Journal of Carcinogenesis
Covering Genesis to Therapeutics

Journal of Carcinogenesis, ISSN: 1477-3163
2025; Vol 24: Issue 8s, https://carcinogenesis.com/

Assessing Cervical Stiffness and Cervical Length about Gestational Age: A Prospective Study Using Transvaginal Ultrasound and Shear Wave Elastography

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ABSTRACT

Preterm birth (PTB) continues to be a major contributor to neonatal health complications worldwide. While transvaginal sonography (TVS) is widely used to assess cervical length as a predictive tool for PTB, its accuracy is limited. Recently, Shear Wave Elastography (SWE) has become a potential supplementary method for evaluating cervical stiffness. This study investigates the connection between cervical length, cervical stiffness, and gestational age to determine whether stiffness serves as an independent indicator of PTB risk. The cross-sectional study was conducted over 18 months and involved 100 pregnant women in their second trimester. Cervical length was measured via TVS, while cervical stiffness was assessed at three specific cervical sites (internal os, mid-cervical canal, and external os) using SWE. Statistical analysis, including Pearson's correlation, was performed utilizing SPSS (Version 19), with a significance level set at $p<0.05$.A significant negative correlation is observed between cervical length and gestational age ($p<0.05$). Additionally, cervical stiffness progressively declined as pregnancy advanced. Women who experienced PTB exhibited considerably shorter cervical lengths (< 25 mm) and lower cervical stiffness values compared to those who carried to term ($p< 0.05$). The findings suggest that SWE-based cervical stiffness assessment, together with the measurement of cervical length, enhances predictive accuracy for PTB. Integrating SWE into routine obstetric evaluation could improve early risk identification and preventive care strategies. To verify these outcomes, more thorough investigations are recommended.

Keywords: *Cervical length, Cervical stiffness, Pre-term birth (PTB), Shear wave elastography (SWE), Transvaginal sonography (TVS)*

How to Cite: Michael Antony Vikram, Sanjaykanth Balachandar, Karthik Krishna Ramakrishnan, Paarthipan Natarajan, (2025) Assessing Cervical Stiffness and Cervical Length about Gestational Age: A Prospective Study Using Transvaginal Ultrasound and Shear Wave Elastography, *Journal of Carcinogenesis*, *Vol.24, No.8s*, 468-475

1. INTRODUCTION

Pre-term birth (PTB) continues to pose a significant challenge in obstetric care, being among the primary global causes of newborn morbidity as well as mortality. Although TVS (transvaginal ultrasound) cervical length measurement is an established method for predicting spontaneous PTB, the positive predictive value is low (18%) for deliveries that occur before 34 weeks [1,2].

The cervix is subject to major biomechanical changes during pregnancy and transitions from a hard, supportive structure to a softer, more elastic canal that allows for labor [3, 4]. This physiologic process, often called cervical ripening, involves changes in collagen composition and tissue elasticity. SWE (Shear Wave Elastography), an advanced ultrasound imaging technique, provides a quantitative measurement of cervical stiffness by evaluating tissue elasticity by measuring the propagation speed of shear waves through tissue, expressed in kilopascal (kPa)as described by Taljanovic et al. [5, 6]. Unlike traditional clinical approaches like the Bishop score, which uses subjective evaluation, SWE provides an objective and reproducible evaluation of the biomechanical properties of the cervix [7, 8].

Recent research indicates that cervical softness, as measured by SWE, can potentially serve as an initial predictor of the risk of PTB even when cervical length is within normal limits [9, 10]. These findings suggest that the incorporation of cervical stiffness with the measurement of cervical length can increase the accuracy in predicting PTB. This research aims

to investigate the relationship among cervical length, cervical stiffness, and gestational age as well as assess whether cervical stiffness can function as an independent marker for determining risk of PTB.

2. MATERIALS AND METHODS

This prospective cross-sectional study was conducted in the Department of Diagnostic Radiology & Imaging at Saveetha Medical College and Hospital, Chennai, over 18 months from September 2022 to March 2024. The research aimed to examine the association among cervix strength (stiffness) with cervical length across various gestational ages. The study population included pregnant women in their second trimester attending routine antenatal checkups.

Participants were chosen according to predetermined inclusion and exclusion parameters. The inclusion criteria required participants to be pregnant women aged 18 years and above with singleton pregnancies. Exclusion criteria included multiple pregnancies (e.g., twins, triplets), a history of cervical surgery or cervical insufficiency, known fetal abnormalities, and maternal medical conditions such as diabetes or hypertension. Pregnant women unwilling to participate were also excluded. A total of 100 pregnant women in their mid-trimester have been recruited using a purposive sampling technique. Ethical approval was obtained from the Institutional Human Ethics Committee (IHEC) of Saveetha Medical College & Hospital, as well as written consent was secured from all participants before enrollment.

Gestational age was determined based on the last menstrual period (LMP) and further confirmed through a first-trimester ultrasound examination. Cervical length was measured via transvaginal sonography (TVS) following a standardized protocol. Three sequential cervical length measurements were taken over 5 minutes, and the shortest recorded length was used for analysis to minimize variations. Cervical stiffness was assessed immediately after cervical length measurement using SWE. The stiffness was measured at three specific anatomical locations: the internal os, the middle cervical canal, and the external os. A TVS probe in SWE mode was used to capture real-time stiffness values in kilopascals (kPa). Special precautions were taken to ensure minimal probe pressure on the cervix to prevent measurement artifacts, and uniform probe placement was maintained to ensure accuracy. Each participant underwent two SWE assessments, performed by two independent sonographers, to minimize inter-observer variability.

Microsoft Excel was utilized to record all of the data, and SPSS (Version 19) was employed for analysis. Demographic and clinical features were summarized utilizing descriptive statistics, like means, standard deviations, and proportions. Pearson's correlation analysis has been performed to determine the relationship between cervical length with gestational age, cervical stiffness with gestational age, and cervical length and cervical stiffness. Hypothesis testing was conducted using independent sample t-tests as well as Chi-square tests, with statistical significance set at a $p\text{-value}<0.05$.

3. RESULTS

This investigation included 100 pregnant women in their second trimester who underwent transvaginal sonography (TVS) for cervical length measurement and SWE for cervical stiffness assessment. The results are presented in terms of demographic characteristics, gestational age distribution, cervical length and stiffness correlations, and pregnancy outcomes.

The investigation participants' average age is 29.39±3.66yrs. The majority of participants (52%) are in the 26- 30 age group, then 22% in the 31-35 years group, 17% under 25 years, and 9% over 36 years. Most participants were employed (59%), while 41% were housewives. Regarding parity, 54% were nulliparous, and 46% were multiparous. (Table 1)

Table 1: Demographic details of the Study Participants

Variable	Frequency (n=100)	Percentage (%)
Age Group(Years)		
<25	17	17%
26 - 30	52	52%
31 - 35	22	22%
> 36	9	9%

Employment Status		
Employed	59	59%
Housewife	41	41%
Parity Status		
Nulliparous	54	54%

Mean gestational age at enrolment was 15.80±1.44weeks. By the first follow-up, it was 19.96 ± 1.42 weeks, and by the second follow-up, it was 23.96 ± 1.42 weeks. (Table 2)

Table 2: Gestational Age Distribution

Gestational Age (Weeks)	Minimum	Maximum	Mean ± SD
At enrolment	13.6	18.4	15.80 ± 1.44
First follow-up	17.6	23.0	19.96 ± 1.42
Second follow-up	21.6	27.0	23.96 ± 1.42

The mean cervical length measured at enrolment was 34.5±4.2mm, which progressively shortened with advancing gestation. There was a statistically significant relationship ($p<0.05$) between cervical length and gestational age, confirming expected cervical shortening as the pregnancy progressed. Cervical stiffness, measured using SWE, also demonstrated a gradual decline with increasing gestational age. The mean stiffness values at the internal os, middle cervical canal, and external os were recorded at different time points. A statistically significant negative correlation ($p<0.05$) was observed between cervical stiffness and gestational age, indicating cervical softening as pregnancy advanced. (Table 3)

Table 3: Cervical Length and Stiffness across Gestational Age

Measurement Site	Gestational Age 14-18 weeks	Gestational Age 18-23 weeks	Gestational Age 22-27 weeks
Cervical Length (mm)	34.5 ± 4.2	30.9 ± 3.8	28.4 ± 3.5
Cervical Stiffness (kPa):			
1. At Internal Os	24.1 ± 2.5	20.5 ± 2.2	18.3 ± 2.1
2. At Mid Cervical Canal	20.8 ± 2.3	18.6 ± 2.1	16.7 ± 1.9
3. At External Os	17.5 ± 2.1	15.9 ± 1.8	14.2 ± 1.7

A strong positive correlation ($r=0.75$) is observed between cervical length and cervical stiffness at all three sites. This indicates that as cervical length decreased, cervical stiffness also reduced, demonstrating the progressive ripening of the cervix during pregnancy. (Figure 1, 2)

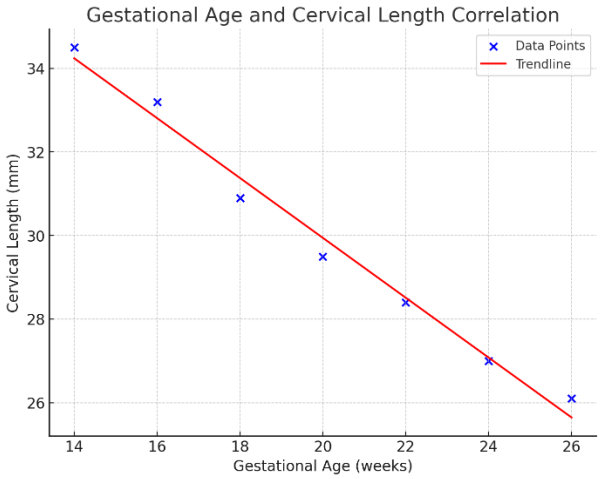

FIGURE 1. Correlation of Cervical Length across Gestational Age

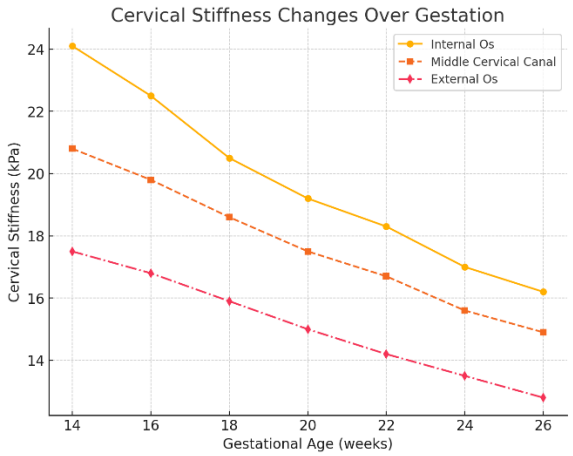

FIGURE 2. Comparison of Cervical Stiffness at the Internal Os, Middle Cervical Canal, and External Os with Advancing Gestational Age

Among the 100 study participants, 29% experienced preterm delivery, while 71% had term deliveries. Women who gave birth prematurely had an average cervical length of less than 25 mm. In contrast, the mean cervical length of women who gave birth at term was greater than 30 mm ($p<0.01$). Similarly, cervical stiffness was significantly lower in women who delivered preterm. The mean stiffness values at the internal os, middle cervical canal, and external os in preterm cases were significantly lower compared to term deliveries (**$p<0.05$**). (Table 4)

Table 4: Comparison of Cervical Measurements in Term vs. Preterm Deliveries

Measurement Site	Term Delivery (n=71)	Preterm Delivery (n=29)	p-value
Cervical Length (mm)	31.2 ± 3.7	24.6 ± 3.3	**< 0.01**
Cervical Stiffness (kPa)			
At Internal Os	21.3 ± 2.4	17.8 ± 2.2	**< 0.05**
At Mid Cervical Canal	19.4 ± 2.1	15.7 ± 1.9	**< 0.05**
At External Os	16.8 ± 1.7	13.9 ± 1.6	**< 0.05**

These findings confirm that lower cervical length and reduced stiffness are strong predictors of PTB (Figure 3, 4).

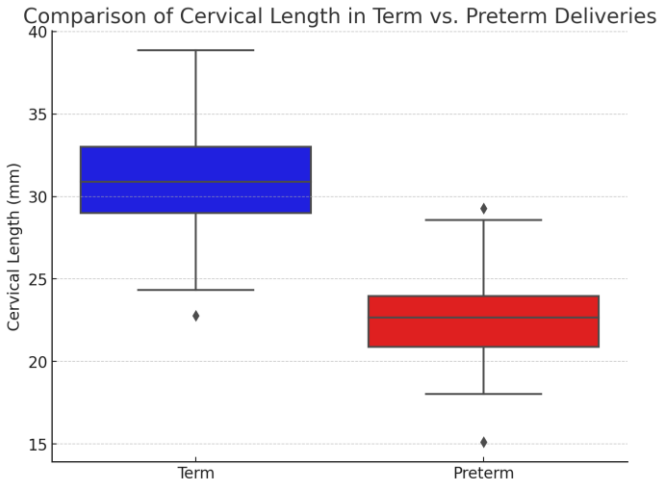

FIGURE 3. Comparison of Cervical Length in Term vs. Preterm Deliveries

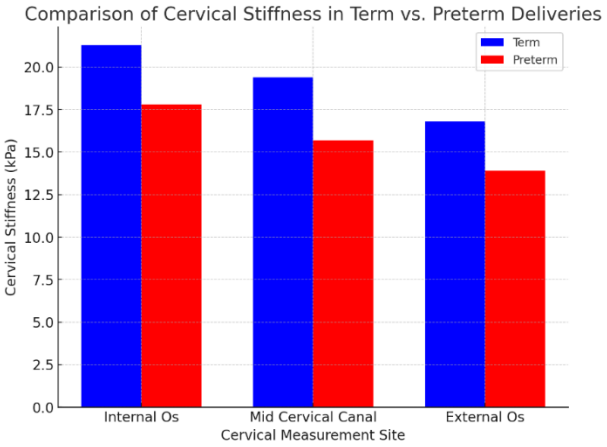

FIGURE 4. Comparison of Cervical Stiffness in Term vs. Preterm Deliveries

4. DISCUSSION

PTB is a leading cause of neonatal morbidity and mortality worldwide. While cervical length has been evaluated extensively as a predictor of preterm delivery, its predictive value is limited due to the variability between patients [3]. Recently, cervical stiffness has been introduced as an additional marker for predicting the risk of preterm labor [4]. This study aimed to evaluate the correlation between cervical stiffness, cervical length, and gestational age to assess whether cervical stiffness could be a useful predictor of PTB.

Our results support that progressive shortening of cervical length is seen with rising gestational age, which is consistent with other studies [3,6]. The mean cervical length was 34.5±4.2mm at 14–18 weeks which gradually decreased to 28.4±3.5 mm by 22–27 weeks in our study. This coincides with Mukherji et al. [11], who observed a strong inverse relationship between cervical length and advancing gestation. Similarly, Tsoi et al. [12] and Chandrasekaran et al. [13] showed that women delivered preterm had a significant decrease in cervical length during the second and third trimesters. Tanvir et al. [14] found a significant correlation between cervical lengths and preterm labor with his study demonstrating a cervical length of less than 25 mm attributes to pre-term deliveries, reinforcing the clinical utility of this threshold in risk stratification. Thain et al. [15] reported that in Asian populations, cervical length measurements were a significant predictor of preterm delivery, emphasizing the importance of ethnic-specific cervical profiling.

In addition to cervical length, we found a progressive decline in cervical stiffness, measured by SWE at the internal os, middle cervical canal, and external os with an increase in gestational age. Cervical stiffness at the internal os lessened from 24.1 ± 2.5 kPa at 14–18 weeks to 18.3 ± 2.1 kPa at 22–27 weeks, showing a statistically significant decrease ($p<0.05$). This pattern is similar to the other cervical sites, indicating cervical softening with advancing pregnancy. Duan et al. [16] reported similar results demonstrating significant negative correlation notable evidence between cervical stiffness and

gestational age based on SWE.

A strong positive correlation ($r=0.75$, $p<0.05$) was noted between cervical length and cervical stiffness, meaning that as the cervix shortens, it also gets less stiff. This supports the paradigm of cervical ripening as a process that involves both shortening and softening [8]. Swiatkowska-Freund et al. [17] presented similar findings and reported that cervical stiffness decreased significantly with increasing gestational age, particularly at the internal os. These results indicate that assessing both cervical length and stiffness may improve the accuracy of PTB prediction.

Our study also evaluated pregnancy outcomes, demonstrating that 29% of participants delivered preterm while 71% had term deliveries. Women with PTB had significantly shorter cervical length and lesser cervical stiffness at all three sites. The mean cervical length was 24.6±3.3mm for the preterm group and 31.2 ± 3.7 mm for the term deliveries ($p < 0.01$). Similarly, cervical stiffness at the internal os was lower in preterm deliveries compared to term cases (17.8±2.2kPa vs 21.3±2.4kPa, $p<0.05$). These results are consistent with Hernandez-Andrade et al. [8], which demonstrated an association between reduced cervical stiffness with a higher incidence of spontaneous PTB. Additionally, Duan et al. [16] showed that nulliparous women had lower cervical stiffness than parous women without a history of preterm labor, which substantiates the clinical relevance of these measurements.

Our findings have important clinical implications. Currently, transvaginal sonography (TVS) based cervical length assessment is known to be the most widely used practice for estimating the risk of PTB [3, 15]. However, our results support the adoption of SWE-based cervical stiffness measurement as an adjunct tool. Combining short cervical length and decreased cervical stiffness could serve as more accurate predictors of preterm labor. Facilitating early interventions including progesterone supplementation, cervical cerclage, or pessary placement [17]. This is consistent with other studies indicating that measurement of cervical stiffness enhances risk stratification beyond cervical length alone [18].

5. LIMITATIONS AND FUTURE RESEARCH

Although this study has shown that incorporating cervical length and cervical stiffness can be used as potential indicators for predicting preterm deliveries; There are some limitations to this study. Firstly, the relatively small sample size ($n = 100$), restricted the generalizability of the findings. Second, PTB is influenced by multiple factors, including maternal infection, inflammation, and genetic predisposition, which were not accounted for in this study [18, 19]. Future studies should involve larger cohorts and more clinical risk factors to refine predictive models. Finally, despite the quantitative evaluation of cervical stiffness obtained through SWE, variations in tissue anisotropy and operator dependence may cause measurement bias [20].

Further research is needed to validate the assessment of cervical stiffness in routine clinical practice. Prospective studies incorporating cervical stiffness, cervical length, and maternal biomarkers at a large scale may contribute to developing integrated risk-prediction models for PTBs. Also, the feasibility of SWE-guided interventions, including individualized progesterone therapy for women with decreased cervical stiffness requires further investigation [21].

With the expanding scope of SWE in obstetrics, there are other potential research avenues outside of the cervix, such as the use of SWE to assess placental stiffness in pre-eclampsia as reported by Singh et al. [22] which can, in turn beattributed as a potential indicator in predicting pre-term deliveries.

6. CONCLUSION

This study demonstrates that cervical length and stiffness decrease with advancing gestational age and that their combined assessment provides a better predictive value for preterm birth than cervical length alone. Women who delivered preterm had markedly shorter cervical length and reduced cervical stiffness, highlighting their role as independent factors for predicting pregnancy outcomes. These findings support the integration of SWE as an adjunct tool in PTB risk assessment. Future studies with larger sample sizes and additional clinical parameters are needed to establish standardized cutoff values and explore the clinical application of cervical stiffness measurement.

Acknowledgements

The authors wish to express their gratitude to Saveetha Medical College and Hospital for their invaluable support in providing the necessary infrastructure to carry out this research.

Conflict of interest:

There is no conflict of interest in the present study

Patient consent:

Written informed consent was obtained from the patients involved in the case study.

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