VIA MEDICA

ORIGINAL PAPER / GYNECOLOGY

Ginekologia Polska
2023, vol. 94, no. 1, 25–32

ISSN 0017–0011, e-ISSN 2543–6767

DOI 10.5603/GP.a2022.0117

Correlation between three-dimensional transperineal ultrasound and pelvic floor electromyography in women with stress urinary incontinence

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ABSTRACT

Objectives: To investigate the relationships among pelvic floor myoelectric level, ultrasound and stress urinary incontinence in women.

Material and methods: 218 women with SUI and 300 normal women were studied. The main outcomes were to determine the relationship between SUI and high-risk factors, PFM intensity, pelvic floor EMG value, and pelvic floor ultrasound data.

Results: In the pelvic floor EMG data, the abnormal rate of type I muscle fibre strength, type I muscle fibre fatigue, type II muscle fibre strength and type II muscle fibre endurance in the SUI group reached more than 50%. The abnormal rates of type I muscle fibre strength and type II muscle fibre strength in the severe SUI group were more significant than those in the mild and moderate SUI. The funnelization of the black neck urethra, bladder neck mobility, posterior angle of the black neck urethra, urinary increment angle and urinary rotation angle of the SUI group were significantly increased. The levator ani muscle in the SUI group was thinner, and the difference was statistically significant. The analysis of the variance results of the overall significance of the regression model were tested, and the final multiple linear regression model was statistically significant.

Conclusions: With the help of a convenient and economic means of the early detection of SUI, the diagnosis rate can be improved so that SUI tendency can achieve a diagnosis and treatment through nonsurgical treatment with fewer complications and a low risk and improve the quality of life of middle-aged and elderly women.

Key words: stress urinary incontinence; pelvic floor electromyography; pelvic floor ultrasound

Ginekologia Polska 2023; 94, 12: 25–32

INTRODUCTION

According to the definition of the International Association for Urine Control, pressure incontinence is caused by a sudden increase in abdominal pressure, such as cough, sneezing, walking and jumping, which results in the outflow of urine [1]. It is characterized by nonurination in the normal state, and involuntary urine leakage only occurs when the abdominal pressure suddenly increases [2]. The occurrence of this condition may be related to changes in the anatomical structure of the pelvic floor and sphincter after prolapsing of the uterus due to weak connective tissue and excessive delivery times [3]. Stress incontinence is a common disorder associated with pelvic floor dysfunction in obstetrics and gynaecology. The main pathological basis is the fracture or relaxation of the pelvic floor supporting tissue. Around 23–45% of women have variable degrees of incontinence, 7% of whom have obvious symptoms, and half of whom have stress urinary incontinence (SUI). The International Urinary Inconsistency Advisory Committee has analysed worldwide epidemiological data. The incidence rate of SUI is as high as 30–55%. Most of the patients with urinary incontinence are middle- and older-aged women. Their median age is 50–60 years old. The incidence of SUI in China is basically the same. The normal life and social activities of patients with direct incontinence seriously affects their health and quality of life [4–7].

According to Delancey's theory of the "hammock" and Petros and Ulmsten's theory of the "whole pelvic floor" [8, 9],

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Received: 18.09.2021 Accepted: 25.10.2021 Early publication date: 20.10.2022

the normal mechanism of urinary control depends on the normal function of the urinary sphincter, and in addition, the bladder neck, urethra and its surrounding supporting structure also play a role in controlling the release of urine. The function of the levator ani muscle in controlling urine has not been confirmed, but some scholars have suggested that the levator ani muscle can help control urination [10]. The mobility of the organs should be kept within a certain range under normal conditions. Excessive or too limited mobility and an abnormal direction of movement indicate that the structure of the pelvic floor is abnormal [11]. When the muscle board of the levator ani or pubic bladder fascia is damaged, the compression effect of the vagina on the urethra will be weakened, and the closed pressure of the normal urethra cannot be maintained, which leads to the occurrence of SUIs [12, 13].

Surface electromyography (EMG) is a set of voltage time series signals obtained by surface electrode guidance, amplification, display and recording. Under the condition of time invariance, the average EMG value increased linearly with the load duration [14]. Compared with traditional needle pole EMG technology, the evaluation scheme of sEMG on the Glazer pelvic floor is a standardized, non-invasive and painless detection technology. The design of the internal electrode in the vagina can detect a set of functional muscle groups (the sphincter of the vagina) at the same time, which makes sEMG more convenient to master and carry out. The space of signal detection is larger, and the repeatability is better. Because of its strong real-time, radiation-free, painless, non-invasive, economic and easy operation characteristics, it is easy to use in clinical practice [15]. Pelvic floor ultrasound can accurately evaluate the movement and damage to the pelvic organs dynamically and intuitively. The location of the organs and the function of the pelvic organs and muscles can be accurately evaluated to provide details about the anatomical structure and movement of the pelvic organs for clinical diagnosis and treatment [16].

Therefore, it is expected that the establishment of diagnostic evaluation methods and the assessment of the pelvic floor muscle function status of patients with SUI, study of the diagnostic criteria of women with SUI and the establishment of relevant models for clinical diagnosis will help to improve the diagnosis rate, which is of great significance for early detection of SUI.

MATERIAL AND METHODS

Women aged 30–65 years old were selected from January 2019 to June 2020 in Ningbo Huamei Hospital, University of Sciences of China. The reported prevalence of incontinence in adult women is quite variable in the literature (5–72%), with approximately 30% being the median prevalence [17–21], and combined with this frequency, bilateral tests are required. The probability of class I errors, $\alpha = 0.05$, and class II errors, $\beta = 0.2$, are required for bilateral tests. The estimated minimum sample size was 218 SUI women. The SUI subjective index was applied: mild, incontinence occurs only during coughing and sneezing, at least twice a week; moderate, incontinence occurs during daily activities such as fast walking; severe, when standing still, incontinence occurs.

The exclusion criteria were short-term hormone replacement therapy; chronic obstructive pulmonary disease; chronic asthma or smoking every day > 20 cigarettes; patients with pacemakers; acute stage urinary and reproductive tract infections; patients with malignant tumours in the pelvis and abdomen; megacolon; incontinence of stool; hysterectomy, vaginal operation or correction of urinary incontinence; pelvic floor reconstruction history; prolapse of pelvic organs; patients with intellectual disorders, mental disease or unstable epilepsy; musculoskeletal disease (multiple sclerosis, severe) myasthenia, polio, spina bifida and cerebrovascular accidents; smoking, alcohol or drug use; illiteracy; and pregnancy within three months after a previous delivery. The inclusion and exclusion criteria were applied and 218 women with SUI were included. In addition, 300 women without SUI were included. All volunteers signed the informed consent form, which was approved by the institutional review committee of Ningbo Huamei Hospital, University of Sciences of China.

The following clinical data were collected: age, menarche age, birth and delivery type (vaginal or caesarean section), weight, height, body mass index (BMI, BMI = body weight/height^2) and waist circumference (WC; measured between the lowest rib and the anterior superior spine), defecation habits (constipation: less than 3 times a week, and defecation is laborious, faecal sclerotic and the quantity is low), physical exercise (active: 5 times a week with moderate intensity aerobic exercise at least 30 minutes or 150 minutes/week, or 3 resistance workouts per week).

The strength of the pelvic floor muscles was assessed during a gynaecological examination. The patient was in the bladder stone cutting position. The examiner inserted a lubricated gloved index finger and middle finger into the vagina to approximately 4 cm. The PFM strength was evaluated by double finger palpation. The patients were asked to contract the maximum PFM but not activate other muscle groups, i.e., abdominal, gluteus and adductor muscles. The test for muscle strength was repeated three times, and the best result was recorded. Based on the results of this process, muscle strength was graded from 0 to 5:0 = no contraction; level 1 = slight muscle flicker; level 2 = weak muscle contraction; level 3 = moderate muscle contraction; level 4 = good muscle contraction; level 5 = strong muscle contraction. All assessments were conducted by the same researcher (HMY), and blinded methods were used to determine the results of the other clinical data mentioned above.

Pelvic floor surface electromyography was performed with Weisi Medical Technology Co., Ltd. used as the detection platform. Methods: 120 degrees of a supine position was taken, the whole body was relaxed, the legs were naturally straight or slightly external rotated (with emphasis on a natural state of relaxation), surface electromyography values of the pelvic floor were collected by the Glazer pelvic floor assessment scheme: (1) baseline: rest for 1 min, wave amplitude and coefficient of variation (coefficient of variation = standard deviation/mean, the same as below); (2) rapid contraction: 5 minutes for the maximum contraction amplitude, contraction reaction time (rise time) and decline time were detected with a 10 s rest between each contraction; (3) continuous contraction: 10 s relaxation, 10 s continuous contraction, a total of 5 times, to detect the contraction amplitude and coefficient of variation; (4) after baseline: another 1 min of rest, to detect the amplitude and coefficient of variation. All evaluations were performed by the same investigator (JL) blinded to the results of the other clinical data.

A 3.5–7 MHz convex array probe and female probe were used, and the model of the 3D ultrasonic probe was 8838. All patients maintained a bladder capacity of 100 mL (the first time they have the intention to urinate), since too much urine will lead to inaccurate evaluation results, and patients will worry about leakage of urine when they perform the Valsalva manoeuvre (close the glottis, contract the diaphragm and abdominal muscles, and then exhale forcefully). All subjects were instructed to hold their breath in the maximum downward direction, and the position of the bladder lithotomy was taken during the ultrasound examination. To reduce the error of the measurement data, all ultrasonic image acquisition and measurements were discussed and confirmed by two specially trained doctors (JLZ, ZYY). Dynamic changes in the bladder neck, posterior angle of the bladder urethra and proximal urethra in the resting and Valsalva states were detected, including the distance between the bladder neck and the horizontal line of the anterior lower edge of the pubic symphysis, urethral inclination angle and posterior angle of the bladder. The anteroposterior diameter, transverse diameter and area of the levator ani hiatus and the thickness of the levator ani muscle were measured by transvaginal three-dimensional ultrasound.

SPSS 20.0 was used to establish the database, and all variables were analysed by the Shapiro Wilk test and Levene test. Measurement data that met the normality test are expressed as the mean ± standard deviation (x ± s); measurement data that did not meet the normality test are expressed as m (Q1, Q3). The chi square test was used for the comparison of count data rates, and the t test and Wilcoxon rank sum test were also used. A regression prediction model was established for the correlation between each parameter and SUI, multiple linear regression analysis was carried out, and the stepwise method was used to screen the variables. The results are given with 95% confidence intervals (95% CIs) and related p values. A 5% significance level or corresponding p value was used in all tests.

RESULTS

The clinical data of the groups are shown in Table 1, including 218 women with SUI and 300 women without SUI. Their clinical characteristics were statistically compared. Table 1 shows that age, menarche age, waist circumference, pregnancy, caesarean section, constipation, and physical status were not significantly associated with exercise ($p > 0.05$), and BMI, the delivery times of vaginal

Table 1. The clinical characteristics of stress urinary incontinence (SUI) and non-SUI women

Characteristics	SUI (n = 218)			Non-SUI (n = 300)	p value
	Mild (n = 89)	Moderate (n = 77)	Severe (n = 52)		
Age (mean, SD)	47.2, 9.3	49.9, 8.8	53.1,10.3	43.5, 12.6	0.23
Menarche age (mean, SD)	11.8, 2.9	12.3, 3.6	12.7, 2.5	12.7, 3.0	0.48
BMI [kg/m^2] (mean, SD)	22.7, 1.9	24.0, 1.5*	24.9, 1.3*	20.5,2.2	< 0.01*
WC [cm] (mean, SD)	77, 7.5	76, 6.9	77, 5.2	75, 5.1	0.15
Gravidity, n (mean, SD)	4.3, 1.6	3.4, 1.9	3.9, 0.2	4.2, 1.4	0.46
Child birth, n (mean, SD)	2.4, 1.9	2.5, 0.9	2.5, 1.3	1.2, 0.9	< 0.01*
Vaginal delivery/parity (%)	1.9, 0.8	2.4, 0.9	2.3, 1.2	1.1, 0.8	< 0.01*
Cesarean delivery/parity (%)	0.4, 0.3	0.6, 0.4	0.3, 0.2	0.3, 0.2	0.41
Intestinal constipation, n (%)	26 (9.4)	25 (8.8)	25 (10.1)	23 (8.4)	0.54
Physical excise, n (%)	35 (11.7)	29 (10.7)	32 (8.7)	30 (9.8)	0.58

Values are expressed as mean (SD) or number (%); BMI — body mass index; WC — waist circumference; MHT — menopausal hormone therapy; SD — standard deviation; *The difference was significant, if $p < 0.05$

Table 2. Comparison of pelvic floor muscle and pelvic floor surface electromyography of stress urinary incontinence (SUI) and non-SUI women

Characteristics	SUI (n = 218)			Non-SUI (n = 300)	p value
	Mild (n = 89)	Moderate (n = 77)	Severe (n = 52)		
PFM (mean, SD)	2.1, 0.7	1.7, 0.8	1.4, 0.9*	3.8, 0.6	< 0.01*
Pre-resting average value (> 4 μV) (n, %)	11, 12.4	11, 14.3	7, 13.5	36, 12.0	0.34
Pre-resting variability (> 0.2) (n ,%)	12, 13.4	11, 14.3	7, 13.5	38, 12.7	0.28
Rapid contraction average value (< 35 μV) (n, %)	45, 50.6	49, 63.6*	42, 80.8*	106, 35.3	< 0.01*
Rapid contraction relaxation time (> 0.5 S) (n, %)	51, 57.3	45, 58.4*	31, 59.6*	111, 37.0	< 0.01*
Tonic contraction average value (< 30 μV) (n, %)	53, 59.6	57, 74.0	46, 88.5*	109, 36.3	< 0.01*
Tonic contraction variability (> 0.2) (n, %)	44, 49.4	40, 51.9	25, 48.1	131, 43.7	0.13
Endurance contraction average value (< 25 μV) (n, %)	65, 73.0	61, 79.2	50, 96.2	117, 39.0	< 0.01*
Post-resting average value (> 4 μV) (%)	18, 20.2	15, 19.5	11, 21.2	40, 13.3	0.09
Post-resting variability (> 0.2) (%)	14, 15.7	16, 20.8	10, 19.2	41, 13.7	0.15

Values are expressed as mean (SD). Values in bold are statistically different; PFM — pelvic floor muscle; *The difference was significant, if p < 0.05 (Student's t-test)

delivery and the number of live births were all significantly higher in the SUI group than in the non-SUI group ($p < 0.05$). Among them, BMI in the medium and severe subgroups was statistically significantly different than that in the mild subgroup (Tab. 1).

Pelvic floor muscle strength was divided into functional PFM (score 2–5) and nonfunctional PFM (score 0–1) [22]. As Table 2 shown, compared with the muscle strength of the pelvic floor muscle group, the PFM in the SUI group was significantly stronger than that in the SUI group ($p < 0.05$), and the PFM in the SUI group was more nonfunctional, among which the severe SUI group was less functional ($p < 0.05$). In the pelvic floor electromyography statistics, the abnormal rate of rapid contraction average value, rapid contraction relationship time, tonic contraction average value, and end contraction average value were more significant in the SUI group than in the non-SUI group. In the analysis of the subgroups of SUI, the middle SUI group had more statistical significance than the non-SUI group. In the analysis of the subgroups of SUI, the middle SUI group had more statistical significance than the non-SUI group. The time was more abnormal in the mild SUI group, and the severe SUI group was more abnormal in rapid contraction average value, rapid contraction correlation time and tonic contraction average value, with statistical significance ($p < 0.05$). The morphology and metabolism characteristics of the muscle fibres of the pelvic floor can be divided into two types: class I (slow contraction) fibres, accounting for 70%, and these deep pelvic floor muscles are mainly responsible for the strong contractions, which last for a long time and do not easily fatigue. This is related to the support energy under the state of resting, and mainly plays a supporting function; class II (fast contraction) fibres account for approximately 30% of the superficial pelvic floor muscles that are mainly comprised of these fibres, which produce fast, short-lived contractions and easily fatigue. They play a role in controlling urine and stool, and in sex, and mainly participate in maintaining a support function under dynamic conditions. The abnormal rate of type I muscle fibre strength, fatigue degree of class I muscle fibre, type II muscle fibre strength and type II muscle fibre endurance of the SUI group reached more than 50%, and the abnormal rate in severe SUI was more significant for the abnormal rate of type I muscle fibre strength and class II muscle fibre strength than that of moderate and light SUI.

In the comparison of two-dimensional ultrasound images between the SUI group and the control group, the tissue structure of the pelvic floor of the SUI and the control group was clearly displayed in the resting state and during Valsalva action. The two groups could complete the Valsalva action under multiple guidance and clearly showed the changes of the pelvic floor structure of the patients before and after the Valsalva action. The bladder neck, proximal urethra and peripheral supporting tissues of the two groups were moved backward and downward under Valsalva action. Compared with the control group, funnelization of the black neck urethra, blade neck mobility, posterior angle of the blank urethra, urethral increased angle, and urethral rotation angle were significantly increased (Tab. 3). P values were all < 0.05. In the analysis of the subgroups of the SUI group, the increase in the urethral angle was especially obvious in the severe subgroup ($p < 0.05$), while Valsalva was used to analyse the funnelization of the black neck urethra, bladder neck mobility, urethral increased angle and urban rotation in severe SUI patients. The difference was statistically significant ($p < 0.05$), and the funnelization of the black neck urethra, blade neck mobility and urethral increase were significantly increased in the patients with mild SUI and moderate SUI ($p < 0.05$). Compared with the control group, there was no statistical significance in the area of the anal lift muscle fissure, anteroposterior diam-

Table 3. Comparison of ultrasonographic characteristics of stress urinary incontinence (SUI) and non-SUI women between the state of resting and Valsalva

Data	SUI (n = 218)			Non-SUI (n = 300)	p value
	Mild (n = 89)	Moderate (n = 77)	Severe (n = 52)		
In resting state					
Funnelization of bladder neck urethra (n, %)	3, 2.2	3, 3.9	3, 5.7	7, 2.3	0.14
Posterior angle of bladder urethra (> 140°) (n, %)	3, 2.2	5, 6.4	4, 7.7	6, 2.0	0.03*
Urethral inclination angle [°] (mean, SD)	22.5, 10.5	23.9, 7.0	29.6, 10.1*	19.9, 7.5	0.06
Urethral rotation angle [°] (mean, SD)	23.1, 7.3	22.8, 4.9	25.2, 6.2	19.1, 5.7	0.22
In Valsalva state					
Funnelization of bladder neck urethra (n, %)	19, 21.3	33, 42.9*	35, 67.3*	22, 7.3	< 0.01*
Bladder neck mobility [mm] (mean, SD)	29.65, 7.62	32.86, 6.82*	39.90, 8.33*	17.02, 6.80	< 0.01*
Posterior angle of bladder urethra (> 140°)	24, 26.7	25, 32.5	19, 55.8	15, 5.0	< 0.01*
Urethral inclination angle [°] (mean, SD)	49.0, 6.4	52.9, 8.1*	56.7, 5.8*	27.1, 8.5	< 0.01*
Urethral rotation angle [°] (mean, SD)	39.1, 8.2	41.1, 7.0	49.4, 6.8*	24.1, 6.2	< 0.01*
Urogenital hiatus area [cm^2] (mean, SD)	14.7, 4.5	15.1, 5.1	15.3,2.6	14.4, 3.9	0.24
Anteroposterior diameter [cm] (mean, SD)	5.1, 0.5	5.1, 0.7	5.3, 0.6	5.2, 0.5	0.32
Transverse diameter [cm] (mean, SD)	4.0, 0.9	4.2, 0.7	4.2, 0.8	4.0, 0.6	0.48
Levator ani muscle (cm) (mean, SD)	0.45, 0.2	0.43, 0.1	0.41, 0.2	0.51, 0.1	< 0.01*

Values are expressed as mean (SD). Values in bold are statistically different; *The difference was significant, if p < 0.05 (Student's t-test)

eter or reverse diameter in the SUI group, while the levator ani muscle and the SUI group were thinner than in the SUI group, and the difference was statistically significant ($p < 0.05$), but the differences among the subgroups of SUI were not statistically significant.

In this study, the influence of BMI, childbirth, marginal delivery, PFM, EMG data of the pelvic floor, resting state and two-dimensional and three-dimensional ultrasound images of the pelvic floor on the incidence of SUI was investigated by using multiple linear regression. The better the regression model, the closer the determinant coefficient r square (R^2), and the better the fitting degree of the model to the data. The corrected R^2 (adjusted R square) is similar to R^2, and it is also one of the important indexes to measure the model. The larger the value, the better the fitting effect of the model. The R^2 in this study was 0.934, and the adjusted R^2 was 0.869. This indicated that 86.9% of the occurrence of SUI can be attributed to the rapid contraction average value, rapid contraction correlation time, BMI, childbirth, marginal delivery, PFM, post or angle and urban increased angle in the resting state, blade neck mobility, posterior angle of the change of the urethra, urethral inclusion angle, and urethral rotation angle in the valve state, and the levator ani muscle thickness. The results of the variance analysis of the overall significance of the regression model were tested. The final built multiple linear regression model has statistical significance, among which the F statistic was 287.928, $p < 0.001$, and under the test level of $\alpha = 0.05$, the fitted multiple linear regression equation can be considered statistically significant. The partial regression coefficient β and 95% CI of each independent variable are shown in the table below (Tab. 4). The partial regression coefficient (β) and its standard error of the regression model are listed in the table (Std. Error), standardized partial regression coefficient (beta), t-statistics and P value of the regression coefficient test, and the 95% confidence interval (95% CI) of the partial regression coefficient B. The regression prediction model: Y_{SUI} = BMI × 0.013 + Child birth × 0.052 – PFM × 0.113 – Rapid contraction average value × 0.195 + Rapid contraction relaxation time × 0.130 – Posterior angle of bladder urethra in resting state × 0.118 – Urethral inclination angle in resting state × 0.003 + Bladder neck mobility in Valsalva state × 0.008 + Posterior angle of bladder urethra in Valsalva state × 0.159 + Urethral inclination angle in Valsalva state × 0.013 + Urethral rotation angle in Valsalva state × 0.004 – Levator ani muscle × 0.250. If the rapid contraction average value < 35μV, the rapid contraction average value = 1; If the rapid contraction relaxation time > 0.5S, the rapid contraction relaxation time = 1; if the rapid contraction average value < 35 μV, the rapid contraction resting bladder angle > 140.

The absolute value of the partial regression coefficient of levator ani muscle is 0.250, which is higher than that of the urethral addition angle in the Valsalva state (0.012), but the absolute value of the standardized partial regression coefficient of the urethral addition angle in the Valsalva state is 0.375, which is higher than that of the levator ani muscle (0.080), which indicates that the urethral addition angle in the Valsalva state has more influence on SUI than the levator ani muscle.

Table 4. Regression coefficient of all variables liner regression

Variables	β	Standard coefficient	95% CI (Beta)	p value
BMI	0.013	0.068	(0.005, 0.021)	0.001
Child birth	0.052	0.119	(0.034, 0.070)	0.000
PFM	–0.113	–0.283	(–0.131, –0.094)	0.000
Rapid contraction average value (< 35 μV)	–0.195	–0.196	(–0.260, –0.129)	0.000
Rapid contraction relaxation time (> 0.5 S)	0.130	0.131	(0.066, 0.193)	0.000
In resting state				
Posterior angle of bladder urethra (> 140°)	–0.118	–0.044	(–0.214, –0.023)	0.015
Urethral inclination angle	–0.003	–0.058	(–0.005, –0.001)	0.002
In Valsalva state				
Bladder neck mobility	0.008	0.181	(0.006, 0.010)	0.000
Posterior angle of bladder urethra (> 140°)	0.159	0.118	(0.106, 0.212)	0.000
Urethral inclination angle	0.013	0.375	(0.011, 0.014)	0.000
Urethral rotation angle	0.004	0.089	(0.002, 0.006)	0.001
Levator ani muscle	–0.250	–0.080	(–0.353, –0.146)	0.000

BMI — body mass index; PFM — pelvic floor muscle; CI — confidence interval

DISCUSSION

According to the surveys, the prevalence of incontinence in 15- to 64-year-old women in the United States is 2–46%. A survey of a large sample (15904) in the UK ≥ 40 years old showed that the prevalence was 34%, the prevalence and severity increased with age, with a prevalence rate of 69% over 60 years old, and the prevalence in the 27936 study in Norway was 25% [23–27]. Our research found that age, menarche age, waist circumference, pregnancy, caesarean section, constipation, and physical exercise were not considered high-risk factors for SUI. BMI, vaginal delivery, and live births were considered high-risk factors for SUI, among which BMI was more important in medium and severe SUI. At present, most people think that age, BMI, delivery time, vaginal delivery times, vaginal dystocia, perineum incision and infection, foetal weight, hypertension, diabetes, long-term cough and pelvic organ surgery, menopause and oestrogen, etc. are involved in SUI. The incidence of SUI is related to the above factors, which are all risk factors for urinary incontinence, and in addition, being white and having a high waist to hip ratio increases the risk of incontinence [28–31].

The biological components of this method include evaluating the support of the pelvic floor muscle, evaluation of the myoelectric energy of the pelvic floor surface, including sexual function, and the feedback therapy of biological stimulation for dysfunction of the pelvic floor muscle, to understand the overall contraction and relaxation function of the pelvic floor muscle, the recovery progress of the pelvic floor function and the evaluation of the therapeutic effect [32, 33]. In this study, the muscle strength of type I and type II muscle fibres in SUI were decreased significantly, and the abnormal rate in severe SUI was more significant than the abnormal rate of type I and class II myofibrillar fibres than that in moderate and light SUI. These results show that electrophysiological examination of the pelvic floor is of great significance to evaluate the function of the pelvic floor muscle. This study is consistent with previous findings [34]. However, although the detection of pelvic floor myoelectricity has been widely used in the assessment of the function of the pelvic floor muscle, the data of each pelvic floor centre have not been collected in a unified database, and there are no standardized data collection methods, along with equipment diversification, data diversification and hospital control of the data, which prevents full exploitation of large amounts of data.

Pelvic floor ultrasound imaging is a reliable imaging method to observe the pelvic morphology and structure. Two-dimensional and three-dimensional pelvic floor ultrasound has been applied to the clinical diagnosis of SUI [35]. There are limitations of the examination of pelvic floor ultrasound. For example, in the severity classification of SUI, there is no unified standard for ultrasound, and there is no unified therapeutic standard for the evaluation of SUI after surgery. The auxiliary diagnosis of SUI is expected to use 2D and 3D ultrasound [36–38]. In this study, funnelization of the black neck urethra, blade neck mobility, posterior angle of the blank urethra, ureteral involvement angle, and ureteral rotation angle were all related to SUI. Yalcin et al. [39] proposed three diagnostic criteria for the diagnosis of SUI based on measurement parameters of the bladder angle and distance between the bladder neck and pubic union, namely, a posterior angle of the bladder urethra ≥ 95 degrees in the quiet state, an angle of rotation of the bladder neck ≥ 20 degrees, a distance between the bladder neck and the lower margin of the pubic union ≥ 2.3 cm, and the above three standards were in accordance with 2 criteria to diagnose SUIs. It is also suggested that the formation of a "funnel" shape of the bladder neck (expansion of the bladder neck) and the change in the bladder neck rotation angle during the Valsalva operation are the main features of ultrasound diagnosis of SUI. The occurrence of SUI is related not only to the mobility of the bladder neck but also to the mobility of the whole urethra [40]. The contour curve of urethral movement described by perineum pelvic floor ultrasound is a new method for describing the stage mobility of the urethra by pelvic ultrasound. There are also limitations of pelvic ultrasound, and there is no uniform standard for various quantitative indicators. The importance of the technique in clinical applications needs to be improved, and further research and a large amount of clinical data accumulation are needed.

In this study, high-risk factors, pelvic floor muscle strength, electromyography and ultrasound data were used to establish a prediction model of SUI. The model fitting is good, and the actual prediction coincidence rate is good. The results show that the multiple linear regression method combined with pelvic floor electromyography and ultrasound can predict the occurrence of SUI and improve the early diagnosis rate. It provides direction and thinking for further study of diagnosis prediction and risk factor analysis of light, medium and severe SUI and to screen for SUI as early as possible. As an effective auxiliary diagnostic method for early SUI, the accuracy of diagnosis and the possibility of disease prediction are improved.

CONCLUSIONS

In short, the diagnosis of SUI is mainly based on the clinical symptoms and chief complaints of patients. Although urodynamic examination can provide an accurate basis for diagnosis, the examination method is cumbersome, and it is not easy to distinguish SUI from common urinary incontinence, such as urgent urinary incontinence and filling urinary incontinence. With the help of convenient and economic early SUI detection methods, the diagnosis rate can be improved so that patients with mild to moderate SUI or an SUI tendency can be identified. Nonsurgical treatment with fewer complications and a lower risk can improve the quality of life of middle-aged and elderly women. Therefore, verifying the SUI prediction model in this study and seeking a diagnostic method that is convenient and accurate can improve the early diagnosis rate and has become a key topic of clinical research.

Funding

Supported by Research Foundation of Medical Scientific Research Foundation of Zhejiang Province, China (Grant No. 2020KY832); Natural Science Foundation of Ningbo, China (Grant No.2019A610305); Ningbo Public Service Technology Foundation, China (Grant No.202002N3154).

Authors' contributions

Zhihong ZHUO contributed to the conception of the study. Huimin YU performed the data on the pelvic muscle strength. Zhiying YU and Jianli ZHANG performed two--dimensional and three-dimensional ultrasound. Zhihong ZHUO and Huimin YU contributed significantly to pelvic floor electromyography. Zhihong ZHUO and Huimin YU performed the data analyses and wrote the manuscript.

Conflict of interests

All authors declare no conflict of interest.

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