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Effect of High-Intensity Focused Ultrasound on Vaginal Relaxation Syndrome

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Abstract: This study was conducted to determine the effect of high-intensity focused ultrasound (HIFU) on vaginal relaxation syndrome (VRS). Thirty sexually active women suffering from vaginal laxity aged 30-45 years participated in this study. Vaginal laxity is often overlooked and underreported, yet it significantly impacts sexual functioning, self-image, and overall quality of life (QoL) in women. These women were randomly assigned to two groups: control group (15 women) received pelvic floor exercises daily for 8 weeks and study group (15 women) received the same exercises daily for 8 weeks plus 2 sessions of HIFU with 4 weeks apart. Evaluation was done before and after the treatment program by vaginal laxity questionnaire (VLQ), sexual satisfaction questionnaire (SSQ), and female sexual function index-19 (FSFI-19) to assess sexual health; International Consultation on Incontinence Questionnaire short-form (ICIQ-SF) to evaluate urinary symptoms; vaginal pH strip to evaluate vaginal pH; vaginal pressure gauge to assess vaginal wall elasticity; and ultrasonographic imaging to assess pelvic floor biometers. The post-treatment results revealed significant improvements in VLQ, SSQ, all domains and total score of FSFI-19, ICIQ-SF, vaginal pH, intravaginal pressure, the length from symphysis pubis to anorectal angle at rest and at contraction, as well as the anteroposterior and transverse diameters, and area of the levator ani hiatus at rest and at Valsalva ($p<0.05$) in favour of the study group. High intensity focused ultrasound is an effective and safe modality for improving sexual health, urinary symptoms, vaginal pH, vaginal wall elasticity, and pelvic floor biometers in women with vaginal relaxation syndrome.

Keywords: High-intensity focused ultrasound, vaginal relaxation syndrome, sexual health, urinary symptoms, vaginal pH, vaginal wall elasticity, pelvic floor biometers.

1 Introduction

Vaginal relaxation syndrome (VRS) refers to a condition marked by vaginal wall laxity and structural damage [1, 2]. Despite affecting a significant proportion of post-partum women (24% to 50%), it remains poorly recognized, with 83% of women failing to discuss their concerns with healthcare professionals [3]. It is attributed to connective tissue alterations, often linked to multiple pregnancies, childbirths, and menopausal onset, which leads to reduced hormonal levels and vaginal atrophy (VA) [1, 2].

It is accompanied by lowered physical sensation and reduced sexual satisfaction [4, 5]. Over time, this laxity may lead to diminished genito-pelvic sensation during coitus, potentially affecting sexual quality of life (QoL) [6]. It can also contribute to various issues like stress urinary incontinence (SUI), atrophic vaginitis, vaginal dryness, irritation, itching, and soreness, as well as pain and vaginal bleeding during intercourse, unusual discharge, and overall dissatisfaction with the appearance of the area [3, 7].

Vaginal rejuvenation covers a range of procedures aimed at correcting and restoring the ideal vaginal structure alongside its surrounding tissues. Noninvasive options like lubricants, hormone replacement medications, and Kegel exercises are used as a primary approach for improving VA and dryness. Conversely, gynecologic or plastic surgeons conduct invasive vaginal procedures that offer longer-lasting results, but they come with higher risks, longer recovery, and potential complications like nerve damage and scar formation causing fibrosis, dysesthesia, and dyspareunia [8-10].

In recent times, noninvasive energy-based systems have emerged as a favorable advancement for women who are cautious about undergoing surgery due to its associated risks, costs, and recovery period. These approaches used for feminine rejuvenation comprise CO_2-laser, erbium: yttrium-aluminum-garnet (Er: YAG) laser, radiofrequency (RF), and high-intensity focused ultrasound (HIFU). Such methods heat the target tissue at different depths, ensuring painless treatment and requiring no recovery time [11].

HIFU technology is preferred over other energy-based devices (EBDs) as it can reach deeper tissue layers beyond the mucosa [12]. It offers better rejuvenation effects compared to laser and RF treatments due to its capability to penetrate deeper into the fibromuscular layer up to adventitia, while lasers and RF treatments have limited depths of penetration [13]. HIFU for vaginal rejuvenation uses focused thermal effects at specific depths determined by a 20 mm ultrasound transducer emitting convergent

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ultrasonic waves. These mechanical waves cause molecular vibrations in the tissue, raising its temperature and inducing physical modifications without damaging adjacent tissue [12]. HIFU utilizes ultrasound energy at various frequencies and focal depths to generate focal thermal injury zones in deeper tissue layers [14]. Despite using lower energy, HIFU can heat tissue to over 60°C, creating small thermal coagulation points up to 5 mm deep [15]. This leads to wound healing responses, tissue rejuvenation, and remodeling in the form of compacted connective tissues with aligned collagen and elastin fibers [16].

Previous studies have extensively investigated the positive impact of various energy-based devices, such as Co_2 laser, erbium-YAG laser, monopolar, bipolar, and quadripolar RF, on enhancing vaginal wall elasticity and vaginal epithelium. These findings were supported by both clinical and histological evidence from multiple sources [11, 17-22]. While prior research has examined the effects of HIFU on the vaginal wall, focusing on its potential for managing conditions like VA, vaginal hyperlaxity, and SUI [12, 23], none of them specifically explored the effect of HIFU on pelvic floor biometrics in VRS patients. Thus, this study aimed to fill the existing research gap by offering valuable insights into the influence of HIFU treatment on sexual health, urinary symptoms, vaginal pH, vaginal wall elasticity, and pelvic floor biometrics in women with VRS.

2 Materials and Methods

2.1 Trial Design:

The research protocol received approval from the Ethical Committee of Faculty of Physical Therapy, Cairo University (Approval No: P.T.REC/012/003488) and adhered to the principles of the Helsinki Declaration for human research. Prior to participation, each participant was provided with a comprehensive explanation of the study and was required to provide written consent. The study took place at a private Women's Health & Infertility Clinic in Cairo, from May 2022 till September 2022.

2.2 Eligibility Criteria:

Thirty women, complained from vaginal laxity, participated in this study. The participants' ages ranged from 30 to 45 years, with a body mass index (BMI) between > 20 kg/m² and < 35kg/ m². All of them had parity ≥ 1 time while having a negative pregnancy test within two months before the treatment and had not been breastfeeding for three months before treatment.

2.3 Exclusion Criteria:

Participants were deemed ineligible for the study if they had unexplained vaginal bleeding episode, active sexually transmitted infection, acute or recurrent urinary tract infection, recurrent pelvic inflammatory diseases, 3rd degree pelvic organ prolapse, severe urinary incontinence and post radical hysterectomy, vaginal surgical procedures within 12 months prior to the study, and previous pelvic reconstruction surgery.

2.4 Evaluation Procedures:

Women participating in this study were randomly distributed into 2 equal groups in number; control group consisted of 15 women, who received pelvic floor training exercise (Kegel exercise) 3 times per day, daily, for 8 weeks; while the study group comprised 15 women, who received HIFU for 2 sessions with 4 week-apart between each HIFU session and pelvic floor training exercise (Kegel exercise), 3 times per day, daily, for 8 weeks.

The protocol of evaluation and treatment of this study was explained in detail to each woman who assigned a consent form before engagement in this study.

2.4.1 Assessment of Sexual Health

All the assessments were done pre-treatment and at the end of the 8 weeks intervention for both groups.

2.4.1. a) vaginal laxity questionnaire (VLQ) was utilized to self-assess the vaginal laxity degree by each woman in both groups. Each participant was asked to pick the right number that refers to her vaginal laxity from 1 to 7 (1= very loose, 2= moderately loose, 3= slight loose, 4= neither loose nor tight, 5= slightly tight, 6= moderately tight, and 7= very tight) [24].

2.4.1. b) Sexual satisfaction questionnaire (SSQ) was utilized to assess sexual satisfaction. Each subject was asked to pick the right number that refers to her level of sexual satisfaction from 1 to 6 (1= none, 2= poor, 3= fair, 4= good, 5=very good, 6= excellent) [25].

2.4.1. c) Female Sexual Function Index-19 (FSFI-19) is a concise and comprehensive 19-item self-report tool used to evaluate different components of sexual function experienced by women. It assesses desire, arousal, lubrication, orgasm, patient satisfaction, and pain. The questionnaire utilizes a scale with five points for the initial two questions and a zero to five scale for the subsequent questions. After collecting the scores, they were multiplied by specific coefficients based on question groups (coefficients for questions 1, 2: 0.6, 3–10: 0.3, 11–19: 0.4). The final score ranged from 2 to 36 [26].

Higher domain and total scores on the FSFI suggest better sexual functioning. The threshold for distinguishing between individuals with and without sexual dysfunction is a total FSFI score of 26.55, as it is usually recognized in the sexual medicine community [27]. Furthermore, a sexual desire domain score of 5.0 or below is considered a potential indicator of hypoactive sexual desire disorder [28].

2.4.2 Assessment of Urinary Symptoms Severity and Impact on Quality of Life

The severity of urinary symptoms and their impact on the participants' QoL were evaluated using the International Consultation on Incontinence Questionnaire Urinary

Incontinence Short-Form (ICIQ-SF). This questionnaire consists of six questions related to demographic variables, frequency, leakage amount, total effect on life quality, and the type of incontinence. The maximum score is 21, and higher scores indicate more severe urinary incontinence [29]. The score ranges are categorized as slight (1-5), moderate (6-12), severe (13-18), and very severe (19-21) [28].

2.4.3 Assessment of Vaginal PH

The vaginal pH was measured by using a vaginal pH strip. This measurement is crucial for evaluating vaginal health and is a straightforward, effective, and affordable procedure. It provides valuable insights into the hormonal environment's effects on the vaginal epithelium and is affected by infections and intimate products. Vaginal pH correlates consistently with indicators like parabasal and superficial cells, as well as the visual changes in vaginal epithelium, and symptoms such as dryness and painful coitus [30].

The woman was positioned in the crock lying position and a small amount of fluid was gently collected from the introitus and mid-vagina using a cotton swab. The fluid was then applied to the rest pad on the strip. After waiting for 30 seconds, the color result of the test pad was compared to the colored chart, and the vaginal pH value was recorded. The values of pH were categorized as follows: pH below 5.0 indicated a lack of VA, pH 5-5.49 suggested mild VA, pH 5.5-6.49 indicated moderate VA, and pH greater than 6.5 indicated severe VA [31].

2.4.4 Assessment of Vaginal Wall Elasticity

The vaginal wall elasticity was assessed by using a vaginal pressure gauge connected to the HIFU machine. The gauge consisted of a rubber tube, which was divided into two parts - one connected to a rubber inflatable vaginal cuff and the other to a bulb and an air valve, facilitating the measurement of intravaginal pressure. The vaginal cuff was carefully cleaned and covered with a condom and gently inserted into the vagina and inflated with air using a bulb until no further increase in pressure could be recorded. The air pressure within the vaginal cuff was measured in millimeters of mercury (mmHg) and recorded on the HIFU machine's screen. Finally, the vaginal cuff was deflated and withdrawn from the vagina by opening the air valve.

2.4.5 Assessment of Pelvic Floor Biometers

An ultrasound unit (Mindray, Resona I9 machine, China) was utilized to measure various biometric parameters. These parameters included the distance between the posterior-inferior edge of the symphysis pubis (SP) and the anorectal angle (ARA) at rest and during squeeze, as well as the anteroposterior and transverse diameters and area of the levator ani at rest and during Valsalva maneuver. The measurements were performed by the same expert in 3D/4D-ultrasound in obstetrics and gynecology.

Before the examination began, the participant was asked to void her bladder. Trans-labial ultrasound was conducted with the participant in the modified lithotomy position. A 3D/4D convex volumetric transabdominal transducer was prepared for scanning by covering it with gel and a thin plastic wrap for hygiene. It is crucial to make sure the probe cover is free from trapped air, as this can negatively impact imaging quality. The transducer was positioned gently on the perineum, between the labia majora, with minimal pressure to facilitate complete pelvic organ descent. The orientation was set in the midsagittal plane, providing a view from left to right of the symphysis pubis (SP), bladder neck, urethra, vaginal length, and distal rectal portion with anorectal junction and proximal anal canal portion. The automatic scanning process took four seconds, and the resulting image appeared on the screen in multiple planes (coronal, axial, and sagittal) as well as in rendering modes. Measurements of the selected parameters were obtained using the sagittal plane as reference [32].

The measured pelvic floor biometers were:

By 2D mode, the distance between the posterior-inferior margin of the SP and the ARA at rest was measured, then the participant was directed to contract pelvic floor muscle and the distance was measured again. The visualization of pelvic floor muscle contraction on the ultrasound screen was employed to quantify pelvic floor muscle activity [33].

Then, the mode was changed to 4D-TLUS, enabling measurement of the levator hiatal area, as well as the anteroposterior and transverse diameters both at rest and during the maximum Valsalva maneuver. These measurements were taken in the plane of minimum hiatal dimensions utilizing the rendered volume technique. The minimal levator hiatus was described in the midsagittal plane as the shortest line between the posterior surface of the SP and the levator plate, serving as the plane of reference, and measurements were recorded in 2.5 mm steps from 5 mm below this plane to 12.5 mm above it. The transverse section in the axial plane facilitated hiatal dimensions assessment, including area and the anteroposterior and transverse diameters. In a recent study, the predictive value of assessing hiatal distension at rest and during the Valsalva maneuver was investigated to determine its relevance in evaluating symptoms of vaginal laxity [33, 34], (Fig. 1).

Fig. 1: Measurement of the hiatal area on the plane of minimum hiatal dimensions

2.5 Treatment Procedures:

2.5.1 Pelvic floor training exercise (Kegel exercise) was

performed by all women in both groups, three times a day, daily, for 8 weeks. The starting position was lying on the back with only one layer of stretched clothes on the lower abdomen to allow clear observation of the lowering of the lower abdomen and thighs. The hips were flexed, abducted, and externally rotated, and the knees were slightly flexed. Thighs were slightly apart to prevent substitution by the hip adductors. Each participant was instructed to perform long holds for pelvic floor muscle strength. They were instructed to contract as if they were controlling bowel movement, the urethral orifice, and draw the vagina up, maintaining this action for 4 seconds, then relaxing. This exercise was to be repeated for 8-12 maximal pelvic floor muscle contractions, described as an inward and upward contraction (or lift) with squeezing around the rectum, vagina, and urethra. Any gluteal contraction must be avoided. She was told as a biofeedback, lowering of the lower part of the abdomen indicate the action was done correctly. Then, she performed quick squeezes for power. Instructed to strongly and swiftly squeeze and lift her pelvic floor muscles without holding the contraction. Resting for a few seconds between each squeeze, this fast contraction was repeated 3-5 times at the end of each long-lasting contraction. The exercise was performed 3 times per day, daily, for two months [35].

2.5.2 High-intensity focused ultrasound (HIFU) with conjunction of a vaginal electrode of 3.0 mm was used to apply 2 sessions of HIFU for each woman in the study group with 4 weeks apart. All women in the study group were given full instructions about treatment procedures and benefits of HIFU to gain their cooperation. The HIFU procedure took place with the woman lying in the crock position, with hips flexed, abducted, and externally rotated, knees flexed, and heels supported on the bed. The intravaginal parameters were set using software, including intravaginal rotation (350°) with an angle of 5° between shots, resulting in a total of 71 lines shot after a complete rotation (350° Round). The focal treatment lines were 25 mm long, each with a density of 1.2 mm focal point per millimeter. The output power was adjustable according to the pain tolerance, aiming for a gentle heat sensation in the vagina [12]. The handpiece was sterilized, and gel was applied to the cartridge, with a condom used to cover the vaginal transducer for hygiene reasons, (Fig. 2). The vaginal transducer was gently inserted into the patient's vagina, and the auto treatment mode was selected. Three 360° treatment rounds were performed at different depths: one at 7.5 cm, the second at 5 cm, and the third at 2.5 cm deep in the outer vaginal part, following the insertion marks on the application device. After completing the treatment, the condom was removed, and the handpiece was sterilized once again. The treatment course included two sessions, with a minimum interval of one month between them. Post-treatment instructions were provided to each woman, advising her to wear loose and breathable cotton underwear during the first week and avoid sexual activity for 72 hours. Additionally, she was recommended to avoid hot baths, saunas, and high temperatures during the first week, as well as swimming and cycling. After using the toilet, she should rinse the area with water and wipe it clean with a towel. A high-fiber diet, including fruits and vegetables, was recommended to prevent constipation, while spicy food, tobacco, and alcohol were advised to be avoided for one week.

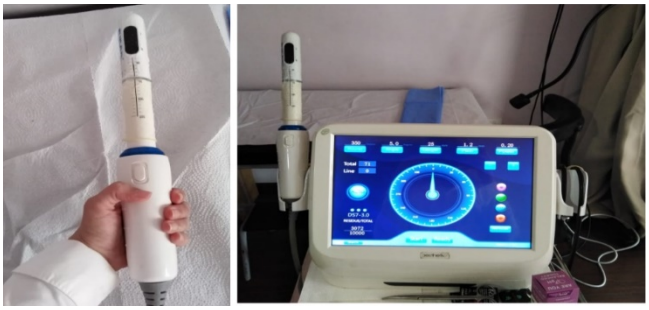

Fig. 2: Preparation of the HIFU vaginal probe

Statistical analysis

The normality of the data was assessed using the Shapiro-Wilk test to determine whether it followed a normal distribution ($p>0.05$) or a non-normal distribution ($p<0.05$) after eliminating outliers identified through box and whisker plots. Moreover, Levene's test for testing the homogeneity of variance to reveal the data was homogenous ($p>0.05$) or non-homogenous ($p<0.05$). The revealed non-normally distributed data, non-parametric analysis was done for mode of delivery, VLQ, SSQ, FSFI-19, and ICIQ variables. While, demographic data, intra-vaginal pressure, vaginal pH, length from SP to ARA, and Levator hiatus variables were normally distributed, and parametric analysis is done.

The statistical analysis was conducted by using statistical SPSS Package program version 25 for Windows (SPSS, Inc., Chicago, IL). Independent t-test used to compare between groups. Multivariate analysis of variance (2 x 2 mixed design) was employed to compare the major variables under investigation: intra-vaginal pressure, vaginal pH, length from SP to ARA (at rest and at contraction), lavator hiatus at rest (AP diameter, coronal diameter, and area), and lavator hiatus at valsalva (AP diameter, coronal diameter, and area) of interest at different tested groups (control group vs. study group) and measuring periods (pre-treatment vs. post-treatment). Bonferroni correction test (Post hoc-tests): to compare between pairwise within and between groups of the tested variables which P-value was significant from MANOVA test.

Qualitative data for mode of delivery, VLQ, and SSQ variables were reported as frequency and percentage. And Chi-square test used for comparisons between groups. Wilcoxon signed ranks and Mann-Whitney U tests used for within groups comparisons for FSFI-19, and ICIQ variables. All statistical analyses for quantitative and qualitative data were significant at probability level ($p\leq0.05$).

3 Results

3.1 Patients' Clinical General Characteristics:

The patients' clinical general characteristics showed no significant differences in mean values of age, weight, height, BMI, vaginal length, mode of delivery, number of pregnancies, and number of children ($p>0.05$) between control and study groups (Table 1).

3.2 Within Group Comparison:

Within the control group, the results revealed non-significant differences in VLQ, SSQ, arousal domain of FSFI-19, and all the measured pelvic floor biometers ($p>0.05$). However, there were significant improvements in desire, lubrication, orgasm, satisfaction, and pain domains and total score of FSFI-19, as well as ICIQ-SF ($p<0.05$) (Tables 2-5).

Within the study group, the results revealed significant improvements in VLQ, SSQ, all domains and total score of FSFI-19, ICIQ-SF, vaginal pH, intravaginal pressure, and all the measured pelvic floor biometers ($p<0.05$) (Tables 2-5).

3.2 Between Group Comparison:

The pre-treatment comparison of both groups showed non-significant differences ($p>0.05$) while there was post treatment comparisons showed significant improvements($p<0.05$) in VLQ, SSQ, all domains and total score of FSFI-19, ICIQ-SF, vaginal pH, intravaginal pressure, and all the measured pelvic floor biometers (Tables 2-5).

Table 1: Patients' clinical general characteristics in both groups

Items		Groups (Mean ±SD)		P-value
		Control group (n=15)	Study group (n=15)	
Age (years)		35.73 ±2.57	35.40 ±3.48	0.768
Weight (kg)		71.46 ±6.91	73.03 ±10.76	0.639
Height (cm)		164.16 ±3.74	164.03 ±6.28	0.944
BMI (kg/cm^2)		26.455 ±2.83	27.11 ±3.56	0.635
Vaginal length (cm)		7.06 ±0.71	7.02 ±0.61	0.830
Mode of delivery	Normal	10 (33.3%)	10 (33.3%)	1.000
	Cesarean	5 (66.7%)	5 (66.7%)	
Number of pregnancy	1	4 (26.7%)	4 (26.7%)	0.611
	2	4 (26.7%)	7 (46.7%)	
	3	6 (40%)	3 (20%)	
	4	1 (6.6%)	1 (6.6%)	
Number of children	1	6 (40%)	5 (33.3%)	0.750
	2	6 (40%)	8 (53.3%)	
	3	3 (20%)	2 (13.4%)	

Quantitative data (age, weight, height, BMI, vaginal length) are reported as mean ±standard deviation and compared by t-independent test

Qualitative data (mode of delivery, number of pregnancy, number of children) are reported as frequency (percentage) and compared Chi-square test

P-value: probability value P-value<0.05: non-significant

Table 2: Distribution of vaginal laxity questionnaire (VLQ) grades within and between groups

VLQ grades	Control group (n=15)		Study group (n=15)		*P*-value (Between group)	
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
Very loose	3 (20.00%)	1 (6.70%)	2 (13.30%)	0 (0.00%)	0.865	0.001*
Moderately loose	4 (26.70%)	4 (26.70%)	4 (26.70%)	0 (0.00%)		
Slightly loose	5 (33.30%)	6 (40.00%)	7 (46.70%)	1 (6.70%)		
Neither tight nor loose	3 (20.00%)	4 (26.70%)	2 (13.30%)	3 (20.00%)		
Slightly tight	0 (0.00%)	0 (0.00%)	0 (0.00%)	5 (33.30%)		
Moderately tight	0 (0.00%)	0 (0.00%)	0 (0.00%)	6 (40.00%)		
Very tight	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)		
P-value (within group)	0.745		0.001*			

Data are expressed as frequency (percentage); P-value: probability value; * Significant (P<0.05)

Table 3: Distribution of sexual satisfaction questionnaire (SSQ) grades within and between groups

SSQ grades	Control group (n=15)		Study group (n=15)		*P*-value (Between group)	
	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment	Pre-treatment	Post-treatment
None	2 (13.30%)	0 (0.00%)	2 (13.30%)	0 (0.00%)	0.429	0.0001*
Poor	2 (13.30%)	3 (20.00%)	2 (13.30%)	0 (0.00%)		
Fair	2 (13.30%)	8 (53.30%)	3 (20.00%)	0 (0.00%)		
Good	1 (6.70%)	0 (0.00%)	8 (53.30%)	3 (20.00%)		
Very good	5 (33.30%)	4 (26.70%)	0 (0.00%)	5 (33.30%)		
Excellent	3 (20.00%)	0 (0.00%)	0 (0.00%)	7 (46.70%)		
P-value (within group)	0.078		0.001*			

Data are expressed as frequency (percentage); P-value: probability value; * Significant (P<0.05)

Table 4: Within and between group comparison for FSFI-19 and ICIQ-SF

	Items	Pre-treatment	Post-treatment	MD	% of change	P- value
FSFI-19						
Desire	Control group	3.49±0.70	3.57 ±0.74	0.08	2.29%	0.041*
	Study group	3.51 ±1.10	4.91 ±0.93	1.40	39.89%	0.001*
	MD (change)	0.02	1.34			
	P-value	0.851	0.001*			
Arousal	Control group	4.14 ±1.16	4.19 ±1.14	0.05	1.21%	0.066
	Study group	4.19 ±1.10	5.18 ±0.64	0.99	23.63%	0.001*
	MD (change)	0.05	0.99			
	P-value	0.983	0.009*			
Lubrication	Control group	4.03 ±1.97	4.09 ±1.99	0.06	1.49%	0.006*
	Study group	4.01 ±1.41	5.27 ±0.82	1.26	31.42%	0.003*
	MD (change)	0.02	1.18			
	P-value	0.547	0.045*			
Orgasm	Control group	3.11 ±1.98	3.40 ±1.61	0.29	9.32%	0.011*
	Study group	3.60 ±1.71	5.29 ±0.70	1.69	46.94%	0.005*
	MD (change)	0.49	1.89			
	P-value	0.589	0.001*			
Satisfaction	Control group	3.33 ±0.91	3.51 ±0.82	0.18	5.41%	0.011*
	Study group	3.96 ±1.24	5.41 ±0.60	1.45	36.62%	0.001*
	MD (change)	0.63	1.90			
	P-value	0.172	0.0001*			
Pain	Control group	4.29 ±1.15	4.48 ±1.13	0.19	4.43%	0.002*
	Study group	4.33 ±1.01	5.42 ±0.65	1.09	25.17%	0.001*
	MD (change)	0.04	0.94			
	P-value	0.934	0.016*			
Total score of FSFI-19	Control group	22.39 ±5.19	23.24 ±4.89	0.85	3.80%	0.001*
	Study group	23.59 ±4.69	31.48 ±3.07	7.89	33.45%	0.0001*
	MD (change)	1.20	8.24			
	P-value	0.507	0.0001*			
ICIQ	Control group	6.53 ±1.56	5.87 ±1.38	0.66	10.11%	0.015*
	Study group	8.47 ±2.00	2.87 ±0.93	5.60	66.12%	0.007*
	MD (change)	1.94	3.00			
	P-value	0.359	0.013*			

FSFI-19: female sexual function index-19 ; ICIQ-SF: International consultation on incontinence questionnaire urinary incontinence.
Data are expressed as mean ±standard deviation (SD); MD: mean difference (change); P-value: probability value;
* Significant (P<0.05)

Table 5: Within and between group comparison for vaginal pH, intra-vaginal pressure, and pelvic floor biometers

		Items	Pre-treatment	Post-treatment	MD (change)	% of change	P- value
Vaginal pH		Control group	5.20 ±0.59	5.07 ±0.62	0.13	2.50%	0.490
		Study group	5.20 ±0.45	4.63 ±0.39	0.57	10.96%	0.005*
		MD (change)	0.00	0.44			
		P-value	1.000	0.028*			
Intra-vaginal pressure (mmHg)		Control group	538.80 ±45.22	560.07 ±41.73	21.27	3.95%	0.133
		Study group	541.13 ±32.22	582.80 ±31.66	41.67	7.70%	0.004*
		MD (change)	2.33	22.73			
		P-value	0.868	0.001*			
Length from SP to ARA	At rest	Control group	6.15 ±0.61	6.10 ±0.60	0.05	0.81%	0.827
		Study group	5.86 ±0.91	4.61 ±0.31	1.25	21.33%	0.0001*
		MD (change)	0.29	1.49			
		P-value	0.223	0.0001*			
	At contraction	Control group	4.71 ±0.48	4.68 ±0.46	0.03	0.64%	0.889
		Study group	4.45 ±0.96	3.32 ±0.33	1.13	25.39%	0.0001*
		MD (change)	0.26	1.36			
		P-value	0.250	0.0001*			
Lavator hiatus (At rest)	Anteroposterior diameter	Control group	5.02 ±0.47	4.88 ±0.43	0.14	2.79%	0.504
		Study group	4.87 ±0.67	4.16 ±0.72	0.71	14.58%	0.002*
		MD (change)	0.15	0.72			
		P-value	0.473	0.002*			
	Coronal diameter (cm)	Control group	4.34 ±0.48	4.23 ±0.50	0.11	2.53%	0.544
		Study group	4.18 ±0.45	3.68 ±0.47	0.50	11.96%	0.007*
		MD (change)	0.16	0.55			
		P-value	0.352	0.003*			
	Area (cm^2)	Control group	17.32 ±3.31	16.41 ±3.23	0.91	5.25%	0.448
		Study group	16.00 ±3.31	12.21 ±3.05	3.79	23.69%	0.002*
		MD (change)	1.32	4.20			
		P-value	0.269	0.001*			
Lavator hiatus (At valsalva)	Anteroposterior diameter	Control group	5.84 ±0.60	5.72 ±0.56	0.12	2.05%	0.658
		Study group	5.52 ±0.80	4.62 ±0.90	0.90	16.30%	0.001*
		MD (change)	0.32	1.10			
		P-value	0.240	0.0001*			
	Coronal diameter (cm)	Control group	4.81 ±0.35	4.70 ±0.37	0.11	2.29%	0.506
		Study group	4.58 ±0.57	4.16 ±0.44	0.42	9.17%	0.013*
		MD (change)	0.23	0.54			
		P-value	0.167	0.002*			
	Area (cm^2)	Control group	22.16 ±3.62	21.28 ±3.58	0.88	3.97%	0.552
		Study group	20.22 ±4.79	15.31 ±3.95	4.91	24.28%	0.001*
		MD (change)	1.94	5.97			
		P-value	0.191	0.0001*			

Data are expressed as mean ±standard deviation (SD); MD: mean difference (change); P-value: probability value; * Significant ($P<0.05$)

4 Discussion

Vaginal laxity and atrophy negatively impact sexual functioning, relationship happiness, body image, self-esteem, and overall QoL in women [3]. Hence, this research aimed to explore the HIFU impact on sexual health, urinary symptoms, vaginal pH, vaginal wall elasticity, and pelvic floor biometrics in women with VRS. Regarding the control group, our findings indicated non-significant differences in VLQ, SSQ, arousal domain of FSFI-19, as well as all the measured pelvic floor biometers after the treatment compared to before. Nevertheless, significant improvements were observed in desire, lubrication, orgasm, satisfaction, and pain domains, as well as the total score of FSFI-19 and ICIQ-SF. These findings highlight the beneficial impact of Kegel exercises on enhancing sexual functioning and reducing urinary symptoms in patients with VRS.

These results agreed with Sacomori et al. [36]; Martinez et al. [37]; Lowenstein et al. [38]; and El-Begawy et al. [39], who found that the pelvic floor muscle strength is positively

associated with the women's sexual functioning, so that the pelvic floor muscle weakness is associated with approximately 1.36 times higher risk of sexual dysfunction. Pelvic floor muscle contraction during sexual intercourse can possibly augment the orgasm. Both bulbospongiosus and ischiocavernosus muscles have insertion in the corpora cavernosa of the clitoris, and an enhanced sensorimotor reflex response (involuntary pelvic floor muscles contraction during orgasm) could occur [40, 41], which reinforce our findings.

In contrast, the findings of the current study were in disagreement with Lara et al. [42] and Citak et al. [43], who demonstrated that Kegel exercises have a great value in increasing the pelvic muscles strength, but do not improve sexual satisfaction.

Regarding the study group, the significant improvements noted in all the measured outcomes either within or between groups comparisons, which reflects the valuable effect of combined Kegel exercise and HIFU on enhancing sexual health, urinary symptoms, vaginal pH, vaginal wall elasticity, and pelvic floor biometers in women with VRS.

These results could be supported by Ahmed et al. [44], who found that the combination of Kegel exercise and energy-based device (erbium-YAG laser) resulted in significant improvements in the strength of pelvic floor muscles and sexual satisfaction among females experiencing vaginal looseness.

Furthermore, Elías et al. [12], who investigated the intravaginal HIFU's impact on managing VA, hyperlaxity, and incontinence of urine. Both histological and clinical evaluations showed positive changes in the vaginal wall. Statistically significant improvements were observed in sexual functioning, vaginal health, and urinary symptoms. The treatment was well-tolerated, with minimal pain reported. Also, our study's findings align with Kolczewski et al. [23], who conducted research on micro-focused ultrasound therapy (MFU) for vaginal laxity and urogenital atrophy. They chose to refer to the treatment as MFU instead of HIFU in their study, taking into account the particular energy, frequency, and depth of action within the vaginal wall. Their study used FSFI, VLQ, and VHI measures, confirming MFU's safety and effectiveness. FSFI scores significantly improved at 6 weeks, 3 months, and 6 months follow-ups. Vaginal health, assessed by VHI, also showed considerable improvement, leveling off after 21 days.

The HIFU for vaginal rejuvenation involves an acoustical energy-based device that operates on focused ultrasound. This method employs significantly lower ultrasound energy to target the skin/mucosal superficial layers, utilizing an energy of 0.4–1.2 J/mm^2, a frequency of 4–10 MHz, and a focal depth of merely 1.5–4.5 mm [45]. In spite of the lower energy, it can heat tissue to temperatures above 60°C. This process creates collagen contraction [46] and small thermal coagulation points, each measuring less than 1 mm^3, at depths reaching up to 5 mm within the mid-to-deep layers while preserving nearby non-target tissues unaffected [15].

Apart from causing local coagulation, the heat from the coagulated areas initiates collagen denaturation and contraction [47]. During this process, intramolecular hydrogen bonds are broken, inducing the rearrangement of collagen chains into a more stable conformation. As a result, the collagen shortens, thickens, and gains greater tensile strength. Additionally, in regions where thermal tissue coagulation takes place, there is a formation of new collagen, contributing to the development of viscoelastic collagen. These combined effects cause a lax vagina to elevate and tighten [48].

The fundamental principle behind energy-based device treatments is to apply heat to the vaginal wall's connective tissues, thereby increasing the local temperature and inducing collagen denaturation and contraction, neocollagenesis, neovascularization, and growth factor infiltration. These processes work together to rejuvenate and restore the vaginal mucosal moisture and elasticity, resulting in improved lubrication, tightness of vaginal structures, and the growth of glycogen-enriched epithelium, ultimately resulting in enhanced natural lubrication [11].

The current study's strengths lie in the utilization of HIFU, which effectively reached the deepest points of the vaginal walls, and the objective measurement of the levator hiatus. Nevertheless, it is constrained by its limited sample size, absence of assessment for long-term effects, and not studying the impact of HIFU on postmenopausal women. In addition, a multicenter research trial is needed.

5 Conclusions

The study has concluded that HIFU is a useful and effective modality for improving vaginal laxity, sexual satisfaction, sexual functioning, urinary incontinence symptoms, vaginal pH, vaginal wall elasticity, and pelvic floor biometers in women with VRS.

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