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Immediate Effect of Active Abdominal Contraction on Inter-recti Distance

STUDY DESIGN: Controlled laboratory study.

BACKGROUND: Inter-recti distance (IRD) is the measurement of the linear distance between the medial aspects of the rectus abdominis muscle. Inter-recti distance has been reported to decrease in postpartum women during a curl-up maneuver.

OBJECTIVE: To determine if IRD decreases with active abdominal contraction in men and in nulliparous and parous women.

METHODS: Fifty-six subjects (male, 11; nulliparous female, 22; parous female, 23) participated. Inter-recti distance was measured with the abdominal muscles at rest and during active contraction (curl-up), at 2 locations (above and below the umbilicus), using ultrasound imaging. A mixed-model, repeated-measures analysis of covariance was used for each of the 2 locations, to determine whether IRD differed between contraction states among the 3 groups, with age and umbilicus circumference as covariates. When significant differences were found, planned *t* test comparisons were made.

RESULTS: The parous group's IRD significantly decreased from rest to contraction at both locations, whereas the nulliparous and male groups' IRD did not significantly change from rest to contraction. The nulliparous group's IRD was significantly narrower than the other groups at rest at both locations, and narrower than the parous group during active contraction.

CONCLUSION: Parous women had a narrower IRD in the curl-up condition than at rest, as hypothesized. However, an unexpected finding of a lack of significant within-group change in IRD in nulliparous women and men occurred. Findings suggest that the IRD in men may only differ from that of nulliparous women. *J Orthop Sports Phys Ther 2016;46(3):177-183. Epub 26 Jan 2016. doi:10.2519/jospt.2016.6102*

KEY WORDS: *abdominal muscle, diastasis recti, linea alba, rectus abdominis, ultrasound imaging*

Inter-recti distance (IRD) is the linear distance between the medial aspects of the rectus abdominis, which spans the linea alba (LA). Inter-recti distance is typically evaluated in pregnant and postpartum women[12,19] to examine the integrity of the abdominal wall and the ability for contractile force to be transmitted across the LA.[36] Measurement of IRD is critical to evaluate the effectiveness of exercise to correct diastasis rectus abdominis (DRA).[5] A DRA is a structural impairment attributed to both the muscular and connective tissue of the anterior abdominal wall, which manifests as an abnormal midline separation of the rectus abdominis along the LA.[6,16]

The LA is a complex meshwork of connective tissue that comprises the tendinous insertions of the abdominal muscles, as well as the anterior and posterior rectus sheaths.[1] As an anterior anchor for all the abdominal muscles, deformation of the LA impacts muscle force transmission across the abdomen.[8] Of all abdominal wall structures, the LA is the stiffest, sustaining the highest mechanical stress under abdominal loading.[17] Compromise of the LA as a load-transfer structure can result in a variety of muscle dysfunctions, including disruption of the fixation for the rectus abdominis muscle within the rectus fascial sheaths,[1] an increase in rectus abdominis length and angle of insertion,[16] and decreased abdominal muscle strength and endurance.[16,20]

Integrity of the anterior abdominal wall, including the LA, is an important component of lumbopelvic stability. A link has been found between DRA and support-related pelvic floor dysfunction[31] and low back pain.[25,27,36] Surgical correction of DRA using a wide abdominal rectus plication has been shown to eliminate chronic low back pain in those who have failed conservative measures.[25,33,34] Oneal et al[25] reasoned that the success of this procedure was due to restoring spinal stability by tightening the lateral abdominal muscles and, consequently, the thoracolumbar fascia. Individuals with lumbopelvic pain[36] demonstrated significantly less abdominal muscle thickness and a wider IRD than controls. Parker et al[27] found that 74% of women seeking physical therapy for abdominal or lumbopelvic symptoms exhibited an IRD of greater than 2 cm and had significantly greater pain than those without DRA. Individual

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characteristics associated with an increase in the occurrence of DRA include age,[30] sex,[2,10,30] pregnancy,[6,16] parity,[4,10,12] obesity,[21,24,25,29] umbilical circumference of males,[11] and connective tissue disorders.[32] While the majority of research to date regarding DRA has been in pregnant and postpartum women, DRA is found in men as well.[11,21,22,30]

Regional differences exist in both connective tissue and muscular components of the abdominal wall. Above the umbilicus, the LA is thicker and contains larger fiber bundles than those below the umbilicus.[2] Similar regional variations in abdominal muscle morphology, such as muscle thickness and fascicle orientation, have been observed above and below the umbilicus.[35] Due to the variation in anatomical structure of the LA, DRA has been measured at various locations above and below the umbilicus along the LA,[4,10,12,19,22] which has resulted in a lack of agreement as to what qualifies as an abnormal IRD or a DRA.

Most of the research to quantify DRA has been in pregnant and postpartum women, using nulliparous women for comparison.[3,6,11,12,16,23] Only a few studies have been specifically designed to identify the normal width of the LA. Beer and associates[4] investigated nulliparous females using ultrasound imaging (USI) and determined that normal IRD is 2.2 cm above the umbilicus and 1.5 cm below the umbilicus. Rath et al[30] used computed tomography imaging to define normal IRD in males and females under 40 years of age, which was found to be 1.0 cm above, 2.7 cm at, and 0.09 cm below the umbilicus.

Clinically, the most frequently used method to assess IRD is palpation,[19] which uses the number of fingers placed between the medial borders of the right and left rectus abdominis muscles to measure the width of the IRD. Ultrasound imaging is a valid[13] and reliable method of measuring IRD[20,23] that improves on the accuracy of palpation measurements[4,12,19] and is becoming more available to physical therapists. Regardless of the method employed, IRD can be measured with the abdominal muscles at rest in a hook-lying position[4,12] and during contraction in a partial curl-up position,[3,7,9,23] or under both conditions.[10,28]

TABLE 1 Participant Characteristics*

Characteristic	Male (n = 11)	Nulliparous (n = 22)	Parous (n = 23)
Age, y	37.0 ± 10	27.9 ± 5.9	39.2 ± 9.7
Body mass index, kg/m^2	30.0 ± 3.9	23.4 ± 4.0	22.6 ± 1.8
Umbilical circumference, cm	100.0 ± 10.2	79.5 ± 8.5	79.0 ± 5.3

**Values are mean ± SD.*

When performing a curl-up, the individual is in supine, with hips and knees flexed and arms placed on the shoulders or behind the head, and lifts the head, neck, and shoulders to raise the scapula off the plinth.[14,15,26] The exertion perceived from a curl-up has been shown to be light to very light, with minimal activity of the psoas, lumbar erector spinae, and latissimus dorsi. However, electromyography studies confirm that, during a curl-up, the upper rectus abdominis is activated at 51% to 53% of the maximum voluntary isometric contraction.[15] There is also a moderate activation of the lower rectus abdominis, external oblique, internal oblique, transversus abdominis,[14,15] and rectus femoris muscles[18] during a curl-up.

Inter-recti distance has been reported to decrease in postpartum women with an isometric contraction of the rectus abdominis during the curl-up maneuver.[28] Previously, when investigating the validity of caliper measurement of DRA in a convenience sample of males and nulliparous females, as well as parous females,[10] we noticed that the pattern of change in IRD was not consistent among all individuals during a curl-up. Because the curl-up is typically used as part of the measurement of IRD, an investigation of the response of IRD to this abdominal contraction is warranted. Therefore, the purpose of this investigation was to examine IRD at 2 locations (above and below the umbilicus) with the abdominal muscles at rest and during curl-up. Based on previous research,[28] we hypothesized that the IRD would be less when the individual actively performed a curl-up than during the resting condition.

METHODS

Participants

This is a secondary analysis of a previous study comparing digital calipers to USI for measuring IRD.[10] Fifty-six men and women between the ages of 18 and 65 years were recruited. Participants were excluded if they were pregnant, had a history of abdominal surgery, or had a rheumatologic or connective tissue disease.[31] The Columbia University Medical Center Institutional Review Board approved the study protocol. All participants reviewed and signed an informed-consent form.

Procedure

Data collection occurred from January 2010 through October 2011 at KIMA Center for Physiotherapy and Wellness and Columbia University, both in New York, NY. Each subject participated in a single data-collection session lasting approximately 30 to 45 minutes. Participants self-reported age, sex, and parity. Data collected by the examiner were height (centimeters) and umbilical circumference (centimeters) via tape measure, weight (kilograms) via digital scale, IRD (centimeters) via ultrasound, and body mass index (BMI) (kg/m^2). Umbilical circumference was measured at the level of the umbilicus with the individual in supine.

TABLE 2 Inter-recti Distance by Group: Above the Umbilicus

Condition	Male*	Nulliparous*	Parous*	Between-Group Differences: Male Versus Nulliparous†	Between-Group Differences: Male Versus Parous†	Between-Group Differences: Nulliparous Versus Parous†
At rest	1.62 ± 1.04	0.75 ± 0.43	2.03 ± 1.05	0.87 (0.36, 1.39)	−0.41 (−1.20, 0.37)	−1.28 (−1.77, −0.80)
P value	...	...	...	.002	.288	<.001
With contraction	1.45 ± 0.95	0.88 ± 0.45	1.69 ± 0.92	0.57 (0.08, 1.06)	−0.24 (−0.93, 0.46)	−0.81 (−1.24, −0.36)
P value	...	...	...	.025	.493	.001
Within-group change‡	0.17	−0.13	0.34	...	...	...
P value	.519	.089	.040	...	...	...

**Values are mean ± SD centimeters unless otherwise indicated.*
†Values are mean difference (95% confidence interval) unless otherwise indicated.
‡Rest minus contraction.

TABLE 3 Inter-recti Distance by Group: Below the Umbilicus

Condition	Male*	Nulliparous*	Parous*	Between-Group Differences: Male Versus Nulliparous†	Between-Group Differences: Male Versus Parous†	Between-Group Differences: Nulliparous Versus Parous†
At rest	0.74 ± 0.89	0.22 ± 0.29	1.05 ± 0.65	0.52 (0.10, 0.94)	−0.31 (−0.86, 0.24)	−0.83 (−1.14, −0.53)
P value	...	...	...	.017	.255	<.001
With contraction	0.48 ± 0.58	0.34 ± 0.36	0.72 ± 0.45	0.14 (−0.19, 0.47)	−0.24 (−0.61, 0.12)	−0.38 (−0.62, −0.14)
P value	...	...	...	.403	.187	.003
Within-group change‡	0.26	−0.12	0.33	...	...	...
P value	.214	.134	.012	...	...	...

**Values are mean ± SD centimeters unless otherwise indicated.*
†Values are mean difference (95% confidence interval) unless otherwise indicated.
‡Rest minus contraction.

The IRD measurements were obtained using a 5-MHz curvilinear USI probe (LOGIQ Book XP ultrasound unit; GE Healthcare, Waukesha, WI). The subjects were positioned in hooklying, with 1 pillow under the head. For the at-rest condition, the arms were at the sides. For the curl-up condition, subjects crossed their arms across the chest and rose until the spines of the scapulae cleared the surface of the plinth. A second examiner ensured that the scapular height was accurate. The USI probe was placed perpendicular to the contact surface at markings drawn at 4.5 cm above and below the midpoint of the umbilicus. Details of the USI technique, as well as intrarater reliability, have been previously reported.[10] One examiner (J.A.M.), who had specific training in USI and had used USI clinically for 7 years, performed image capture and IRD measurements for all participants. Intrarater reliability was very high, as intraclass correlation coefficients ranged from 0.90 to 0.98.[10] The standard error of measurement (SEM) ranged from 0.005 cm to 0.017 cm, and the minimal detectable difference (MDD) ranged from 0.015 cm to 0.048 cm.[10]

Statistical Analysis

Descriptive statistics included age, umbilicus circumference, BMI, and IRD by location and condition. The Levene test of equality of error variances was used to test for homogeneity of variance. The sample was allocated to 3 groups: men, nulliparous women, and parous women. An analysis of variance (ANOVA) was performed to determine whether age, umbilical circumference, and BMI were different between the groups. Where differences were found, covariates were added as appropriate. Two mixed-model, repeated-measures ANOVAs (within-group variable of condition and between-group variables of sex and parity) were used to test for differences in IRD between resting and

contraction conditions in men, nulliparous women, and parous women. A repeated-measures ANOVA was run for IRD above the umbilicus and another for below the umbilicus. When significant differences were found, planned *t* test comparisons were made. The a priori alpha level was set at .05. All statistical analyses were performed with IBM SPSS Statistics Version 21.0 (IBM Corporation, Armonk, NY).

RESULTS

The groups demonstrated significant differences in age, BMI, and umbilicus circumference (**TABLE 1**). Post hoc independent *t* tests indicated that nulliparous women were significantly younger than men ($P = .016$) and parous women ($P<.001$), and that men had significantly greater BMIs and umbilicus circumferences than nulliparous and parous women ($P<.001$). Given the strong correlation between BMI and umbilicus circumference ($r = 0.889$, $P<.001$), only age and umbilicus circumference were chosen as covariates in the mixed-model, repeated-measures analysis of covariance (ANCOVA). Inter-recti distances by group and condition, as well as the difference between resting and contraction states, are listed for both above the umbilicus (**TABLE 2**) and below the umbilicus (**TABLE 3**).

Above the Umbilicus

After accounting for age and umbilicus circumference, there was a significant main effect of group ($P<.001$, partial $\eta^2 = 0.279$) for the repeated-measures ANCOVA above the umbilicus; no significant main effect of condition ($P = .656$, partial $\eta^2 = 0.004$) or interactions between condition and covariates ($P \geq .124$, partial $\eta^2 \leq 0.08$) were found (**FIGURE 1**). Planned paired *t* tests indicated that the IRD did not differ between rest and curl-up for men ($P = .519$, partial $\eta^2 = 0.043$) or nulliparous women ($P = .089$, partial $\eta^2 = 0.131$); however, the IRD in parous women significantly decreased from rest to curl-up ($P = .04$, partial $\eta^2 = 0.179$). Planned independent *t* tests determined that the IRD of the nulliparous group was significantly narrower than those of men and parous women during the resting state and the contraction state; however, the IRD of men was not different from that of the parous group for either the resting or the curl-up condition (**TABLE 2**, **FIGURE 1**).

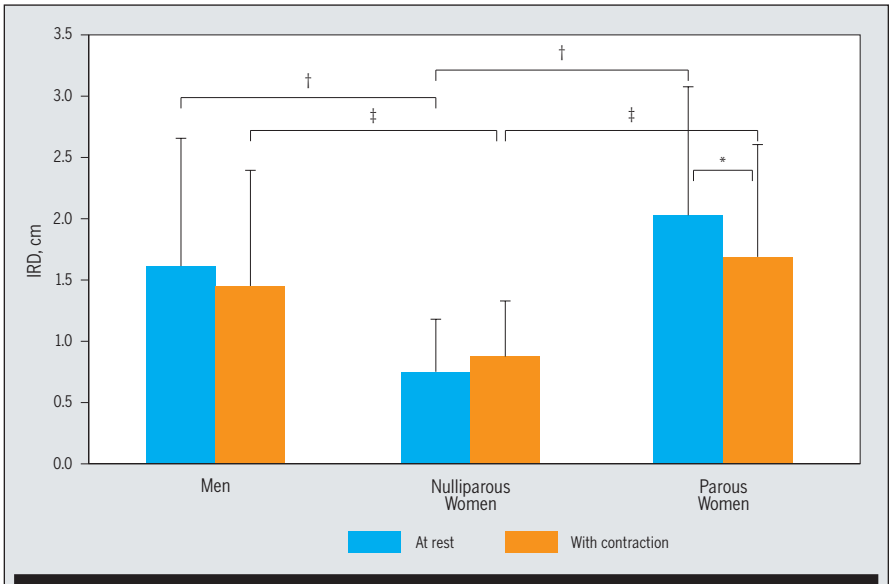

FIGURE 1. Mean ± SD IRD above the umbilicus for each condition (rest, contraction), by group. *Within-group difference for the parous group, $P = .040$. Between-group differences: †the nulliparous group IRD was narrower than that of the other groups at rest ($P \leq .002$) and ‡with contraction ($P \leq .025$). Mean age, 34.27 years; umbilical circumference, 83.416 cm. Abbreviation: IRD, inter-recti distance.

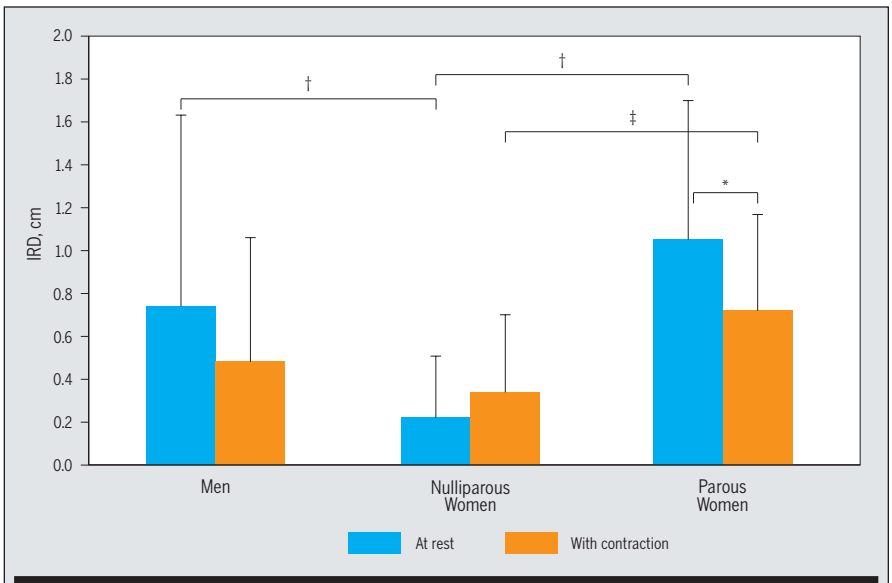

FIGURE 2. Mean ± SD IRD below the umbilicus for each condition (rest, contraction), by group. *Within-group difference for the parous group, $P = .012$. Between-group differences: †the nulliparous group IRD was narrower than that of the other groups at rest ($P \leq .017$) and ‡narrower than that of the parous group with contraction ($P<.003$). Mean age, 34.27 years; umbilical circumference, 83.416 cm. Abbreviation: IRD, inter-recti distance.

Below the Umbilicus

After accounting for age and umbilicus circumference, there was also a sig-

nificant main effect of group (P = .002, partial η^2 = 0.228) for the repeated-measures ANCOVA below the umbilicus; no significant main effect of condition (P = .578, partial η^2 = 0.006) or interactions between condition and covariates ($P \geq .082$, partial η^2 = 0.095) were found (**FIGURE 2**). Planned paired t tests indicated that the IRD did not differ between rest and curl-up for men (P = .214, partial η^2 = 0.150) or nulliparous women (P = .134, partial η^2 = 0.104). However, the IRD in parous women significantly decreased from rest to curl-up (P = .012, partial η^2 = 0.256). Planned independent t tests determined that the IRD of the nulliparous group was narrower than those of men and parous women during the resting state. However, during the curl-up, the IRD of the nulliparous group was only narrower than that of parous women. The IRD of the male group was no different from those of the nulliparous and parous groups below the umbilicus during the curl-up (**TABLE 3**, **FIGURE 2**).

DISCUSSION

This investigation explored the differences in IRD from the abdominal muscles at rest to a curl-up in a convenience sample. We hypothesized that IRD would decrease from rest to curl-up, yet only parous women demonstrated statistical differences in IRD between rest and curl-up. Though the effect size was small (partial η^2 = 0.179 above and 0.256 below the umbilicus), the narrowing at both locations was statistically meaningful, and the difference in IRD between contraction states surpassed the measurement error. This direction of change implies that the immediate effects of the curl-up are unlikely to worsen (widen) the IRD.

The IRD of parous women was significantly wider than that of nulliparous women for both locations and conditions (**FIGURES 1** and **2**). A wider IRD postpartum has been reported.[4,12,19] Liaw et al[20] found that IRD, both at rest and during muscle activation, did not return to normal at 6 months postpartum and that a wider IRD was negatively correlated with abdominal muscle strength and endurance. The parous women in our sample averaged 8.2 years since delivering their last child. Our results support the assertion that IRD does not return to the original width following childbirth. However, prospective data that compare a woman's prepregnancy IRD to postpartum IRD are needed to confirm this assertion.

While there is no consensus in the literature, definitions of DRA and normal IRD tend to cluster around 2.0 cm or greater and less than 2 cm, respectively.[27] Using a definition of 2.0 cm or greater for DRA, 14 of our subjects (4 men and 10 parous women) exhibited a DRA above the umbilicus at rest (2.58 ± 0.58 cm). Eleven subjects (3 men and 8 parous women) exhibited a DRA above the umbilicus during the curl-up (2.76 ± 0.46 cm). Below the umbilicus, only 2 subjects (1 man and 1 parous woman) displayed an IRD of 2.0 cm or greater at rest (2.70 ± 0.04 cm). This study was not designed to investigate subjects with a known DRA, yet a quarter of the subjects exhibited a DRA above the umbilicus.

Our 3 groups differed in age, which has been shown to increase IRD.[1,30] In this investigation, men and parous women were significantly older than nulliparous women, and therefore age was used as a covariate. After accounting for differences in age, the men in this study exhibited a small but not significant decrease in IRD width from rest to curl-up. Sex differences in IRD have been found in cadaver studies.[2,11] While there are limited studies examining IRD in men, Moesbergen et al[22] found that 63% of normal males with an average age of 71 years exhibited DRA, measured with the abdominal muscles at rest. It is possible that Moesbergen et al[22] reported such a large percentage of DRA in males due to age alone. More research is necessary to determine normal IRD of males in relation to age.

The average IRD decrease from rest to curl-up in men exceeded 1 SEM; however, there was a high degree of variability and a small sample size, which likely contributed to the lack of a significant difference between the 2 states in this group (**FIGURES 1** and **2**). Although these small changes did not reach statistical significance, they exceeded the SEM of 0.012 cm and MDD of 0.032 cm above the umbilicus, and the SEM of 0.017 cm and MDD of 0.048 cm below the umbilicus.[10] Within this context, though the changes in IRD from rest to curl-up are measured in millimeters in our subjects, the magnitude is far removed from the measurement error and outside of the minimal detectable change value. Research is warranted to determine whether this small change was insignificant due to a lack of power or whether this unexpected small increase in IRD is of concern clinically.

The IRD at rest in our nulliparous group was smaller than that reported by Beer et al[4] and Coldron et al,[12] but comparable to the IRD width reported by Liaw et al[20] both above and below the umbilicus. The age of our nulliparous subjects was similar to that of previous studies.[4,12,19,28] In our study, there was no measurable IRD at rest in 3 nulliparous women above the umbilicus and in 13 nulliparous women below the umbilicus. A floor effect could have occurred, as women who exhibit an extremely small IRD at rest cannot decrease IRD further with contraction. The discrepancies in IRD reported in nulliparous women by different researchers suggest that not all nulliparous women present similarly. Further research is needed to determine if these findings are consistent across a larger sample of nulliparous women.

Clinical Relevance

Actively flexing the trunk during a curl-up is a common exercise used in both training and rehabilitation to strengthen the abdominal musculature and is frequently prescribed to decrease IRD in postpartum women with DRA.[18] Given that IRD sig-

nificantly narrowed when measured during a curl-up, the curl-up appears to be an exercise that may reduce DRA in parous women. We recommend that IRD be measured at rest and during contraction prior to initiating any abdominal exercise, to ensure that IRD does not increase with contraction. Further research is needed to determine whether the absolute width of the IRD and the ability to decrease IRD with muscle activation improve function.

Limitations

This study examined the immediate response of IRD to a curl-up in a convenience sample. This investigation is a secondary analysis of previously reported data and, as such, the original study was not designed to examine factors that impact the size of IRD. The small sample of convenience may not be representative of IRD in the larger normal population and cannot be generalized to individuals with a specific DRA and associated impairments.

All participants in this investigation used their self-selected, preferred muscle strategy during a curl-up. We did not examine muscle contraction with electromyography or USI and did not instruct the participants on abdominal muscle activity. Therefore, we are unable to determine whether muscle activity and instruction might have influenced IRD.

CONCLUSION

This study indicates that in parous women, IRD decreased from rest to curl-up. This study supports the evidence that DRA may be improved with appropriate exercise for women who have been pregnant. We strongly recommend that specific attention to the individual pattern of change in IRD displayed during abdominal activities be considered in prescribing exercises to diminish excessive IRD width. Future research should be directed toward examining factors that impact IRD in males and nulliparous females as well. ◉

KEY POINTS

FINDINGS: In parous women, IRD decreased with curl-up.

IMPLICATIONS: Not all individuals decrease IRD with curl-up. Inter-recti distance should be measured at rest and during contraction prior to initiating any abdominal exercise to ensure that IRD does not increase with contraction. Further study is needed to examine the factors contributing to this finding.

CAUTION: This investigation was a secondary analysis of a convenience sample and cannot be generalized to a population with specific DRA-associated impairments.

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