MAK HILL Publications Research Journal of Medical Sciences

Research Article
doi: 10.59218/makrjms.2024.1.259.264

Evaluation of Abdominal Muscle Elasticity and Thickness Among Multiparous Women of Indian Origin Using Shear Wave Elastography and Enumerate the Factors Which Influence the Parameters Cross Sectional Study in a Tertiary Care Hospital

[1]E. Sathish Kumar, [2]S. Karthiyayini, [3]S. Pradhap Lenin and [4]T. Mithula

[1,2,3]*Department of Radio diagnosis, Karpagam Faculty of Medical Sciences and Research, Coimbatore, Tamil Nadu, India*

[4]*Department of Community Medicine, Karpagam Faculty of Medical Sciences and Research, Coimbatore, Tamil Nadu, India*

ABSTRACT

To evaluate the abdominal muscle elasticity and thickness among multiparous women of Indian population and to depict the inter observer variability in detecting the elasticity and thickness values of abdominal wall muscles among multiparous woman using shear wave elastography. Cross sectional study done at Department of Radio diagnosis, Karpagam Faculty of Medical Sciences and Research, Coimbatore, Tamil Nadu, India from June 2023 to November 2023. PHILIPS AFFINITY 70 machine was used for the study. Two observers with experience of more than 5 years on ultrasound did the study. All multiparous women aged >18 years were included in our study. Ten skin landmarks were made and the rectus abdominis thickness is obtained by taking the mean values of observed 6 points. The measurement of external oblique, internal oblique, transverse abdominis thickness were obtained by taking the mean value of observed points. Similarly elasticity was obtained using the above mentioned landmarks. Rectus abdominis elasticity was obtained by taking the mean of 6 observed points. The measurement of external oblique, internal oblique and transverse abdominis elasticity were obtained by taking the mean value of observed points. Thickness of internal oblique and transverse abdominal have reduced with increase in number of delivery. Post LSCS individuals show decrease in thickness of transverse abdominis muscle when compared with post normal vaginal delivery. No association found between the thickness of anterior abdominal wall muscles with age, BMI. Significant reduction in elasticity of rectus abdominis found as the age increases (p value of 0.012). No association found between BMI, number of deliveries, mode of delivery and abdominal wall elasticity. No interobserver variability noted in evaluating thickness of abdominal wall muscles. Elasticity values of rectus abdominis muscles show significant interobserver variability ($p<0.001$). No significant interobserver variability noted between elasticity of Oblique muscles on either side. Reduction in abdominal wall thickness and elasticity indicate reduced strength of abdominal wall muscles which make the individuals susceptible to develop ventral wall hernia/diastasis recti. So the susceptible individuals were instructed to follow up core strengthening exercises, which reduce the incidence of developing such conditions.

OPEN ACCESS

Key Words
Abdominal wall muscles, elasticity, thickness, shear wave speed

Corresponding Author
E. Sathish Kumar,
Department of Radio diagnosis, Karpagam Faculty of Medical Sciences and Research, Coimbatore, Tamil Nadu, India

Author Designation
[1,3]Assistant Professor
[2]Post Graduate
[4]Senior Resident

Received: 31 January 2024
Accepted: 20 February 2024
Published: 12 March 2024

Citation: E. Sathish Kumar, S. Karthiyayini, S. Pradhap Lenin and T. Mithula, 2024. Evaluation of Abdominal Muscle Elasticity and Thickness Among Multiparous Women of Indian Origin Using Shear Wave Elastography and Enumerate the Factors Which Influence the Parameters Cross Sectional Study in a Tertiary Care Hospital. Res. J. Med. Sci., 18: 259-264, doi: 10.59218/ makrjms.2024.1.259.264

Copy Right: MAK HILL Publications

INTRODUCTION

Abdominal muscles generate forces that produce movement of and stabilize, the spinal column. They are unique morphologically: rectus abdominis (RA) is comprised of bundles of short muscle fibers arranged in-series to create one longer muscle; external oblique (EO), internal oblique (IO) and transverse abdominis (TrA) are tightly bound layered muscular sheets with fibers running at oblique angles to one another[1]. As a composite, these muscles function together supports stability, motion of the trunk, protects the abdominal viscera. Anatomy of the abdominal wall is affected by pregnancy, obesity and other conditions that stretch and widen the muscles, fascia and skin[2]. Physiological cross sectional area (PCSA) PCSA of the abdominal muscles has been estimated utilizing a number of imaging modalities (computed tomography, MRI, ultrasound)[3-5].

According to Pascal's principle any pressure that is created inside the abdomino-pelvic cavity is uniformly distributed equally across its walls. Muscular abdominal wall contractions produce counter pressure in reaction to the elevated abdominal pressure[6]. Herniation will result from the abdominal wall rupturing at its weakest location if the intra-abdominal pressure is higher than the abdominal wall pressure. In diastasis recti abdominis, the rectus abdominis is the weakest point's margin. Treatment approaches that combine physiotherapy and surgical repair take this variation in muscle elasticity into account[7].

Elastography: Elastography is a non-invasive, high accuracy technique, performed to evaluate tissue elasticity[8]. Elasticity is the tendency of the tissue to resist deformation against applied force or to regain its original shape after removal of the force. Increased tissue thickness and greater resistance to deformation are correlated with higher elastic modulus. Shear wave speed is a quantitative measure of tissue stiffness and can be converted to shear modulus using the following equation[9].

$\mu = Cs^2 p.$

μ-shear modulus.

Cs-Shear wave speed.

p-Density 1000 kg/m³ for all soft tissues.

Higher speed values, higher the stiffness. Study includes analysis of thickness and elasticity of abdominal muscles including Rectus Abdominis (RA), External Oblique (EO), Internal Oblique (IO), Transversus Abdominis (TrA) on multiparous women.

Objectives:

- To evaluate the abdominal muscle elasticity and thickness among multiparous women of Indian population
- To depict the inter observer variability in detecting the elasticity and thickness values of abdominal wall muscles among multiparous woman using shear wave elastography

MATERIALS AND METHODS

It was a cross sectional study done among multiparous women aged >18 years attending Department of Radio diagnosis, Karpagam Faculty of Medical Sciences and Research, Coimbatore. It was conducted over a period of six months in June 2023 to November 2023.A total of hundred participants were studied. The participants were selected using simple random sampling from the list obtained from the outpatient registration record. All multiparous women aged above 18 years with BMI <30 kg/m^2 and no history of previous major abdominal surgery except LSCS were included in this study. Participants previously diagnosed with chronic or degenerative pathology of muscle, e.g, autoimmune myositis and who underwent abdominal rehabilitation of neuromuscular electric stimulation were excluded from this study. Patients with diastasis recti abdominis and incision hernia were also excluded from this study. Study was explained to patients in local language and written consent was taken from the participants. Philips Affinity 70 (Philips Medical system, California, USA) scanner using multi frequency linear array transducer (5.0-13.0 MHZ) in shear wave elastography mode were used to assess the thickness and elasticity. The study was carried out by two observers. The first observer having an experience of 10 years in ultrasonography and the second observer having an experience of 5 years in ultrasonography.

Measurement of Abdominal Muscle Thickness and Elasticity: Three locations identified on each side of rectus abdominis region i.e., Supraumbilical (4.5 cm above umbilicus), at umbilicus and Infra umbilicus (4.5 cm below umbilicus). Two locations identified on each side of the abdomen, along the anterior axillary line equidistant between costal margin at 9th rib and point anterior to anterior superior iliac spine. Each measurement is initiated with the B-mode acquisition of the muscle. The transducer is placed with light pressure to obtain the transverse view of the target muscle. Muscle thickness obtained by measuring the length between anterior and posterior layers of sheath/myofascial (Rectus abdominis, External oblique, internal oblique and transverse abdominis). The measurement of rectus abdominis thickness (mm) is obtained by taking the mean value of 6 observed points (Points 1, 2, 3, 4, 5 and 6). The measurement of external oblique, internal oblique and transverse abdominis thickness(mm) are obtained by taking the mean value of Points 7, 8, 9 and 10 (Fig 2). After the

landmarks identified, the elasto mode turned on and adjusted the elastography box to the appropriate size. Interpretation of the quality score was done using red-yellow-green colour scheme representing low to high quality with a uniform green image which indicates the highest quality and IQR/Med value less than 30%[10]. The value of SWS were superimposed on a two dimensional grey scale image with colour coding (red for high, blue for low, and yellow or green for intermediate). Then small ROI with a diameter of 2 mm was positioned. The ROI was placed on the muscle belly, avoiding the tendons, aponeurosis, blood vessels and fascial tissues. Shear modulus, Shear wave speed (SWS) automatically reported by the scanner. The measurement of the SWS subsequently recorded (Fig 3). The measurement of rectus abdominis elasticity (m/sec) is obtained by taking the mean value of 6 observed points (Points 1, 2, 3, 4, 5 and 6). The measurement of external oblique, internal oblique and transverse abdominis elasticity (m/sec) are obtained by taking the mean value of Points 7, 8, 9 and 10. The values were measured in kPa and converted to m/s in report by shear wave elastography. Data was collected using questionnaire having patient details, elasticity and thickness of abdominal muscles. The data was entered in Microsoft Excel, exported and analyzed using SPSS v25. Percentages or mean and standard deviations were computed for baseline characteristics. Comparisons of categorical data were done using Chi-square test. The corresponding P values were found to determine the level of significance. $p<0.05$ was considered statistically significant.

RESULTS AND DISCUSSIONS

Most of the study participants were aged between 36-45 years, ranging from 28-58 years. Mean age was 46.93 years with SD of 11.23 years. Among the study participants, 5% of them had more than deliveries (Table 1). Most of the study participants were

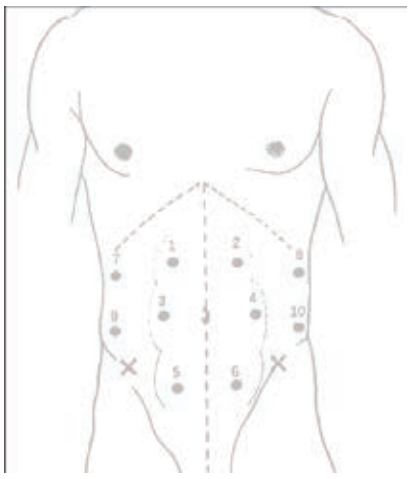

Fig 1: 10 water proof skin landmarks drawn with the marker under 2D-mode monitoring

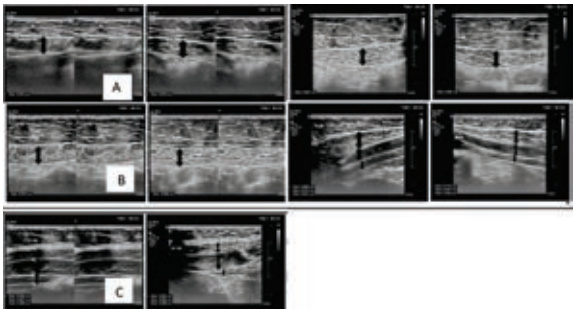

Fig 2: Thickness at point 1 to 4 (A, rectus abdominis (in cm)), at point 5 and 6 (B, rectus abdominis (in cm)), 7 and 8 (B, external oblique muscle, internal oblique muscle and transverse abdominis (in cm) and 9 and 10 (C, external oblique muscle, internal oblique muscle and transverse abdominis (in cm)

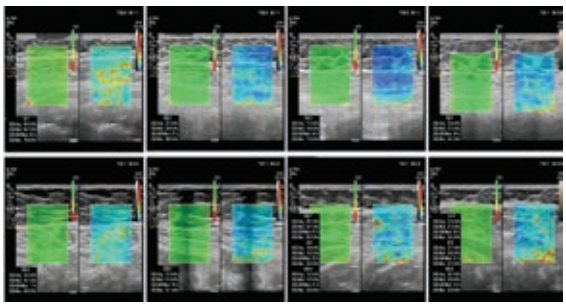

Fig 3: Elastograms at point 1 to 6 (A, rectus abdominis (in kPa)), point 7 (B, external oblique muscle, internal oblique muscle and transverse abdominis (in kPa) and point 8 (C, external oblique muscle, internal oblique muscle and transverse abdominis (in kPa)).

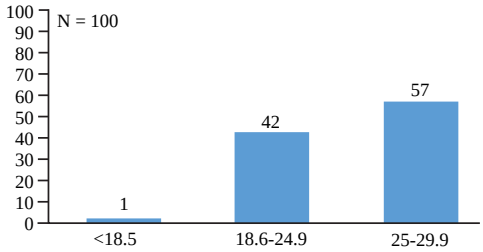

Fig 4: Body Mass Index (BMI) of the study participants (n=100)

overweight with BMI ranging between 25 to 29.9 years (as per WHO classification for BMI) (Fig 4). In the study we found that there is a significant difference ($p<0.001$) between the elasticity of rectus abdominis and transverse abdominis muscle by observer 1 and 2 (Table 2). In our study, the range of SWS values of abdominal muscles (RA, EO, IO) is 1.25-3.31 m/sec and for TrA muscle is 1.4 to 3.91 m/sec (Table 3). Our study

Table 1: Distribution of socio-demographic variables among the study population (n=100)

Variables	Categories	Frequency
Age	25-35 years	13
	36-45 years	33
	46-55 years	29
	56-65 years	19
	>65 years	6
	Minimum Age-28 years	
	Maximum Age-85 years	
Mean age (SD)	47.93 years	(11.23 years)
No of deliveries	Two	79
	Three	16
	Four	4
	Five	1
Type of deliveries	NVD	77
	LSCS	23

Table 2: Intra-operator-Elasticity in m/sec

Muscle elasticity	Operator-1 mean (SD)	Operator-2 mean (SD)
Rectus Abdominis	2.05 (0.41)	2.14 (0.35)
External Oblique	2.08 (0.395)	2.18 (0.34)
Internal Oblique	2.13 (0.46)	2.19 (0.38)
Transverse Abdominis	2.36 (0.54)	2.39 (0.51)

Table 3: Elasticity of abdominal muscles (observer 1)

Values	RA(m/sec)	EO(m/sec)	IO(m/sec)	TA(m/sec)
Minimum	1.34	1.25	1.25	1.40
Maximum	3.23	3.19	3.31	3.91

Table 4: Association between Sociodemographics and Elasticity-RA (observer 1)

Variable	Rectus Abdominis	Good(>1.82 m/sec (10))	Less(<=1.82 m/sec(10))	p-Value	OR	95% CI
Age	<=45 YEARS	35(76.1%)	11(23.9%)	0.012*	2.95	1.24-7.00
	>45 YEARS	28(51.9%)	26(48.1%)			
Type of delivery	NVD	46(59.7%)	31(40.3%)	0.217	0.52	0.18-1.47
	LSCS	17(73.9%)	6(26.1%)			
Number of delivery	Two	52(65.8%)	27(34.2%)	0.257	1.75	0.66-4.63
	More than Two	11(52.4%)	10(47.6%)			

*p < 0.05 was considered to be significant.

Table 5: Association between Sociodemographics and Thickness-IO (observer 1)

Variable	Internal oblique	Good(>=5.49 mm(10))	Less(<5.49 mm(10))	p-Value	OR	95% CI
Age	<=45 YEARS	28(60.9%)	18(39.1%)	0.172	1.73	0.78 to 3.83
	>45 YEARS	26(47.3%)	28(52.7%)			
Type of delivery	NVD	38(49.4%)	39(50.6%)	0.18	0.52	0.19 to 1.36
	LSCS	15(65.2%)	8(34.8%)			
Number of delivery	Two	46(58.2%)	33(41.8%)	0.04*	2.7	1.01 to 7.66
	More than Two	7(33.3%)	14(66.7%)			

*p< 0.05 was considered to be significant.

Table 6: Association between Sociodemographics and Thickness-TA (observer 1)

Variable	Transverse abdominis	Good(>=2.96 mm(10))	Less(<2.96 mm(10))	p-Value	OR	95% CI
Age	<=45 YEARS	30(65.2%)	16(34.8%)	0.148	1.80	0.80-4.04
	>45 YEARS	28(50.9%)	26(49.1%)			
Type of delivery	NVD	38(49.4%)	39(50.6%)	0.005*	0.205	0.06-0.65
	LSCS	19(82.6%)	4(17.4%)			
Number of delivery	Two	49(62%)	80(38%)	0.04*	2.65	0.98-7.150
	More than Two	8(38.1%)	12(61.9%)			

*p< 0.05 was considered to be significant.

strongly emphasizes the hypothesis that when the age increases, rectus abdominis muscle elasticity decreases with significant p value of 0.012 (Table 4). Our study strongly emphasize the hypothesis that when the number of delivery increases the thickness of internal oblique muscle decreases with significant p value of 0.04 (Table 5). Our study emphasizes that the thickness of Transverse abdominis muscle (TrA) is found inversely proportional to number of deliveries (P value 0.005). The thickness of Transverse abdominis muscle (TrA) decreases in post caesarean section women compared to normal vaginal delivery individuals. Significant P value of 0.04 (Table 6).

Ultrasound is becoming more popular in the evaluation of different musculoskeletal abnormalities with excellent reproducibility. With the recent developments in ultrasound elastography, it is now possible to quantitatively evaluate the stiffness of muscle[7]. Over the past 20 years, a number of ultrasound elastography techniques have been studied

globally, including strain elastography, shear wave elastography, acoustic radiation force impulse and transient elastography[11]. Recent research has shown that shear wave elastography is a more extensively utilized and dependable method for quantitatively measuring muscle stiffness when it comes to inter-or intra-operator variability[7,10,12,13]. The main purpose of this study was to compare elasticity and thickness of abdominal wall musculature in multiparous woman. Partially consistent with the first part of our hypothesis, we found a significantly higher SWS in the RA, EO, IO, TrA ($p<0.001$) among the Indian population when compared with Chinese population[8]. These findings can be due to the ethnicity differences. The range of SWS values of abdominal muscles (RA, EO, IO) is 1.25 to 3.31 m/sec and for TrA muscle is 1.4 to 3.91 m/sec, which is significantly higher than abdominal muscle elasticity among the Chinese population[7]. There is a significant difference ($p<0.001$) between the elasticity of rectus abdominis and transverse abdominis muscle by observer 1 and 2. To the best of our knowledge, the present study is the first to reveal these findings about muscle elasticity and thickness among multiparous woman in Indian origin based on the specific 10-location setting.

The Intra class Correlation Coefficient (ICC) values from the current study show moderate to high intra-operator reliability in response to our main goal of assessing muscular elasticity, particularly for the RA and TrA muscles. This result was consistent with our earlier investigation of SWE in individuals[14]. However, it was observed that the EO and IO ICC values were comparatively lower, which may be related to the effect of the patient's breathing on the superficial oblique muscles. In our study, we used SWE in 10-location setups to more accurately and objectively measure the flexibility of the abdominal muscles. Considering the available data demonstrating morphological alterations and functional deficiencies in the abdominal muscles during pregnancy[15]. From a biomechanical viewpoint, the abdominopelvic cavity is a cylinder enveloped by muscles, tendons and bony structures. According to Pascal's principle[6], 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 intra-abdominal pressure exceeds abdominal wall pressure, the abdominal wall will rupture at its weakest point, causing herniation. The elasticity and thickness of the abdominal wall muscles should be within the normal limits to prevent herniation.

To summarize the main findings of our study, the application of SWE for assessing abdominal wall muscles is feasible and credible in multiparous woman. Our study revealed higher SWS in the RA and TrA in normal vaginal delivery individuals and number of deliveries (two). As age increases, the thickness of internal oblique muscle in multiparous women decreases. As number of deliveries increases, the thickness of internal oblique and transverse abdominis in multiparous women decreases. This is due to the less volume of fibers in postpartum women.

Limitation: The force exerted by different observers may vary in different circumstances to calculate the abdominal muscle thickness and elasticity.

Recommendation: As the elasticity of rectus abdominis decreases with age, it is recommended that women of reproductive age group should perform regular abdominal muscle strengthening exercises to strengthen the rectus abdominis muscle thereby preventing future risk of ventral herniation and diastasis recti abdominis. As the number of delivery increases, the thickness of the internal oblique and transverse abdominis muscle decreases. Thickness of transverse abdominis muscle decreases in post caesarean section when compared to normal vaginal delivery. Hence parous women are advised to undergo regular ante natal and postnatal abdominal strengthening exercises. Hence, we strongly recommend that high risk women(age >35 years, Post caesarean and number of deliveries >2) to undergo regular antenatal and postnatal abdominal strengthening exercises to reduce the future risk of ventral herniation and diastasis recti.

CONCLUSION

This cross-sectional study is one of the first attempts to evaluate elasticity among multiparous woman in Indian population. Based on our results and methodology employed, we have concluded from out study that As the age increases the elasticity of rectus abdominis muscle decreases. As the number of delivery increases the thickness of internal oblique and transverse abdominis muscle decreases. The thickness of transverse abdominis muscle decreases in post caesarean section women compared to normal vaginal delivery individuals. There is strong association between elasticity of rectus abdominis and transverse abdominis muscles measured by observer 1 and observer 2.

REFERENCES

1. Hellinger, A., I. Roth, F.C. Biber, M. Frenken, S. Witzleb and B.J. Lammers, 2016. Chirurgische anatomie der bauchdecke. Der. Chirurg, 87: 724-730.
2. Woxnerud, K., G. Sandblom, C. Hedbeck and A. Olsson, 2023. Reference data on the normal abdominal wall anatomy and baseline characteristics in seventy-one nulliparous women. J. Abdomin. Wall Surg., 2: 1-8.

3. McGill, S.M., N. Patt and R.W. Norman, 1988. Measurement of the trunk musculature of active males using ct scan radiography: Implications for force and moment generating capacity about the joint. J. Biomech., 21: 329-341.
4. Hirayama, K.,R. Akagi, Y. and Moniwa, 2017. Transversus abdominis elasticity during various exercises: A shear wave ultrasound elastography study. Int. J. Sport. Phys. Ther., 12: 601-606.
5. Marras, W.S., M.J. Jorgensen, K.P. Granata and B. Wiand, 2001. Female and male trunk geometry: Size and prediction of the spine loading trunk muscles derived from mri. Clin. Biomech., 16: 38-46.
6. Rajkumar, J.,S.P. and Chopra, 2015. Basic physics revisited for a surgeon. Indian. J. Surg., Vol. 77 .10.1007/s12262-015-1308-6.
7. He, K., X. Zhou, Y. Zhu, B. Wang and X. Fu *et al.*, 2021. Muscle elasticity is different in individuals with diastasis recti abdominis than healthy volunteers. Ins. Imag., Vol. 12 .10.1186/s13244-021-01021-6.
8. Wang, B., K. He, Y. Zhu, X. Fu, Q. Yao, H. Chen and X. Wang, 2022. Quantitative analysis of abdominal muscles using elastography in female patients with incisional hernia. Front. Surg., 9: 831-884.
9. Tran, D., F. Podwojewski, P. Beillas, M. Ottenio, D. Voirin, F. Turquier and D. Mitton, 2016. Abdominal wall muscle elasticity and abdomen local stiffness on healthy volunteers during various physiological activities. J. Mech. Behav. Biomed. Mater., 60: 451-459.
10. Gabrielsen, D.A., M.J. Carney, J.M. Weissler, M.A. Lanni and J. Hernandez *et al.* 2018. Application of arfi-swv in stiffness measurement of the abdominal wall musculature: A pilot feasibility study. Ultra. Med. Biol., 44: 1978-1985.
11. Shimoyama, D., H. Shitara, N. Hamano, T. Ichinose and T. Sasaki *et al*. 2020. Reliability of shoulder muscle stiffness measurement using strain ultrasound elastography and an acoustic coupler. J. Med. Ultrason., 48: 91-96.
12. Šarabon, N., Ž. Kozinc and N. Podrekar, 2019. Using shear-wave elastography in skeletal muscle: A repeatability and reproducibility study on biceps femoris muscle. Plos one., Vol. 14 .10.1371/journal.pone.0222008.
13. Bortolotto C. L. Lungarotti, I. Fiorina, M. Zacchino, F. Draghi and F. Calliada, 2017. Influence of subjects' characteristics and technical variables on muscle stiffness measured by shear wave elastosonography. J. Ultra., 20: 139-146.
14. Wang, X., K. He, Y. Zhu, X. Fu and Z. Huang *et al.* 2020. Use of shear wave elastography to quantify abdominal wall muscular properties in patients with incisional hernia Ultra. Med. Biol., 46: 1651-1657.
15. Liaw, L.J., M.J. Hsu, C.F. Liao, M.F. Liu and A.T. Hsu, 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. Sport. Phys. Ther., 41: 435-443.