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Research article

The predicting value of the ratio of levator hiatus diameter to fetal head circumference in pregnant women at 37 weeks of gestation in the progression of the second stage of labor and levator ani injury 6 weeks postpartum

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ABSTRACT

Objective: This study investigated the predicting value of the ratio of levator hiatus diameter (LHS) to fetal head circumference (HC) in pregnant women at 37 weeks of gestation in the progression of the second stage of labor and levator ani injury 6 weeks postpartum.
Methods: A total of 120 first-time women who gave vaginal delivery at 37 weeks of pregnancy were selected as the subjects in our hospital during March 2021 to March 2022. The subjects were divided into the second stage of labor > 1 h group and the second stage of labor ≤ 1 h group, according to the delivery time of the second stage of labor. According to the 6-week postpartum follow-up ultrasound examination with or without levator ani injury, they were divided into levator ani injury group and no injury group. All primipara women underwent three-dimensional ultrasonography at 37 weeks of gestation, and the resting LHS, Valsalva LHS, fetal HC and the ratio of resting LHS and fetal HC were compared. The correlation between these factors and the length of the second labor stage was analyzed using Pearson correlation analysis. The value of these factors in predicting labor progression and postpartum levator ani injury was assessed by receiver operating characteristic (ROC) curves.
Results: The resting LHS, Valsalva LHS and the ratio of resting LHS and fetal HC in the levator ani injury group were lower than these in the no injury group, while fetal HC in the levator ani injury group was higher than that in the no injury group ($P < 0.05$). The resting LHS, Valsalva LHS and the ratio of resting LHS and fetal HC in the second stage of labor > 1 h group were lower than these in the second stage of labor ≤ 1 h group, while fetal HC in the second stage of labor > 1 h group was higher than that in the second stage of labor ≤ 1 h group ($P < 0.05$). A significant negative correlation was observed between resting LHS/HC and total labor process (=-0.333, P < 0.01). ROC curve analysis showed that the AUCs of resting LHS, Valsalva LHS, HC, and resting LHS/HC ratio in predicting prolongation of the second stage of labor were 0.741, 0.740, 0.702, and 0.843 respectively. Besides, the AUCs of resting LHS, Valsalva LHS, HC, and resting LHS/HC ratio in predicting the total labor process were 0.657, 0.684, 0.768, and 0.836 respectively. The AUCs of resting LHS, Valsalva LHS, HC, and resting LHS/HC ratio in predicting postpartum levator ani muscle injury were 0.769, 0.773, 0.747, and 0.885 respectively.These results suggested

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that the ratio of resting LHS and fetal HC may have certain clinical value in predicting levator ani injury in pregnant women.
Conclusion: LHS, fetal HC and the ratio of resting LHS and fetal HC are significantly correlated with labor progression and postpartum levator ani injury, which have certain value in predicting labor progress and postpartum levator ani injury. Therein, the ratio of resting LHS and fetal HC has the highest predictive value, and early detection of the ratio of resting LHS and fetal HC is helpful to guide the selection of appropriate delivery mode.

1. Introduction

Vaginal delivery is the process by which a pregnant woman delivers the fetus and placenta from the vagina, including the first, second and third stages of labor. During vaginal delivery, the structure and function of pelvic floor tissue are greatly affected, and the levator ani muscle is extremely stretched and dilated [1]. Postpartum levator ani injury is a high-risk factor for pelvic floor dysfunction. Some studies have suggested that levator ani hiatus circumference and diameter are related to pelvic floor organ prolapse. The larger levator hiatus diameter (LHS) is, the greater the possibility of pelvic floor organ prolapse is. Therefore, the LHS measurement can evaluate the levator ani function. A larger hiatus can lead to stress urinary incontinence, pelvic floor organ prolapse, fecal incontinence, and sexual dysfunction, which can seriously affect women's quality of life and physical and mental health [2]. It has been showed that the duration of labor process is closely related to the postpartum levator ani injury. The longer second stage of labor is, the greater risk of levator ani injury is [3,4]. Therefore, early prediction of the course of labor, assessment of the risk of levator ani injury, and targeted intervention can help improve the prognosis of pregnant women and ensure the normal course of delivery.

Three-dimensional (3D) ultrasound is an emerging type of ultrasound in clinical practice. By reconstructing the static image in three dimensions, the morphology and edge of the lesion can be observed more clearly, and the nature of the lesion can be better judged. At present, 3D ultrasound is gradually applied to fetal examination. 3D ultrasound has a high spatial resolution of pelvic floor structure, and can observe the position of pelvic organs, fetal head circumference (HC) and levator hiatus diameter (LHS). The analysis of the ratio of LHS to head circumference in primiparous women may be helpful in assessing the progression of labor and analyzing the risk of levator ani muscle injury in the postpartum period, so as to better guide the clinical selection of appropriate delivery modalities [5,6].

The study has found that factors such as primary delivery, older age at delivery, prolongation of the second stage of labor, excessive fetal head circumference and forceps delivery can cause excessive stretching and injury of the levator ani muscle, which enlarges the levator ani hiatus, resulting in pelvic organ prolapse, stress urinary incontinence, overactive bladder, fecal incontinence and other pelvic floor dysfunction diseases [7]. The use of transperineal ultrasound to measure the angle of progression and the head-perineal distance in the second stage of labor has good predictive value for the mode and duration of labor, and can assist in the management of labor [8]. However, current research mainly focuses on the measurement of LHC or related indicators in pregnant women, the normal range, and its changes during labor. There are few studies on the ratio of LHS to HC, and further exploration is needed.

Here, it was hypothesized that the ratio of LHS to HC could be used to assess labor progression and postpartum levator ani injury. Based on this, 120 primiparous women who gave vaginal delivery at 37 weeks of pregnancy were selected as the subjects in this study. By analyzing the correlation between the ratio of LHS to HC and labor progression and postpartum levator ani muscle injury, and analyzing the risk factors for abnormal labor progress and postpartum levator ani muscle injury, high-risk factors in women were evaluated early, so as to choose the correct delivery method, reduce the occurrence of complications, and improve the quality of life of patients. The correlation between intrapartum ultrasound and the progression of labor was investigated, which made this objective, convenient, painless and more acceptable auxiliary examination method for pregnant women to be more effectively applied to clinical practice.

2. Materials and methods

2.1. General materials

A total of 428 first-time women who gave vaginal delivery at 37 weeks of pregnancy were admitted to our hospital from March 2021 to March 2022. A total of 325 pregnant women were included after screening according to the inclusion criteria. According to the exclusion criteria, 205 pregnant women were excluded, and 120 pregnant women were finally included as the study subjects. The inclusion and exclusion criteria were the key to obtaining the samples required for the purpose of the study, and the rigorous screening of the study participants indicated that the study had a certain degree of reliability. A retrospective analysis was performed on the clinical data of primiparous women at the time of hospitalization and delivery. Inclusive criteria: (1) The subjects were all primipara with 37–42 weeks of gestation, single live birth, and vaginal delivery. (2) Primipara aged between 23 and 30. (3) The subjects could complete the standard Valsalva manoeuvre. (4) The primipara and their family members were informed, had good compliance, and could cooperate with the examination and treatment. All of them signed an informed consent form. Exclusion criteria: (1) Primipara with severe metabolic and endocrine diseases such as diabetes and hypertension. (2) Primipara with previous history of constipation and pelvic surgery. (3) Primipara with urinary incontinence, pelvic organ prolapse and other symptoms before pregnancy. (4) Primipara with sexually transmitted diseases. (5) Primipara who have had instrumental deliveries and cesarean sections due to delayed and stopped labor. The average age of 120 cases of pregnant women was 26.16 ± 1.85 years. According to clinical experience, the second stage of labor was selected as the critical point and the subjects were divided into the second stage of labor > 1 h group and the second stage of labor ≤ 1 h group. According to the 6-week postpartum follow-up, 3D ultrasound examination for pelvic floor was performed to check whether there was levator ani injury, and the subjects were then divided into the levator ani injury group and no injury group. Diagnostic criteria for levator ani muscle injury [9]: Levator ani muscle fiber was completely or partially interrupted, the edge of the broken end was rough, the levator ani muscle hole was asymmetric, and it was inclined to the injured side. The urethral space of levator ani muscle on the injured side was widened (≥23 mm). The operation of this experiment was approved by the hospital Ethics Association. The experimental process of this study was shown in Fig. 1.

2.2. Methods

All maternal age, pre-pregnancy body mass index, current body mass index, and birth body weight of newborns were collected. Balloon induction of labor, artificial rupture of membranes, oxytocin induction, episiotomy, forceps assisted delivery were recorded. The time of the second stage of labor and the total time of labor were recorded. The second stage of labor referred to the stage from the opening of the uterus to the delivery of the fetus. Total labor referred to the whole process from the beginning of regular contractions to the delivery of the fetal placenta. All relevant contents were recorded by the midwifery nurse.

The resting LHS, Valsalva's, HC and ratio of LHS to HC were compared in different second stage labor groups, different total labor groups, and groups with and without levator ani injury.

VolusonE8 color Doppler ultrasonic diagnostic instrument (purchased from GE Company in the United States) was used for ultrasonic examination. The ultrasound probe model was RAB2-5 L with a linear frequency of 4–8 MHz. All primipara were examined with 3D ultrasound at 37 weeks of gestation. Before the examination, the pregnant women were instructed to empty their intestines and bladders and take the lithotomy position. The probe was covered using a sterile disposable inspection cover, which was smeared with sterile coupling agent and placed close to the vulva of pregnant women. The position should be adjusted to display the standard midsagittal plane section of the pelvic floor. LHS was measured in the static state and Valsalva state of pregnant women, respectively.

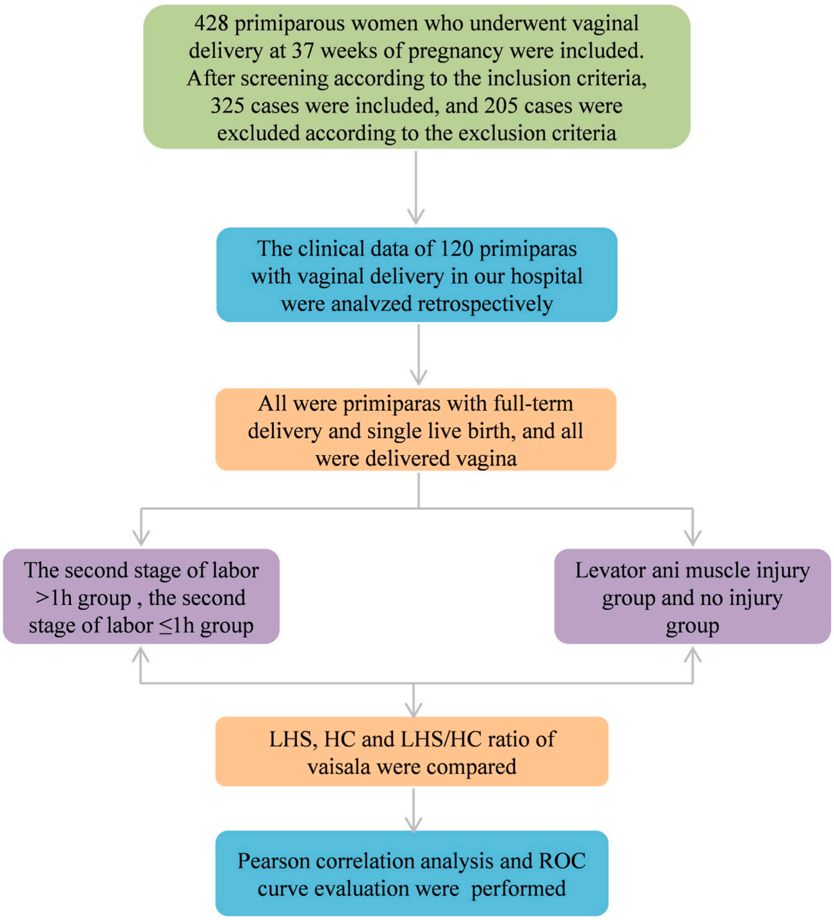

Fig. 1. The experimental process.

Pictures and dynamic images were retained. The average value of LHS was taken for three measurements [10], the images were shown in Fig. 2. All primipara were examined by ultrasound at 37 weeks of gestation. The transverse, longitudinal and oblique sections of the abdomen of pregnant women were examined with probes to measure fetal HC. The LHS/HC ratio was calculated. Two attending physicians or above who have worked in prenatal ultrasound for more than 10 years performed ultrasound examinations in a double-blind method, and at least two chief physicians jointly conducted further examinations for difficult and complex cases.

Pearson correlation analysis was used to analyze the correlation between resting LHS, Valsalva's LHS, fetal HC as well as the LHS/HC ratio and the second stage of labor.

The receiver operating characteristic (ROC) curve was used to evaluate the value of resting LHS, Valsalva's LHS, fetal HC and the LHS/HC ratio in predicting labor progression and postpartum levator ani injury, and the area under the curve (AUC), sensitivity, specificity, cut-off value, Youden index, positive predictive value and negative predictive value were calculated.

2.3. Statistical analysis

SPSS20.0 software was used to analyze the experimental data. The measurement such as the age, resting LHS, Valsalva LHS, the LHS/HC ratio were all accord with a normal distribution, and then expressed as $(\bar{x} \pm s)$ and compared using *t*-test. Pearson correlation analysis was used to analyze the correlation between resting LHS, Valsalva LHS, fetal HC and the LHS/HC ratio with the second stage of labor. The values of resting LHS, Valsalva LHS, fetal HC and the LHS/HC ratio to predict the progress of labor and postpartum levator ani injury were evaluated by the ROC curve. $P < 0.05$ indicated that the data were statistically significant.

3. Results

3.1. Comparison of LHS in patients with different second stages of labor

The resting LHS, Valsalva LHS and the ratio of resting LHS and fetal HC in the second stage of labor > 1 h group were lower than these in the second stage of labor ≤ 1 h group, while fetal HC in the second stage of labor > 1 h group was higher than that in the second stage of labor ≤ 1 h group ($P < 0.05$, Table 1).

3.2. Comparison of LHS in patients with different total stages of labor

The resting LHS, Valsalva LHS and the ratio of resting LHS and fetal HC in the total stage of labor >12 h group were lower than these in the second stage of labor ≤12 h group, while fetal HC in the second stage of labor >12 h group was higher than that in the second stage of labor ≤12 h group ($P < 0.05$, Table 2).

3.3. Comparison of obstetric related factors in patients with or without postpartum levator ani injury

There were no significant differences in proportion of maternal age, pre-pregnancy BMI, current BMI, neonatal birth weight,

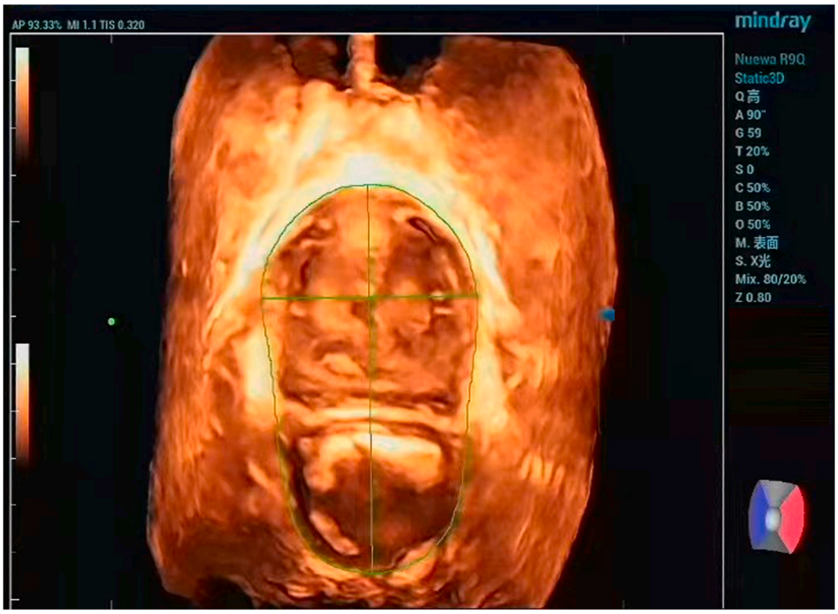

Fig. 2. 3D sonogram of the levator ani hiatus.

Table 1
Comparison of LHS in patients with different second stages of labor ($\bar{x} \pm s$).

Group	Cases	LHS (cm^2)		HC (cm)	Resting LHS/HC (cm)
		Resting	Valsalva		
The second stage of labor > 1 h group	48	12.85 ± 2.39	15.03 ± 2.58	32.85 ± 2.45	0.39 ± 0.12
The second stage of labor ≤ 1 h group	72	14.09 ± 2.46	17.59 ± 4.15	31.21 ± 1.26	0.45 ± 0.05
t		2.736	3.808	4.811	3.784
P		0.007	< 0.001	< 0.001	< 0.001

Table 2
Comparison of LHS in patients with different total stages of labor ($\bar{x} \pm s$).

Group	Cases	LHS (cm^2)		HC (cm)	Resting LHS/HC (cm)
		Resting	Valsalva		
The second stage of labor >12 h group	54	13.44 ± 3.05	15.26 ± 3.18	33.89 ± 2.87	0.40 ± 0.18
The second stage of labor ≤12 h group	66	14.99 ± 2.56	17.48 ± 3.62	30.25 ± 4.52	0.50 ± 0.15
t		3.027	3.528	5.130	3.320
P		0.003	0.001	< 0.001	0.001

balloon induction, artificial rupture and oxytocin induction between the levator ani injury group and the no injury group ($P > 0.05$). The second stage of labor and the proportion of forceps delivery in the levator ani injury group was longer than that in the no injury group, while the proportion of episiotomy in the levator ani injury group was lower than that in the no injury group ($P < 0.05$, Table 3).

3.4. Comparison of LHS in patients with or without postpartum levator ani injury

The resting LHS, Valsalva LHS, and resting LHS/HC ratio in the levator ani injury group were lower than these in the no injury group, while the fetal HC in the levator ani injury group was higher than that in the no injury group ($P < 0.05$, Table 4).

3.5. Correlation between resting LHS/HC and the second or total stage of labor

Pearson correlation analysis showed that a significant negative correlation was detected between resting LHS and the duration of the second stage of labor ($r = -0.223$, $P < 0.05$, Fig. 3A). However, Valsalva LHS was negatively correlated with the duration of the second stage of labor ($r = -0.298$, $P < 0.01$, see Fig. 3B). There was a significant positive correlation between HC and the duration of the second stage of labor ($r = 0.389$, $P < 0.001$, Fig. 3C). A significant negative correlation was observed between resting LHS/HC and the duration of the second stage of labor (=-0.370, $P < 0.001$, Fig. 3D). Besides, resting LHS was negatively correlated with the total labor process ($r = -0.184$, $P < 0.05$, Fig. 3E). Valsalva LHS was also negatively correlated with total labor process ($r = -0.297$, $P < 0.01$, Fig. 3F). In addition, resting LHS/HC was significantly negatively correlated with total labor process (=-0.333, $P < 0.01$, Fig. 3H). But a significant positive correlation was measured between HC and total labor process ($r = 0.428$, $P < 0.001$, Fig. 3G–Table 5).

3.6. Clinical value of resting LHS/HC in predicting labor progress and postpartum levator ani injury

ROC curve analysis showed that the AUCs of resting LHS, Valsalva LHS, HC, and resting LHS/HC ratio in predicting prolongation of the second stage of labor were 0.741, 0.740, 0.702, and 0.843 respectively (Fig. 4A). Besides, the AUCs of resting LHS, Valsalva LHS, HC, and resting LHS/HC ratio in predicting prolongation of the total labor process were 0.657, 0.684, 0.768, and 0.836 respectively (Fig. 4B). The AUCs of resting LHS, Valsalva LHS, HC, and resting LHS/HC ratio in predicting postpartum levator ani muscle injury were 0.769, 0.773, 0.747, and 0.885 respectively (Fig. 4C–Table 6).

Table 3
Comparison of obstetric related factors in patients with or without postpartum levator ani injury.

Factors	The levator ani injury group (n = 22)	The no injury group (n = 98)	*t*	*P*
Age (year)	29.06 ± 4.58	28.78 ± 3.52	0.318	0.751
Pro-gestational BMI (kg/m^2)	21.20 ± 3.46	21.62 ± 2.79	0.610	0.543
Current BMI (kg/m^2)	23.40 ± 3.18	22.65 ± 2.82	1.101	0.273
The birth body mass of the newborn (g)	3530.56 ± 425.52	3346.62 ± 421.30	1.847	0.067
Episiotomy	2 (9.09)	40 (40.82)	7.949	0.005
Balloon induction	11 (50.00)	52 (53.06)	0.068	0.795
Artificial rupture	13 (59.09)	38 (38.78)	3.034	0.082
Forceps delivery	10 (45.45)	20 (20.41)	6.011	0.014
Oxytocin induction	8 (36.36)	40 (40.82)	0.148	0.700
The second stage of labor (min)	96.71 ± 30.22	43.68 ± 32.88	6.933	<0.001

Table 4
Comparison of LHS in patients with or without postpartum levator ani injury ($\bar{x} \pm s$).

Groups	Cases	LHS (cm^2)		HC (cm)	Resting LHS/HC (cm)
		Resting	Valsalva		
The levator ani injury group	22	13.12 ± 1.56	15.45 ± 1.09	33.15 ± 2.85	0.39 ± 0.12
The no injury group	98	14.73 ± 1.06	16.75 ± 1.06	31.11 ± 1.63	0.47 ± 0.07
t		5.859	5.172	4.539	4.177
P		<0.001	<0.001	<0.001	<0.001

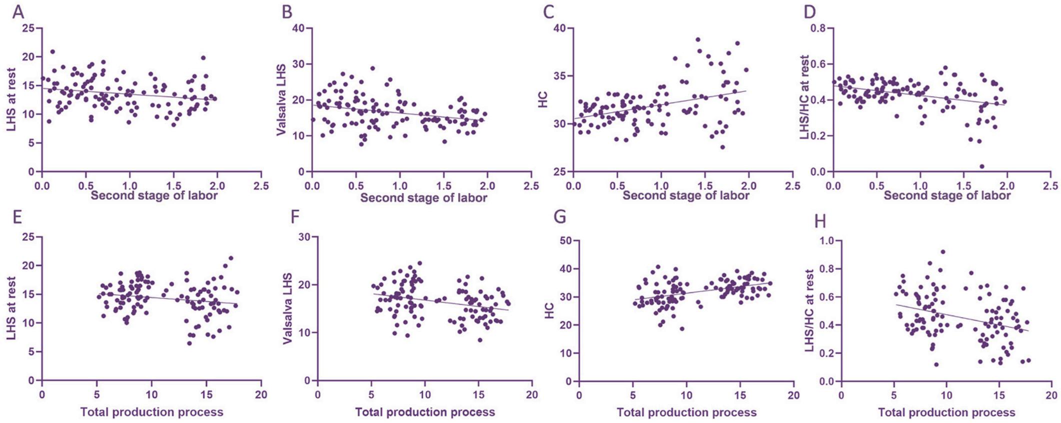

Fig. 3. Correlation between LHS/HC in resting state and the second stage of labor.
A: Correlation between resting LHS and the second stage of labor; B: Correlation between Valsalva LHS and the second stage of labor; C: Correlation between HC and the second stage of labor; D: Correlation between resting LHS/HC and the second stage of labor. E: Correlation between resting LHS and the total production process; F: Correlation between Valsalva LHS and the total production process; G: Correlation between HC and the total production process; H: Correlation between resting LHS/HC and the total production process.

Table 5
Correlation between resting LHS/HC and the second or total stage of labor.

Indicators		Resting LHS	Valsalva LHS	HC	Resting LHS/HC
The second stage of labor	*r*	−0.223	−0.298	0.389	−0.370
	P	0.014	0.001	<0.001	<0.001
The length of total labor	*r*	−0.184	−0.297	0.428	−0.333
	P	0.044	0.001	<0.001	0.001

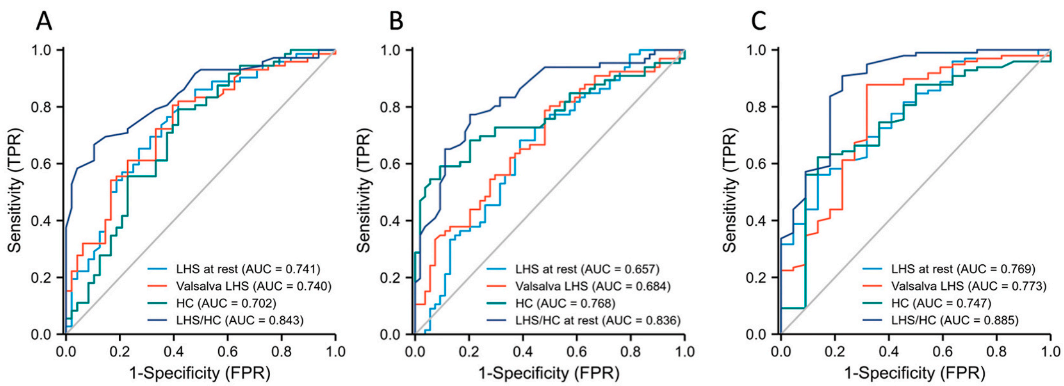

Fig. 4. Clinical value of LHS/HC at resting state in predicting labor progress and postpartum levator ani injury.
A: ROC curve of resting LHS/HC in predicting prolonged second stage; B: ROC curve of resting LHS/HC in predicting prolonged total labor process. C. ROC curve of resting LHS/HC in predicting postpartum levator ani muscle injury.

4. Discussion

In recent years, a growing body of research has confirmed the subjectivity of prenatal ultrasound. However, the results of prenatal ultrasound examination are still the main basis for decision-making in clinical work. Therefore, if the judgment is wrong, it may lead to adverse outcomes for mothers and children. In 2018, the International Society of Obstetrics and Gynecology Ultrasound published guidelines on intrapartum ultrasound affirmed the role of ultrasound in assisting in the management of labor [11]. The study has suggested that cesarean section in the second stage of labor is associated with adverse pregnancy outcomes such as postpartum hemorrhage, fever, incision infection, neonatal amniotic fluid meconium, and hyperbilirubinemia, the risk of preterm birth in another pregnancy is also increased, and instrument-assisted delivery may also cause various maternal and infant complications [12]. Thus, a smooth vaginal birth in the second stage of labor is a common psychological expectation of doctors, midwives and mothers. If the risk of dystocia in the second stage of labor can be known at the beginning of the labor stage, it will help doctors make early decisions and actively intervene, which may improve the delivery outcome. Maternal LHS is closely related to factors such as mode of delivery, progress of labor, and neonatal head circumference. Under normal circumstances, maternal LHS gradually expands with increasing gestational age to meet the needs of fetal growth and development. However, when the diameter is too large or too small, it can lead to complications such as pelvic floor muscle damage during childbirth and postpartum urinary incontinence. The larger ratio of maternal LHS to fetal HC indicates larger fetal head circumference, which causes the increased pressure on the pelvic floor muscles and the greater the difficulty of delivery. Therefore, accurate assessment of maternal LHS is of great significance for predicting the risk of childbirth and formulating corresponding diagnosis and treatment plans.

Postpartum levator ani injury is a common injury in the delivery process. Because of the atypical early symptoms, it is very easy to cause misdiagnosis or missed diagnosis and miss the best treatment time for the parturient, thus affecting the prognosis of the parturient [13]. The previous study shows that the second stage of labor is also related to postpartum levator ani muscle injury. The longer the stage of labor is, the greater the risk of postpartum levator ani muscle injury is [14]. Levator ani hiatus is a relatively weak position in pelvic floor tissue structure. The second stage of labor is the process of the fetal head passing through the pelvic septal hiatus, which will lead to extreme expansion of levator ani muscle, soft birth canal and surrounding pelvic floor tissues. Excessive expansion or prolonged traction will lead to postpartum levator ani injury [3,15]. 3D ultrasound has the advantages of real-time dynamic, high accuracy, repeatable, low price, etc, which can effectively detect the level of maternal LHS and fetal HC with good accuracy [16,17]. Transperineal ultrasound indexes are closely related to the duration of labor. The study has found that smaller levator hiatus diameter may be associated with a longer duration of the second stage of labour and a higher risk of caesarean and surgical delivery [18]. In addition, a smaller levator hiatus diameter is associated with a higher fetal head position during pregnancy, as assessed by perineal ultrasound. Kamel R et al. [19] found that by assessing the correlation between levator hiatus anterior, posterior diameters as well as levator ani coactivation and different modes of labor and different labor durations, the results showed that a larger anterior and posterior diameter of the levator diaphragm in Valsalva was associated with a shorter second stage of labor and an active second stage of labor, and that there was an independent and significant correlation between levator ani muscle coactivation and longer active time in the second stage of labor. In this study, we found that the group with the second stage of labor>1 h and the group with total labor duration>12 h had lower resting state LHS, Valsalva LHS, resting LHS/HC and larger fetal HC than the group with the second stage of labor ≤ 1 h and the group with total labor duration ≤12 h ($P < 0.05$). The study has found that the degree of dilation of the levator ani hiatus is closely related to organ prolapse, especially in the Valsalva state, where the larger the hiatus is, the more severe the prolapse is [20]. The results from this study showed that the group with ani injury had lower resting state LHS, Valsalva LHS, and resting LHS/HC and larger fetal HC than the group without injury. It was suggested that the levels of maternal LHS and fetal HC were related to the second stage of labor, the total stage of labor and the injury of levator ani after delivery, in line with the above findings. Detection of maternal LHS and fetal HC levels before delivery may help to assess the feasibility of vaginal delivery and the risk of levator ani injury after delivery. In a study [21], the diameter and area of the genital hiatus and levator ani hiatus in patients with pelvic prolapse were measured by a double-blind method, and the results showed that the diameter and area of the levator ani hiatus were significantly higher in both positions (rest or Valsalva maneuver) than in the normal pelvic floor group. In addition, in patients with pelvic prolapse, the levator ani foramen length at rest was significantly lower than that of the Valsalva maneuver. Combined with the reference data and the results of this study, it was found that the diameter and area of the levator ani hiatus could be used as evaluation indicators to evaluate the progress of labor and levator ani injury, and the double-blind method could eliminate the subjective factors of both examiners and subjects, and maintain the impartiality and objectivity of the test.

The second stage of labor is the most critical and dangerous link in the delivery process. If the second stage of labor is delayed or even stagnated, forceps midwifery or emergency cesarean section is required, which increases the risk of complex cesarean section, pelvic floor injury and neonatal asphyxia [22]. The study found that 13.00 %–14.00 % of primipara have postpartum levator ani muscle injury during delivery [23]. It is reported that the probability of levator ani injury after vaginal delivery of primipara in China is as high as 21.70 % [24]. Postpartum levator ani injury not only increases the pain of the parturient, but also affects the rapid recovery of the parturient. Therefore, it is important to find indicators to effectively predict the labor process and postpartum levator ani injury. In this study, duration of the second and total stages of labor was closely negatively correlated with resting LHS, Valsalva LHS, and resting LHS/HC, and was positively correlated with HC. In addition, the AUCs of resting LHS/HC in predicting prolonged second stage of labor, prolonged total labor, and postpartum levator ani injuries were 0.843, 0.784, and 0.885, respectively. It was suggested that the level of resting LHS/HC was of high value in predicting the levator ani injury after the prolonged second and prolonged total stages of labor. Early detection of LHS/HC level at resting state is helpful to guide the selection of appropriate delivery mode. As a new index to evaluate the labor process, the ratio of LHS and fetal HC in pregnant women is of great research significance. First of all, this ratio can reflect the pressure on the levator ani muscle during labor, which can help predict complications during labor. Secondly, by

Table 6
Clinical value of LHS/HC at resting state in predicting labor progress and postpartum levator ani injury.

Predicting labor progress	Indicators	AUC	95 %CI	*P* value	Cutoff value	Sensitivity	Specificity	Youden Index
Prolonged second stage	Resting LHS	0.741	0.649–0.832	0.001	13.65 cm^2	81.90	58.30	0.402
	Valsalva LHS	0.740	0.650–0.830	0.001	16.74 cm^2	60.40	60.40	0.208
	HC	0.702	0.603–0.801	0.001	31.69 cm	79.20	58.30	0.375
	Resting LHS/HC	0.843	0.775–0.912	0.001	0.41 cm	66.70	89.60	0.863
Prolonged total labor process	Resting LHS	0.657	0.601–0.752	0.001	13.85 cm^2	71.33	60.00	0.313
	Valsalva LHS	0.684	0.633–0.768	0.001	16.22 cm^2	80.00	52.26	0.323
	HC	0.768	0.701–0.835	0.001	32.15 cm	72.05	74.38	0.464
	Resting LHS/HC	0.836	0.789–0.901	0.001	0.46 cm	84.45	75.62	0.607
Postpartum levator ani injury	Resting LHS	0.769	0.667–0.872	0.001	14.41 cm^2	56.10	86.40	0.425
	Valsalva LHS	0.773	0.654–0.891	0.001	16.37 cm^2	87.80	68.20	0.560
	HC	0.747	0.631–0.864	0.001	32.63 cm	62.20	86.40	0.486
	Resting LHS/HC	0.885	0.798–0.971	0.001	0.43 cm	90.80	77.30	0.681

Predicting labor progress	Indexes	Positive predictive value	Negative predictive value
Prolonged second stage	Resting LHS	87.25	83.54
	Valsalva LHS	66.33	79.82
	HC	74.85	79.33
	Resting LHS/HC	76.06	76.34
Prolonged total labor process	Resting LHS	77.25	73.26
	Valsalva LHS	79.15	75.44
	HC	81.52	82.36
	Resting LHS/HC	85.74	88.79
Postpartum levator ani injury	Resting LHS	80.77	82.22
	Valsalva LHS	82.15	79.98
	HC	81.10	78.70
	Resting LHS/HC	79.19	83.57

studying the changes of LHS and fetal HC ratios in pregnant women, it can provide clinicians with a more accurate evaluation basis and guide the choice of delivery mode. Finally, the study of this ratio can help to improve the safety of childbirth and reduce the incidence of complications for pregnant women and fetuses. Therefore, the purpose of this study was to explore the clinical value of maternal LHS and fetal HC ratio in predicting the progression of the second stage of labor and levator ani muscle injury, in order to provide a useful reference for clinical practice.

In general, LHS, fetal HC, and LHS/HC had some predictive values in labor progress and postpartum levator ani injuries. Among which, LHS/HC had the highest predictive value. Thus, early detection of LHS/HC level was helpful to guide the selection of appropriate delivery methods. However, due to the influence of research conditions and limited research time, a total of 120 cases of parturients were collected as observation objects, and there were few samples collected, and there were sampling errors, which may affect the experimental results. In addition, levator ani injury is not the only important birth-related injury that occurs in the development of prolapse or incontinence, so this study is limited to the evaluation of levator ani injury at 6 weeks postpartum. Moreover, there was also a risk of damage to the perineal body and perineal membrane in the postpartum period, and this study did not correlate with LHS and fetal HC ratio. Therefore, in the future, we will expand the experimental subjects and research time for in-depth exploration. The potential of LHS and fetal HC ratios in the prediction of other childbirth-related complications in pregnant women can be further explored, so as to provide more strong support for clinical delivery management. In addition, the application value of ultrasonography in the measurement of LHS and fetal HC ratio in pregnant women is also worthy of further discussion, in order to provide a safer and more convenient examination method for pregnant women.

Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent was obtained from all individual participants included in the study. All procedures performed in studies were in accordance with the ethical standards of the ethics committee of The First Affiliated Hospital of Fujian Medical University (2015-084-2).

Consent for publication

Informed consent was obtained from all individual participants included in the study. The patients participating in the study all agree to publish the research results.

Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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CRediT authorship contribution statement

Bei Gan: Writing – original draft, Validation, Methodology, Data curation. **Shan Zheng:** Writing – review & editing, Resources, Data curation. **Xiuyan Wu:** Writing – review & editing, Resources, Data curation. **Xuemei Li:** Writing – review & editing, Software, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] W.R. Cohen, E.A. Friedman, Clinical evaluation of labor: an evidence- and experience-based approach, J. Perinat. Med. 49 (3) (2020 Oct 19) 241–253.
[2] D. Luo, H. Wen, G. Peng, Y. Lin, M. Liang, Y. Liao, Y. Qin, Q. Zeng, J. Dang, S. Li, A prenatal ultrasound Scanning approach: one-touch technique in second and third trimesters, Ultrasound Med. Biol. 47 (8) (2021 Aug) 2258–2265.
[3] F. Pipitone, J.M. Miller, J. DeLancey, Injury-associated levator ani muscle and anal sphincter ooedema following vaginal birth: a secondary analysis of the EMRLD study, BJOG 128 (12) (2021 Nov) 2046–2053.
[4] I. Volløyhaug, A. Taithongchai, I. Van Gruting, A. Sultan, R. Thakar, Levator ani muscle morphology and function in women with obstetric anal sphincter injury, Ultrasound Obstet. Gynecol. 53 (3) (2019 Mar) 410–416.
[5] A.N. Bulut, V. Ceyhan, Evaluation of the labour process with serial transperineal ultrasonography and prediction of the type of birth, J. Perinat. Med. 49 (1) (2020 Sep 7) 36–42.
[6] Y. Yune, H.Y. Jeong, D.H. Park, J.K. Lee, Three-dimensional pelvic floor ultrasound assessment of pelvic organ prolapse: minimal levator hiatus and levator ani deficiency score, Ann. Coloproctol. 37 (5) (2021 Oct) 291–297.
[7] V.L. Handa, J. Roem, J.L. Blomquist, H.P. Dietz, A. Muñoz, Pelvic organ prolapse as a function of levator ani avulsion, hiatus size, and strength, Am. J. Obstet. Gynecol. 221 (1) (2019 Jul) 41.e1–41.e7.
[8] L. Angeli, F. Conversano, A. Dall'Asta, N. Volpe, M. Simone, E. Di Pasquo, D. Pignatelli, G.B.L. Schera, M. Di Paola, P. Ricciardi, A. Ferretti, T. Frusca, S. Casciaro, T. Ghi, New technique for automatic sonographic measurement of change in head-perineum distance and angle of progression during active phase of second stage of labor, Ultrasound Obstet. Gynecol. 56 (4) (2020 Oct) 597–602.
[9] D. Li, R. Lu, Research progress in pelvic floor ultrasound for assessing the morphology and function of levator ani muscle in women, Zhong Nan Da Xue Xue Bao Yi Xue Ban 48 (8) (2023 Aug 28) 1267–1273.
[10] J.A. García Mejido, C.M. Suárez Serrano, A. Fernéndez Palacín, A. Aquise Pino, M.J. Bonomi Barby, J.A. Sainz Bueno, Evaluation of levator ani muscle throughout the different stages of labor by transperineal 3D ultrasound, Neurourol. Urodyn. 36 (7) (2017 Sep) 1776–1781.
[11] T. Ghi, T. Eggebø, C. Lees, K. Kalache, P. Rozenberg, A. Youssef, L.J. Salomon, B. Tutschek, ISUOG Practice Guidelines: intrapartum ultrasound, Ultrasound Obstet. Gynecol. 52 (1) (2018 Jul) 128–139.
[12] J. Sandall, R.M. Tribe, L. Avery, G. Mola, G.H. Visser, C.S. Homer, D. Gibbons, N.M. Kelly, H.P. Kennedy, H. Kidanto, P. Taylor, M. Temmerman, Short-term and long-term effects of caesarean section on the health of women and children, Lancet 392 (10155) (2018 Oct 13) 1349–1357.
[13] S. Mathew, R.A. Guzmán Rojas, K.A. Salvesen, I. Volløyhaug, Levator ani muscle injury and risk for urinary and fecal incontinence in parous women from a normal population, a cross-sectional study, Neurourol. Urodyn. 38 (8) (2019 Nov) 2296–2302.
[14] B.D. Heliker, K. Kenton, A. Leader-Cramer, O. Brown, K. Bochenska, J. Geynisman-Tan, M. Mueller, C. Lewicky-Gaupp, Adding insult to injury: levator ani avulsion in women with obstetric anal sphincter injuries, Female Pelvic Med. Reconstr. Surg. 27 (7) (2021 Jul 1) 462–467.
[15] D.O.C. Anumba, S. Gillespie, S. Jha, S. Abdi, J. Kruger, A. Taberner, P.M.F. Nielsen, X. Li, Postnatal pelvic floor muscle stiffness measured by vaginal elastometry in women with obstetric anal sphincter injury: a pilot study, Int. Urogynecol. J. 31 (3) (2020 Mar) 567–575.
[16] C.F.A. Smeets, T.F.M. Vergeldt, K.J.B. Notten, F.M.J. Martens, S.M.J. van Kuijk, Association between levator ani avulsion and urinary incontinence in women: a systematic review and meta-analysis, Int. J. Gynaecol. Obstet. 153 (1) (2021 Apr) 25–32.
[17] L. Nandikanti, A.G. Sammarco, E.K. Kobernik, J.O.L. DeLancey, Levator ani defect severity and its association with enlarged hiatus size, levator bowl depth, and prolapse size, Am. J. Obstet. Gynecol. 218 (5) (2018 May) 537–539.
[18] A. Youssef, E. Brunelli, G. Pilu, Fundal pressure in the second stage of labor (Kristeller maneuver) and levator ani avulsion, Int. Urogynecol. J. 32 (2) (2021 Feb) 471–472.
[19] R. Kamel, E. Montaguti, K.H. Nicolaides, M. Soliman, M.G. Dodaro, S. Negm, G. Pilu, M. Momtaz, A. Youssef, Contraction of the levator ani muscle during Valsalva maneuver (coactivation) is associated with a longer active second stage of labor in nulliparous women undergoing induction of labor, Am. J. Obstet. Gynecol. 220 (2) (2019 Feb) 189.e1–189.e8.
[20] A.G. Sammarco, L. Nandikanti, E.K. Kobernik, B. Xie, A. Jankowski, C.W. Swenson, J.O.L. DeLancey, Interactions among pelvic organ protrusion, levator ani descent, and hiatal enlargement in women with and without prolapse, Am. J. Obstet. Gynecol. 217 (5) (2017 Nov) 614.e1–614.e7.
[21] S.F. Siahkal, M. Iravani, Z. Mohaghegh, F. Sharifipour, M. Zahedian, M.B. Nasab, Investigating the association of the dimensions of genital hiatus and levator hiatus with pelvic organ prolapse: a systematic review, Int. Urogynecol. J. 32 (8) (2021 Aug) 2095–2109.
[22] C.C. Liao, S.H. Lan, Y.Y. Yen, Y.P. Hsieh, S.J. Lan, Aromatherapy intervention on anxiety and pain during first stage labour in nulliparous women: a systematic review and meta-analysis, J. Obstet. Gynaecol. 41 (1) (2021 Jan) 21–31.
[23] J.S. Kubotani, E. Araujo Júnior, A.S.Q. Campos, J.P. Passos, C.F.D.N. Neri, M.R.D. Zanetti, Physiotherapeutic treatment for levator ani avulsion after delivery: a transperineal three-dimensional ultrasound assessment, J. Med. Ultrasound 28 (4) (2020 Nov 9) 245–248.
[24] A.M. Roos, L. Speksnijder, A.B. Steensma, Postpartum sexual function; the importance of the levator ani muscle, Int. Urogynecol. J. 31 (11) (2020 Nov) 2261–2267.