Between-rater reliability ranged from ICC = 0.746 to 0.766. Based on this, the researchers questioned the implication of the distortion index in women with DRA.

Contrary to the results of the experimental studies on the immediate effect of a single contraction, a pilot RCT[29] found a significant difference in IRD in 2 groups training with in-drawing compared with an untreated control group. However, the study was small with only five to ten participants in each group, and the authors concluded that larger, robust and high-quality RCTs are needed to confirm these results.

Measurements above and below the umbilicus

In agreement with other studies,[37,49,50] the present study found a narrower IRD at rest below the umbilicus than above the umbilicus (Table 3).

It is noteworthy that poorer reliability coefficients have been reported for measurements below compared to above the umbilicus.[14,15] For example, only a moderate intra-rater reliability with an ICC of 0.50 was found below the umbilicus.[15]

The present study found an immediate decrease in IRD during head lift and twisted curl-up both above and below the umbilicus. Curl-up led to a decrease only for measurements above the umbilicus. However, an increase in IRD during PFM contraction and maximal in-drawing was only found for measurements below the umbilicus. A possible explanation for the observed differences below and not above the umbilicus might be due to the different tendinous fibers from the abdominal muscles in the anterior and posterior rectus sheath above

and below the umbilicus. In addition, a regional variation in the morphology of the linea alba, with more transverse collagen fibers than oblique collagen fibers below the umbilicus being reported in women, may also explain the observed differences being below but not above the umbilicus.[7-9]

Interpretation

The mean IRD above the umbilicus during a curl-up in the present study was 34.5 mm (SD 10.6). The highest reported mean IRD during a curl-up in previously published studies[37-39,41,42] was 23 mm (SD 11.5) above the umbilicus.[42] Although all studies found a significant decrease in IRD when compared to rest, the mean IRD values during curl-up in the above-mentioned studies do not classify as a DRA according to Candido et al.[12] We chose the cut-off point set by Candido et al[12] because they classified DRA into severity groups. In addition, cut-off of ≥ 2 finger widths have been used in several studies[4,51] and is the most commonly used method in clinical practice.[32] That is the reason we used palpation as the inclusion criteria prior to the real-time ultrasound assessment in the present study. Moreover, van de Water & Benjamin[14] concluded that finger widths can be a valid assessment to separate between presence or no presence of DRA, but not to measure changes in IRD. That is the reason we used real-time ultrasound to measure change in IRD during each of the eight exercises.

Limitations and strengths

One limitation of the present study was that the assessments were not limited to a single time point after delivery. Time since last birth was ≥ 12 months in 65.8 % of the total sample. By contrast, the time since the last birth varied between ten weeks and one year postpartum in earlier studies.[37,38,42,48] The results of the present study may therefore not be comparable with

the studies assessing women up to 12 months postpartum. Unfortunately, the small sample sizes of our subgroups (mild, moderate and severe DRA, or women with vaginal birth or Cesarean section) precluded statistical analysis of any sub-group differences. In regarding to our statistical analyses, the present study aimed to test whether each of the eight exercises decreased DRA above and below the umbilicus. Each t test relates to one of the eight specific exercises. Four of eight tests were significant, both for measurements above and below the umbilicus. Therefore, these findings are likely to be reliable. While some might argue that we should have used a Bonferroni correction, but such a correction would only be appropriate if multiple outcomes were used in an intervention study where multiple testing could yield statistical significance by chance. Moreover, the disadvantages of using Bonferroni, or other adjustments for multiple testing are well documented.[52,53]

The strengths of the present study include the use of 2D real-time ultrasonography to measure both IRD and the confirmation of correct in-drawing and PFM contraction. We also included head lift and twisted curl-up, exercises that, as far as we know, had not been studied when the protocol for this study was finalized. An additional strength is that 2D ultrasonography has been shown to be a reliable and valid method to assess IRD.[14,15] In addition, a trained physical therapist conducted all the ultrasound assessments. Furthermore, because the analyses of the ultrasound images were performed offline, this allowed the assessor to be blinded for the IRD measurements during the eight different exercises. In addition, the eight exercises were performed in random order with standardized instructions. As earlier studies assessing the immediate effect of exercises have included only women with normal and mild diastasis,[37-42,48] we aimed to also include women with moderate (n = 14) and severe diastasis (n = 4).[12] Finally, our study was based on a power calculation enabling us to detect statistically significant differences between rest and the different exercises.

Recommendations for clinical practice

In recent years women with DRA have been discouraged from doing curl-ups,[51] while in-drawing has been recommended as a gentle exercise to decrease the IRD.[49,54] The majority of women`s health physical therapists have reported prescribing in-drawing and PFM exercises for the treatment of DRA,[32] a practice that might be questioned based on the results of the present study. Head lift, twisted curl-up and curl-up all decreased the IRD. Whether or not these exercises might be able to cause a permanent reduction in IRD over time is a hypothesis that should be tested in a future RCT. Finally, results can differ between subjects so clinicians should assess IRD both above and below the umbilicus during chosen exercises.

Generalizability

The sample in the present study represents a heterogeneous population of women with DRA. We included both primi and multiparous women, in addition to women with vaginal births and Caesarean sections. However, more than half of these women were one year postpartum, so one cannot generalize these results to women less than a year postpartum. Finally, the results are limited to Caucasian women with a high educational level.

CONCLUSIONS

Head lift and twisted decreased the IRD both above and below the umbilicus. Maximal in-drawing and PFM contraction increased the IRD below the umbilicus. A randomized controlled trial is needed to investigate whether the head lift and twisted curl-up exercises can permanently narrow the IRD.

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Ethics Approval

This study was approved by the Regional Medical Ethics Committee (REK South East 2018/2312) and the Norwegian Centre for Research Data (440860). Written consent was obtained from all participants.

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Disclosures

The authors completed the ICMJE Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

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Table 1. Operational Definitions of the 8 Exercises in the Study[a]

Exercise	Operational Definition
Head lift	Supine position with flexed knees and hips and feet resting on the plinth. Arms resting alongside the body. Instruction: Lift head so the chin rest against the chest. The ending position is illustrated in Figure 1.
Curl-up	Supine position with flexed knees and hips and feet resting on the plinth. Arms crossed above the chest. Instruction: Lift head so the chin rest against the chest and lift the upper back until shoulder blades are off the plinth. The ending position is illustrated in Figure 1.
PFM contraction	Supine position with flexed knees and hips and feet resting on the plinth. Arms are resting alongside the body. Instruction: Contract muscles around all pelvic openings lifting upward and forward inside the pelvis. The test position is illustrated in Figure 2.
PFM contraction + curl-up	Supine position with flexed knees and hips and feet resting on the plinth. Arms crossed above the chest. Instruction: Contract muscles around all pelvic openings lifting upward and forward inside the pelvis. Hold contraction while you perform a curl-up. The test position is illustrated in Figure 2 and the ending position during a curl-up is illustrated in Figure 1.
Maximal in-drawing	Supine position with flexed knees and hips and feet resting on the plinth. Arms are resting alongside the body. Instruction: Pull the lower part of the abdominal wall in towards the spine as far as possible. The test position is illustrated in Figure 2.
PFM contraction + Maximal in-drawing	Supine position with flexed knees and hips and feet resting on the plinth. Arms are resting alongside the body. Instruction: Contract and lift upward and forward the muscles around all pelvic openings. Hold contraction while you perform a maximal in-drawing. The test position is illustrated in Figure 2.
Pelvic tilt	Supine position with flexed knees and hips and feet resting on the plinth. Arms are resting alongside the body. Instruction: Tilt your pelvis backwards and push the lower back down against the plinth. The ending position is illustrated in Figure 1.
Twisted curl-up	Supine position with flexed knees and hips and feet resting on the plinth. One arm resting alongside the body and the other hand behind the neck. Instruction: Lift head and the upper back obliquely up until the raised shoulder blade is off the plinth. The ending position is illustrated in Figure

	1.

[a]PFM = pelvic floor muscles

Table 2. Demographic and Other Characteristics of the Women Classified as Having DRA (N = 38)[a]

Variable	Total Sample (N = 38)
Age, y, mean (SD)	36.2 (5.2)
BMI, kg/m^2, mean (SD)	23.2 (3.6)
Weight gain last pregnancy, kg, mean (SD)[b]	15.8 (10.2)
Waist circumference, cm, mean (SD)	79.8 (8.7)
Parity 1 2 3 4	 4 (10.5) 28 (73.7) 5 (13.2) 1 (2.6)
Time since last birth < 6 months 6-11 months 1-3 years > 3 years	 2 (5.3) 11 (28.9) 19 (50.0) 6 (15.8)
Mode of delivery Vaginal Cesarean Both Vaginal and Caesarean	 26 (68.4) 8 (21.1) 4 (10.5)
Birthweight, g > 4,500 4,000 – 4,500 3,000 – 3,999 2,500 – 2,999 1,500 – 2,499 1,000 – 1,499 < 1,000	 1 (1.2) 19 (24.0) 45 (57.0) 9 (11.4) 3 (3.8) 2 (2.6) 0 (0.0)
Use of contraceptives Yes No	 15 (39.5) 23 (60.5)
Current breastfeeding [c] > 3 times or more/day 1-2 times/day Rarely/never	 13 (40.6) 2 (6.3) 17 (53.1)
Heavy lifting at work[d] Perform heavy lifting	 5 (16.7)

Rarely/never perform heavy lifting	25 (83.3)

[a]*Values are presented as numbers (percentages) of women unless otherwise indicated.*
BMI = body mass index, DRA = diastasis recti abdominis, PFM = pelvic floor muscles
[b] Total n = 35; 3 women did not answer this question in the questionnaire.
[c] Total n = 32; this question was only given to women who were < 3 years since last birth (valid percentages are reported)
[d] Total n = 30; this question was only given to women who were working (valid percentages are reported)

Table 3. Mean IRD (mm), With Standard Deviation (SD), at Rest and During Each of the 8 Exercises Measured 2 cm Above and 2 cm Below the Umbilicus (N = 38)[a]

Exercise	Measurement Location	
	2 cm Above Umbilicus Mean (SD)	2 cm Below Umbilicus Mean (SD)
Rest	43.6 (12.7)	32.9 (13.1)
Head lift	33.5 (10.9)	26.8 (9.4)
Curl-up[b]	34.5 (10.6)	30.2 (10.0)
PFM contraction[c]	43.9 (12.2)	35.2 (15.3)
PFM contraction + curl-up[d]	39.0 (10.7)	32.7 (10.5)
Maximal in-drawing	44.8 (13.6)	37.6 (16.1)
PFM contraction + maximal in-drawing	43.8 (12.8)	37.3 (14.5)
Pelvic tilt	43.4 (12.5)	32.7 (14.6)
Twisted curl-up	34.2 (11.0)	29.4 (9.9)

Table 4. Mean IRD Differences, Measured 2 cm Above and 2 cm Below the Umbilicus, Between the Measurement at Rest and During Each of the 8 Different Exercises[a]

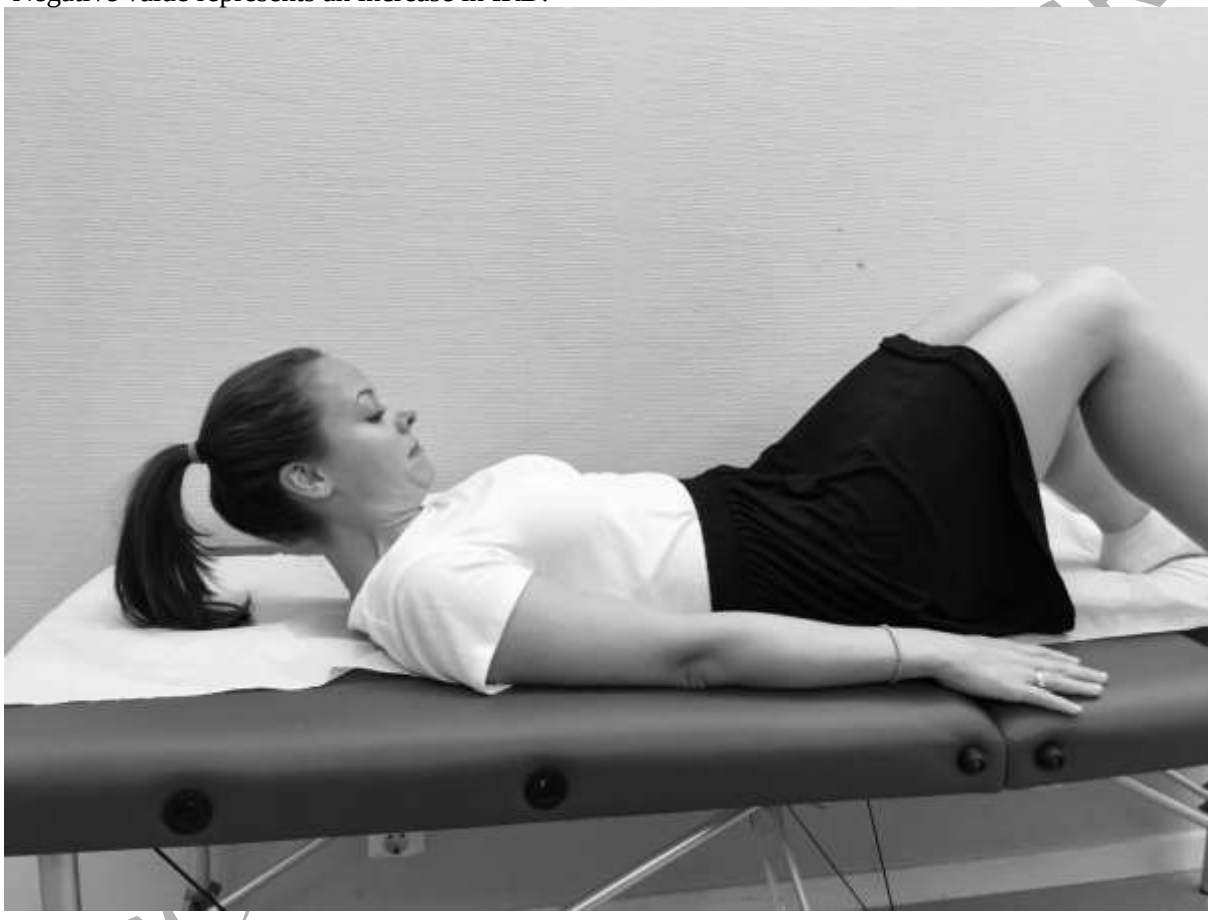
Probe	Exercise	Mean	95% CI of	*P*	Cohen

location		difference	the difference		d
2 cm above umbilicus	Rest vs head lift	10.0	7.0 to 13.2	< **.01**[b]	1.06
	Rest vs curl-up	8.7	5.0 to 12.5	< **.01**[b]	0.77
	Rest vs PFM contraction	-0.2[c]	-2.5 to 2.2	.89	0.03
	Rest vs PFM contraction + curl-up	4.3	1.1 to 7.4	**.01**[b]	0.49
	Rest vs maximal in-drawing	-1.2[c]	-3.7 to 1.2	.31	0.16
	Rest vs PFM contraction + maximal in-drawing	-0.1[c]	-2.9 to 2.6	.93	0.17
	Rest vs pelvic tilt	0.2	-2.0 to 2.4	.84	0.03
	Rest vs twisted curl-up	9.4	6.3 to 12.5	< **.01**[b]	0.99
2 cm below umbilicus	Rest vs head lift	6.1	3.2 to 8.9|	< **.01**[b]	0.71
	Rest vs curl-up	2.3	-0.9 to 5.6	.15	0.24
	Rest vs PFM contraction	-2.8[c]	-5.2 to 0.5	**.02**[b]	0.41
	Rest vs PFM contraction + curl-up	-0.9[c]	-4.2 to 2.3	.57	0.10
	Rest vs maximal in-drawing	-4.7[c]	-7.2 to -2.1	< **.01**[b]	0.60
	Rest vs PFM contraction +	-5.0[c]	-7.9 to -2.1	< **.01**[b]	0.61

	maximal in-drawing				
	Rest vs pelvic tilt	0.2	-2.2 to 2.5	.90	0.03
	Rest vs twisted curl-up	3.5	0.5 to 6.4	**.02**[b]	0.40

[a]The 95 % confidence interval (CI) and effect size is also provided. IRD=inter-recti distance, PFM =pelvic floor muscles.

[b]Statistically significant (p >.05) values in bold.
[c]Negative value represents an increase in IRD.



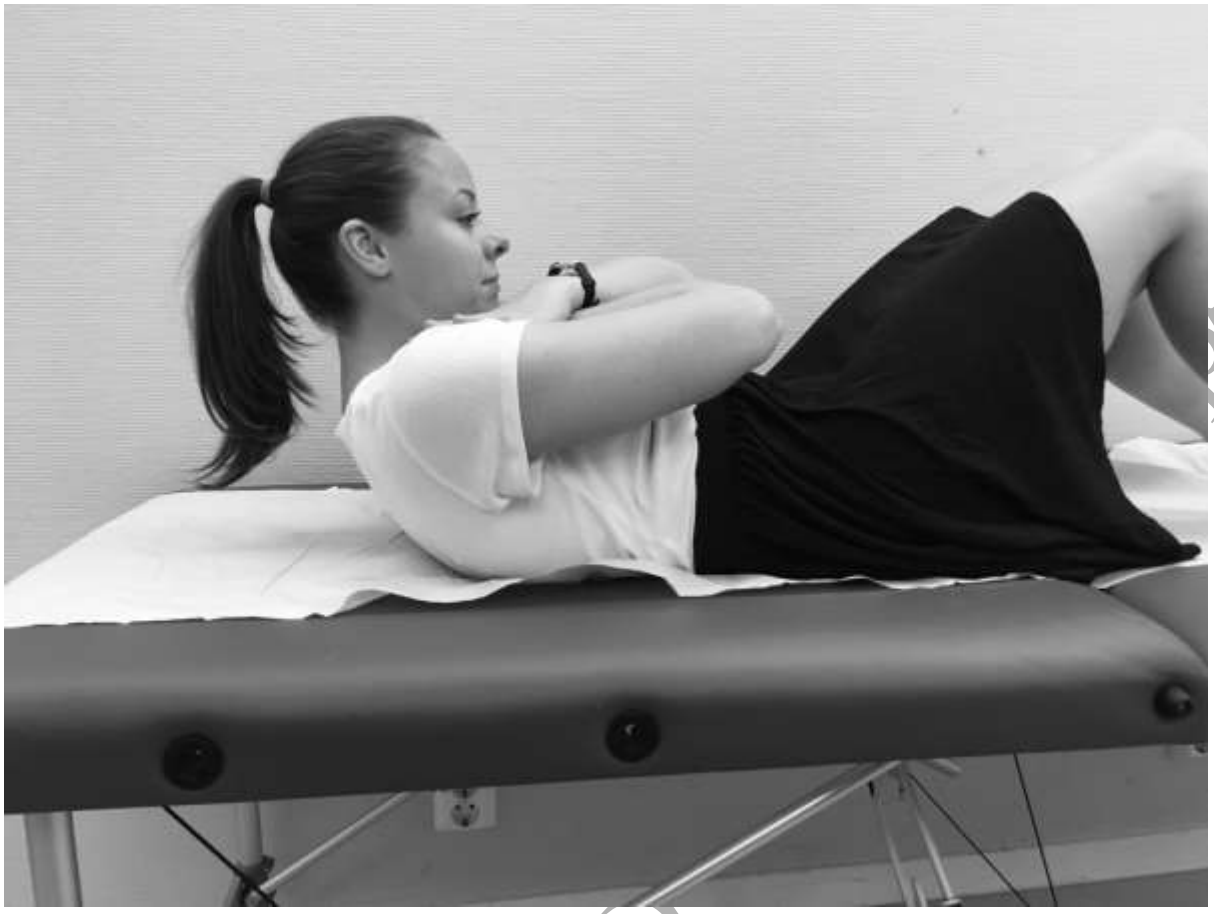


Figure 1. Illustration of four of the exercises performed in the study: (1) head lift (2) curl up, (3) pelvic tilt (4) twisted curl up. Reproduced with permission by Kristina L. Skaug.

Figure 2. Illustration of the test position during rest, maximal in-drawing, PFM contraction, PFM contraction + maximal in-drawing. Reproduced with permission by Kristina L. Skaug.