

SURAT KETERANGAN

Nomor: 1182/UNUSA-LPPM/Adm-I/VII/2023

Lembaga Penelitian dan Pengabdian Kepada Masyarakat (LPPM) Universitas Nahdlatul Ulama Surabaya menerangkan telah selesai melakukan pemeriksaan duplikasi dengan membandingkan artikel-artikel lain menggunakan perangkat lunak **Turnitin** pada tanggal 04 Juli 2023

Judul : Implementation of Examining Inter Rectus Distance of Post Partum Women with Diastasis Recti Abdominalis

Penulis : Rizki Amalia, Elly Dwi Masitha, Yunik Windarti, Lailatul Khusnul Rizki, Esty Puji Rahayu

No. Pemeriksaan : 2023.07.04.402

Dengan Hasil sebagai Berikut:

Tingkat Kesamaan diseluruh artikel (*Similarity Index*) yaitu 5%

Demikian surat keterangan ini dibuat untuk digunakan sebagaimana mestinya.

Surabaya, 04 Juli 2023

Ketua LPPM



UNUSA
LPPM

Achmad Syafiuddin, Ph.D

NPP: 20071300

LPPM Universitas Nahdlatul Ulama Surabaya

Website : lppm.unusa.ac.id

Email : lppm@unusa.ac.id

Hotline : 0838.5706.3867

Paper 6

by Rizki Amalia

Submission date: 04-Jul-2023 09:23AM (UTC+0700)

Submission ID: 2126239815

File name: ance_of_Post-_Partum_Women_with_Diastasis_Recti_Abdominalis.pdf (105.23K)

Word count: 4611

Character count: 24650

ORIGINAL ARTICLE

Implementation of Examining Inter Rectus Distance of Post-Partum Women with Diastasis Recti Abdominalis

Rizki Amalia, Elly Dwi Masitha, Yunik Windarti, Lailatul Khusnul Rizki, Esty Puji Rahayu

Department of Nursing, Faculty of Nursing and Midwifery, Universitas Nahdlatul Ulama Surabaya, 60237 Surabaya, East Java, Indonesia

ABSTRACT

Introduction: To determine the value of shear wave elastography (SWE) in assessing abdominal wall muscles, including rectus abdominis (RA), external oblique muscle (EO), internal oblique muscle, and transversus abdominis (TrA) in patients with diastasis recti abdominis (DRA) and healthy controls. **Methods:** From October 2018 to December 2019, 36 postpartum DRA patients and 24 nulliparous healthy women were identified. Inter-rectus distance (IRD) measurements were taken by B-mode ultrasound. Shear wave speed (SWS) values were acquired by one operator at ten specific locations. Clinical and ultrasound variables, including demographics, IRD, muscle thickness, and muscle SWS, were compared between the two groups using Student's t test or Fisher's exact test. Pearson correlation analyses were conducted for the variables of IRD, muscle thickness, and SWS in the 36 DRA patients. **Results:** The maximum diameter of recti abdominis separation was located at the umbilicus in DRA patients (4.59 ± 1.14 cm). The SWS value was significantly lower in the RA ($p=0.003$) and higher in the TrA muscle ($p < 0,001$) in DRA patients compared with the age-matched controls. However, SWS in both muscles (RA and TrA) showed a statistically positive correlation with IRD ($p < 0,05$). In addition, the SWS value in EO statistically decreased in DRA patients compared with the healthy controls (1.65 ± 0.15 vs. 1.79 ± 0.14 , $p=0.001$). **Conclusion:** The application of SWE to abdominal wall muscles in DRA patients is feasible. The correlation between SWS value and IRD in RA should be interpreted with caution.

Keywords: Postnatal period, Diastasis recti abdominis, Linea alba, Abdominal wall muscle

Corresponding Author:

Rizki Amalia., MPH
Email: amalia24@unusa.ac.id
Tel: +62855581002

INTRODUCTION

Diastasis recti abdominals (DRA) is the enlargement of the distance between the edges of the recti abdominis along the linea alba with no facial defect (1, 2). Normally, the rectus muscles are fused at the midline with no more than 1 to 2 cm separation (3). A significant number of women are affected by DRA during the pre-natal and postnatal periods (4), resulting in functional problems, such as back pain and hernia (5).

Clinically, DRA is evaluated by finger breadth. The widths of the two recti abdominis muscles are assessed by palpation 4.5 cm above and 4.5 cm below the umbilicus, along the linea alba (6). Separation is observed most commonly at the umbilicus. A width greater than or equal to the width of two fingers is defined as DRA (5). No separation or a width of less than two fingers is defined as no DRA. However, in the past twenty years, the reliability of palpation has been debated (1, 3, 4).

Therefore, prior studies investigated the application of advanced imaging technology, like B-mode ultrasound (US), on the evaluation of inter-rectus distance (IRD) measurement. Most studies demonstrate the superior accuracy and validity of imaging tools compared to palpation (7-9).

Clinical management of DRA is challenging (10). Based on the pathophysiology described by Baumann et al. (11), the combination of physiotherapy and surgical repair has the potential to improve the anatomical divarication and the laxity of the ventral abdominal muscles. In other words, the preoperative assessment of DRA is not solely a distance measurement problem. Individual preoperative evaluation of physiologic tension is important. Up to now, conventional modalities, including B-mode ultrasound, computed tomography, and magnetic resonance imaging, have been used to assess the IRD, but no functional biomechanical property evaluation was available. Therefore, an objective imaging assessment of the intrinsic abdominal muscle characteristics, such as the elasticity, is needed to predict successful treatment and disease progression.

In recent years, ultrasound shear wave elastography

(SWE) has been increasingly used to measure physiologic and pathologic muscle behavior due to its non-invasiveness, high accuracy, user-friendliness, and availability in commercial ultrasound scanners (12–14). However, no convincing evidence in the current literature has established the application of SWE for detecting muscle properties in DRA patients. Based on our previous study of SWE in incisional hernia patients (15), we hypothesize that the elasticity in rectus abdominis (RA) of DRA patients is significantly lower than that in healthy controls, while the elasticity of lateral abdominal wall muscles, including the external oblique (EO) muscle, internal oblique (IO) muscle, or transversus abdominis (TrA), is comparatively higher. This study aimed to determine the utility of applying SWE to the evaluation of abdominal wall muscles, including rectus abdominis, external oblique muscle, internal oblique muscle, and transversus abdominis, in patients with DRA and healthy controls, to assist in clinical management. No study has been reported on the SWE of abdominal wall muscles in DRA patients.

MATERIALS AND METHODS

Samples

This study was reviewed and approved by the Institute Ethics Committee of UNUSA. Informed consent forms were signed by all participants. The study protocol was registered in RSI Jemursari Clinical Registry Center. From October 2018 to December 2019, postpartum women suspected of DRA at the outpatient clinic in our institution were identified. Eligible subjects were recruited based on the following inclusion criteria: 1) age between 18 and 60 y/o; 2) IRD greater than or equal to 2-finger width on palpation, irrespective of the locations along the midline, measured in the standard supine crock-lying position with arms crossed over the chest; and 3) full-term fetus. The exclusion criteria for all postpartum women were as follows: (1) additional history of abdominal surgery or injury (except cesarean section); (2) chronic or degenerative pathology of the muscle (e.g., autoimmune myositis); (3) abdominal rehabilitation of neuromuscular electrical stimulation within the previous 6 months; and (4) inadequate clinical and ultrasound (US) imaging data. Nulliparous age-matched women were recruited from the physicians and nurses at our institution to participate as healthy controls. The exclusion criteria for the healthy participants were similar to that for DRA patients, including age (< 18 and > 60 y/o), surgery, and history. The clinical variables of age, weight, and height were recorded for each subject.

Instrument

Ultrasound images were obtained using a high-end scanner (Aixplorer, Supersonic Imagine, France) equipped with an SWE mode (general preset). The scanner was coupled with a linear array probe (SL10-2, Supersonic Imagine, and France). Elastography was performed to evaluate tissue elasticity. Elasticity is the

tendency of tissue to resist deformation against an applied force or to resume its original shape after removal of this force. A higher elastic modulus correlates with a higher resistance to deformation and an increased stiffness (16). Shear wave speed is a quantitative measure of tissue stiffness and can be converted to shear modulus using the following equation:

$$\mu_s = C_s^2 \rho$$

μ_s is shear modulus; C_s is shear wave speed (SWS) in this equation; and ρ is density, which can be assumed to be 1000 kg/m³ for all soft tissues (17). Higher speed values are associated with increased tissue stiffness. A senior radiologist (XW) with 10 years of experience in abdominal and musculoskeletal ultrasound imaging performed the IRD measurement on B-mode US and SWS measurement on SWE.

Data collection

The DRA patients underwent B-mode US examination of their anterior rectus abdominis sheath to evaluate the width of rectus diastasis. To standardize the position of the transducer, each measurement location was marked on the skin when the participant was resting in the supine position, with their arms across their chests. Additionally, special attention was paid to the pressure imposed on the probe to avoid reflexive responses from the participants. A thick gel layer was applied to replace the air gap between the US transducer and the targeted region.

According to the European Hernia Society (EHS) classification of midline incisional hernias (3), the transducer was placed transversely along the midline at five specific locations identified with skin markers in the following order: subxiphoidal, epigastric, umbilical, infraumbilical, and suprapubic location. The aforementioned locations were recorded as M1, M2, M3, M4, M5, respectively. Using the medial margins of both rectus abdominis muscles, the inter-rectus distance could be clearly identified, from one side of the anterior recti sheath to the corresponding position of its counterpart on the other side. Measurements were taken with an on-screen caliper to the nearest 0.1 cm. Finally, the maximum diastasis was recorded as the width of the recti abdominis separation in this study.

Further assessment of anatomical variations of rectus abdominis muscle diastasis by B-mode US was made based on a recent study by Corvino et al. (18), including the following five patterns: open only above the navel, open only below the navel, open at the navel level, open completely but wider above the navel, and open completely but wider below the navel.

Shear wave elastography measurement

After the IRD measurements, SWE was measured in the DRA patients and healthy nulliparous participants. Tissue SWS of the RA and lateral muscles (EO, IO, and TrA) were bilaterally measured. Based on our previous

experience (15) and the suggestions of Rath et al. (19), SWE measurements were taken on both the left and right sides of the abdomen as per the following guidelines:

1. Three locations were identified on each side of the RA region, the supraumbilicus (4.5 cm above the umbilicus), umbilicus, and subumbilicus (4.5 cm below the umbilicus).

2. Two locations were identified on each side of the abdomen along the anterior axillary line equidistant between the costal margin at the level of the ninth rib and a point anterior to the anterior superior iliac spine.

Each measurement was initiated with a B-mode acquisition of the muscle. The transducer was placed with light pressure to obtain the transverse view of the target muscle. To maximize intra-operator reliability and minimize the duration of transducer repositioning at the same location in each subject, 10 waterproof skin landmarks were drawn with a marker under 2D-mode monitoring by the same operator before SWE. The depth was set to optimize the target muscle centrally. Muscle thickness was obtained by measuring the length.

Ethical Clearance

This study was granted by Research Ethics Committee from Universitas Nahdlatul Ulama Surabaya, number 093/EC/KEPK/UNUSA/2019.

RESULTS

A power analysis was performed to determine the number of patients needed. We assumed that the mean value for mean trunk rotation torque was 37 (N·m) in DRA patients and 45.3 (N·m) in non-DRA patients, based on the data reported by Hills et al. (21). The probability was 80 percent that the study would detect a difference of 8.3, based on a standard deviation of 3.6, the mean trunk rotation torque, and a two-sided 0.05 significance level. Thus, 44 subjects (22 patients and 22 controls) were required for this retrospective study. Accordingly, 24 nulliparous healthy women were recruited for this study. From October 2018 to December 2019, 42 postpartum women suspected of DRA at our outpatient clinic were identified. After removing 6 patients, 36 patients were enrolled for the final analysis. Among the excluded patients were (a) 2 patients with IRD less than 2-finger width, (b) 1 patient with additional surgical history except for cesarean section, (c) 1 patient with recent abdominal rehabilitation of neuromuscular electrical stimulation, and (d) 2 patients without adequate ultrasound data. Table I shows the frequency distribution of respondents according to age, parity and degree of abdominal rectal diastasis.

DISCUSSION

Ultrasound is becoming more popular in the evaluation of different musculoskeletal abnormalities with excellent reproducibility (22). With the recent developments

Table I: Frequency distribution of respondents according to age, parity and degree of abdominal rectal diastasis (n=63)

Age	Frequency	Percentage (%)
Age		
≤ 20	5	6.7
21 - 35	25	83.3
≥ 36	3	10
Parity		
Primipara	29	16.7
Multipara	34	83.3
Degree of abdominal rectal diastasis		
DDR is normal	29	16.7
DDR is not normal	34	83.3

in ultrasound elastography, it is now possible to quantitatively evaluate the stiffness of muscle (12–14). There are several ultrasound elastography methods investigated around the world in the past twenty years, including strain elastography, acoustic radiation force impulse, shear wave elastography, and transient elastography (23). As a semiquantitative approach, strain ratio values generated by strain elastography depend significantly on reference and target region of interest being above the same tissue, while not influenced by depth (24). Shear wave speeds would probably decrease with increasing scanning depth (24). Comparatively, more recent studies demonstrated that, in terms of inter- or intra-operator variability, shear wave elastography is a more reliable and widely used tool for quantitatively assessing muscle stiffness (25–29). The main purpose of this study was to compare elasticity of abdominal wall musculature in individuals with and without DRA. Partially consistent with the first part of our hypothesis, we found a significantly lower SWS in the RA ($p = 0.003$) and a higher SWS in the TrA muscle ($p < 0.001$) in participants with DRA compared with the age-matched control group without previous pregnancy. However, the correlation between muscle elasticity and IRD should be interpreted with caution. As SWS in both muscles were positively correlated with IRD ($p < 0.05$), the greater the IRD, the higher the SWS in RA. In addition, the value of SWS in EO unexpectedly decreased in DRA patients (1.65 ± 0.15 vs. 1.79 ± 0.14 , $p = 0.001$). To the best of our knowledge, the present study is the first to reveal these findings about muscle elasticity in DRA patients based on the 10-location setting. The reliability of IRD measurement in postpartum women using B-mode ultrasound has been widely validated by multiple studies in the past decade (7–9). In response to our primary goal of muscle elasticity assessment, the ICC values obtained in the current study indicate moderate to high intra-operator reliability, especially for the RA and TrA muscles. This finding was in agreement with our previous study of SWE in incisional hernia patients (15). However, it was noted that the ICC values for EO and IO were relatively lower, which might be attributed to the impact of patient breathing on superficial oblique muscles (30). The maximum separation distance was

located at the umbilicus, which is in line with the DRA classification system suggested by Rath et al. (19). Contrary to Liaw's finding, no inter-rectus separation was found among the 24 nulliparous healthy subjects, irrespective of the locations along the midline (M1–M5). Of note, the mean age of the control subjects differed between the two studies (31.9 ± 4.1 vs. 26.7 ± 4.7 mm). However, both studies complied with the commonly accepted definition of DRA, with no more than 1 to 2 cm separation (3). Our study is unique in the use of SWE in 10-location settings to better quantify the elasticity of abdominal muscles in an objective approach. **Then the current evidence of morphological changes and abdominal muscle functional deficits present during pregnancy (8),** a group of nulliparous healthy women was enrolled as controls in this study. Generally, the range of SWS values acquired in the four abdominal wall muscles (0.85 – 2.08 m/s) was similar to the values reported by others (15, 25–28). From a biomechanical viewpoint, the abdominopelvic cavity is a cylinder enveloped by muscles, tendons, and bony structures. According to Pascal's principle (31), any pressure generated within the abdominopelvic cavity is transmitted equally to the walls of that cavity. In response to increased abdominal pressure, the muscular abdominal wall contracts to generate counter-pressure. If intraabdominal pressure exceeds abdominal wall pressure, the abdominal wall will rupture at its weakest point, causing herniation. Correspondingly, the rectus abdominis in DRA patients, which is considered the margin of the weakest point, displayed a lower SWS value than that in healthy controls, especially for the locations above and at the umbilicus. This difference in muscle elasticity should be considered when making treatment plans that include a combination of physiotherapy and surgical repair (11). However, subgroup analysis in 36 DRA patients showed a positive correlation between IRD and SWS. This can be explained by the biomechanical and pathological changes in muscle fibers as the inter-rectus separation increases (25–27). The composition of the RA, including muscle fibers, connective tissue, and adipose tissue infiltration, might vary at different stages of DRA progression, resulting in changes in shear wave speed at the later stage. Converse to our results in incisional hernia patients (15), the SWS of the EO muscle in DRA patients decreased in comparison with healthy subjects. This decrease mainly resulted from the biological and physical differences between the two studies.

CONCLUSION

The application of SWE to abdominal wall muscles in DRA patients is feasible. The correlation between SWS value and IRD in RA should be interpreted with caution.

ACKNOWLEDGEMENT

This work is supported by Nahdlatul Ulama University of Surabaya and RISTEKBRIN.

REFERENCES

1. Sperstad JB, Tennford MK, Hilde G, Ellstrum-Eng M, Bw K (2016) Diastasis recti abdominis during pregnancy and 12 months after childbirth: prevalence, risk factors and report of lumbopelvic pain. *Br J Sports Med* 50(17):1092–6. <https://doi.org/10.1136/bjsports-2016-096065>
2. Doubkova L, Andel R, Palascakova-Springrova I, Kolar P, Kriz J, Kobesova A (2018) Diastasis of rectus abdominis muscles in low back pain patients. *J Back Musculoskelet Rehabil* 31(1):107–12. <https://doi.org/10.3233/BMR-169687>
3. Reinhold W, Kuckerling F, Bittner R et al (2019) Classification of rectus diastasis—a proposal by the German Hernia Society (DHG) and the International Endohernia Society (IEHS). *Front Surg* 6:1. <https://doi.org/10.3389/fsurg.2019.00001>
4. Keshwani N, Mathur S, McLean L (2018) Relationship between interrectus distance and symptom severity in women with diastasis recti abdominis in the early postpartum period. *Phys Ther* 98(3):182–90. <https://doi.org/10.1093/ptj/pzx117>
5. Wang Q, Yu X, Chen G, Sun X, Wang J (2020) Does diastasis recti abdominis weaken pelvic floor function? A cross-sectional study. *Int Urogynecol J* 31(2):277–83. <https://doi.org/10.1007/s00192-019-04005-9>
6. Bw K, Hilde G, Tennford MK, Sperstad JB, Engh ME (2017) Pelvic floor muscle function, pelvic floor dysfunction and diastasis recti abdominis: prospective cohort study. *Neurourol Urodyn* 36(3):716–21. <https://doi.org/10.1002/nau.23005>
7. de Mendes A, Nahas FX, Veiga DF et al (2007) Ultrasonography for measuring rectus abdominis muscles diastasis. *Acta Cir Bras* 22(3):182–6. <https://doi.org/10.1590/s0102-86502007000300005>
8. Liaw LJ, Hsu MJ, Liao CF, Liu MF, Hsu AT (2011) The relationships between inter-recti distance measured by ultrasound imaging and abdominal muscle function in postpartum women: a 6-month follow-up study. *J Orthop Sports Phys Ther* 41(6):435–43. <https://doi.org/10.2519/jospt.2011.3507>
9. Mota P, Pascoal AG, Sancho F, Carita AI, Bw K (2013) Reliability of the inter-rectus distance measured by palpation. Comparison of palpation and ultrasound measurements. *Man Ther* 18(4):294–8. <https://doi.org/10.1016/j.math.2012.10.013>
10. Nahabedian MY (2018) Management strategies for diastasis recti. *Semin Plast Surg* 32(3):147–54. <https://doi.org/10.1055/s-0038-1661380>
11. Baumann DP, Butler CE (2019) Diastasis recti and primary midline ventral hernia: the plastic surgery approach. *Hernia* 23(5):1017–8. <https://doi.org/10.1007/s10029-019-02055-y>
12. Phan A, Lee J, Gao J (2019) Ultrasound shear wave elastography in assessment of skeletal muscle

- stiffness in senior volunteers. *Clin Imaging* 58:22–26. <https://doi.org/10.1016/j.clinimag.2019.06.006>
13. MacDonald D, Wan A, McPhee M, Tucker K, Hug F (2016) Reliability of abdominal muscle stiffness measured using elastography during trunk rehabilitation exercises. *Ultrasound Med Biol* 42(4):1018–25. <https://doi.org/10.1016/j.ultrasmedbio.2015.12.002>
 14. Lima K, Costa Junior JFS, Pereira WCA, Oliveira LF (2018) Assessment of the mechanical properties of the muscle-tendon unit by supersonic shear wave imaging elastography: a review. *Ultrasonography* 37(1):3–15. <https://doi.org/10.14366/usg.17017>
 15. Wang X, He K, Zhu Y et al (2020) Use of shear wave elastography to quantify abdominal wall muscular properties in patients with incisional hernia. *Ultrasound Med Biol* 46(7):1651–1657. <https://doi.org/10.1016/j.ultrasmedbio.2020.03.027>
 16. Sigrist RMS, Liao J, Kaffas AE, Chammas MC, Willmann JK (2017) Ultrasound elastography: review of techniques and clinical applications. *Theranostics* 7(5):1303–29. <https://doi.org/10.7150/thno.18650>
 17. Eby SF, Zhao H, Song P et al (2017) Quantifying spasticity in individual muscles using shear wave elastography. *Radiol Case Rep* 12(2):348–52. <https://doi.org/10.1016/j.radcr.2017.01.004>
 18. Corvino A, Rosa D, Sbordone C et al (2019) Diastasis of rectus abdominis muscles: patterns of anatomical variation as demonstrated by ultrasound. *Pol J Radiol* 84:e542–e548. <https://doi.org/10.5114/pjr.2019.91303>
 19. Rath AM, Attali P, Dumas JL, Goldlust D, Zhang J, Chevrel JP (1996) The abdominal linea alba: an anatomico-radiologic and biomechanical study. *Surg Radiol Anat* 18(4):281–8. <https://doi.org/10.1007/bf01627606>
 20. Linek P, Wolny T, Sikora D, Klepek A (2019) Supersonic shear imaging for quantification of lateral abdominal muscle shear modulus in pediatric population with scoliosis: a reliability and agreement study. *Ultrasound Med Biol* 45(7):1551–61. <https://doi.org/10.1016/j.ultrasmedbio.2019.03.001>
 21. Hills NF, Graham RB, McLean L (2018) Comparison of trunk muscle function between women with and without diastasis recti abdominis at 1 year postpartum. *Phys Ther* 98(10):891–901. <https://doi.org/10.1093/ptj/pzy083>
 22. Razeq AA, El-Basyouni SR (2016) Ultrasound of knee osteoarthritis: inter-observer agreement and correlation with Western Ontario and McMaster Universities Osteoarthritis. *Clin Rheumatol* 35(4):997–1001. <https://doi.org/10.1007/s10067-015-2990-2>
 23. Shimoyama D, Shitara H, Hamano N et al (2001) (2021) Reliability of shoulder muscle stiffness measurement using strain ultrasound elastography and an acoustic coupler. *J Med Ultrason* 48(1):91–96. <https://doi.org/10.1007/s10396-020-01056-0>
 24. Ewertsen C, Carlsen F, Christiansen R, Jensen A, Nielsen B (2016) Evaluation of healthy muscle tissue by strain and shear wave elastography—dependency on depth and ROI position in relation to underlying bone. *Ultrasonics* 71:127–133. <https://doi.org/10.1016/j.ultras.2016.06.007>
 25. Bortolotto C, Lungarotti L, Fiorina I, Zacchino M, Draghi F, Calliada F (2017) Influence of subjects' characteristics and technical variables on muscle stiffness measured by shear wave elastography. *J Ultrasound* 20(2):139–46. <https://doi.org/10.1007/s40477-017-0242-9>
 26. Chino K, Kawakami Y, Takahashi H (2017) Tissue elasticity of in vivo skeletal muscles measured in the transverse and longitudinal planes using shear wave elastography. *Clin Physiol Funct Imaging* 37(4):394–9. <https://doi.org/10.1111/cpf.12315>
 27. Gabrielsen DA, Carney MJ, Weissler JM et al (2018) Application of ARFI-SWV in stiffness measurement of the abdominal wall musculature: a pilot feasibility study. *Ultrasound Med Biol* 44(9):1978–85. <https://doi.org/10.1016/j.ultrasmedbio.2018.05.007>
 28. Gennisson JL, Deffieux T, Masy E, Montaldo G, Fink M, Tanter M (2010) Viscoelastic and anisotropic mechanical properties of in vivo muscle tissue assessed by supersonic shear imaging. *Ultrasound Med Bio* 36(5):789–801. <https://doi.org/10.1016/j.ultrasmedbio.2010.02.013>
 29. Arabon N, Kozinc Ž, Podrekar N (2019) Using shear-wave elastography in skeletal muscle: a repeatability and reproducibility study on biceps femoris muscle. *PLoS One* 14(8):e0222008. <https://doi.org/10.1371/journal.pone.0222008>
 30. Kim SH, Park SY (2018) Effect of hip position and breathing pattern on abdominal muscle activation during curl-up variations. *J Exerc Rehabil* 14(3):445–50. <https://doi.org/10.12965/jer.1836170.085>
 31. Rajkumar JS, Chopra P, Chintamani A (2015) Basic physics revisited for a surgeon. *Indian J Surg* 77(3):169–75. <https://doi.org/10.1007/s12262-015-1308-6>
 32. van Wingerden JP, Ronchetti I, Sneyders D, Lange JF, Kleinrensink GJ (2020) Anterior and posterior rectus abdominis sheath stiffness in relation to diastasis recti: abdominal wall training or not? *J Bodyw Mot Ther* 24(1):147–53. <https://doi.org/10.1016/j.jbmt.2019.10.015>
 33. Brauman D (2008) Diastasis recti: clinical anatomy. *Plast Reconstr Surg* 122(5):1564–9. <https://doi.org/10.1097/PRS.0b013e3181882493>
 34. Murillo C, Falla D, Rushton A, Sanderson A, Heneghan NR (2019) Shear wave elastography investigation of multifidus stiffness in individuals with low back pain. *J Electromyogr Kinesiol* 47:19–24. <https://doi.org/10.1016/j.jelekin.2019.05.004>
 35. Nahabedian MY (2018) Management strategies for

- diastasis recti. *Semin Plast Surg* 32(3):147–154. <https://doi.org/10.1055/s-0038-1661380> shear wave elastography. *Clin Physiol Funct Imaging* 37(4):394–9. <https://doi.org/10.1111/cpf.12315>
36. Gabrielsen DA, Carney MJ, Weissler JM et al (2018) Application of ARFI- SWV in stiffness measurement of the abdominal wall musculature: a pilot feasibility study. *Ultrasound Med Biol* 44(9):1978–85. <https://doi.org/10.1016/j.ultrasmedbio.2018.05.007>
 37. Gennisson JL, Defieux T, Масй Е, Montaldo G, Fink M, Tanter M (2010) Viscoelastic and anisotropic mechanical properties of in vivo muscle tissue assessed by supersonic shear imaging. *Ultrasound Med Bio* 36(5):789–801. <https://doi.org/10.1016/j.ultrasmedbio.2010.02.013>
 38. arabon N, Kozinc Ž, Podrekar N (2019) Using shear-wave elastography in skeletal muscle: a repeatability and reproducibility study on biceps femoris muscle. *PLoS One* 14(8):e0222008. <https://doi.org/10.1371/journal.pone.0222008>
 39. Kim SH, Park SY (2018) Effect of hip position and breathing pattern on abdominal muscle activation during curl-up variations. *J Exerc Rehabil* 14(3):445–50. <https://doi.org/10.12965/jer.1836170.085>
 40. Rajkumar JS, Chopra P, Chintamani A (2015) Basic physics revisited for a surgeon. *Indian J Surg* 77(3):169–75. <https://doi.org/10.1007/s12262-015-1308-6>
 41. van Wingerden JP, Ronchetti I, Sneiders D, Lange JF, Kleinrensink GJ (2020) Anterior and posterior rectus abdominis sheath stiffness in relation to diastasis recti: abdominal wall training or not? *J Bodyw Moe Ther* 24(1):147–53. <https://doi.org/10.1016/j.jbmt.2019.10.015>
 42. Brauman D (2008) Diastasis recti: clinical anatomy. *Plast Reconstr Surg* 122(5):1564–9. <https://doi.org/10.1097/PRS.0b013e3181882493>
 43. Murillo C, Falla D, Rushton A, Sanderson A, Heneghan NR (2019) Shear wave elastography investigation of multifidus stiffness in individuals with low back pain. *J Electromyogr Kinesiol* 47:19–24. <https://doi.org/10.1016/j.jelekin.2019.05.004>
 44. Nahabedian MY (2018) Management strategies for diastasis recti. *Semin Plast Surg* 32(3):147–154. <https://doi.org/10.1055/s-0038-1661380>

Paper 6

ORIGINALITY REPORT

5%

SIMILARITY INDEX

0%

INTERNET SOURCES

5%

PUBLICATIONS

0%

STUDENT PAPERS

PRIMARY SOURCES

1

Lih-Jiun Liaw, Miao-Ju Hsu, Chien-Fen Liao, Mei-Fang Liu, Ar-Tyan Hsu. "The Relationships Between Inter-recti Distance Measured by Ultrasound Imaging and Abdominal Muscle Function in Postpartum Women: A 6-Month Follow-up Study", Journal of Orthopaedic & Sports Physical Therapy, 2011

Publication

3%

2

Bo Wang, Kai He, Yulan Zhu, Xiaojian Fu, Qiyuan Yao, Hao Chen, Xiaohong Wang. "Quantitative Analysis of Abdominal Muscles Using Elastography in Female Patients With Incisional Hernia", Frontiers in Surgery, 2022

Publication

3%

Exclude quotes On

Exclude bibliography On

Exclude matches < 3%