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Introducing and Validating the Cranial-Dorsal-Hip Angle (∠CDH): A Method for Accurate Fetal Position Assessment in the First Trimester and Future AI Applications

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ABSTRACT

Purpose To introduce the cranial-dorsal-hip angle (∠CDH) as a novel quantitative tool for assessing fetal position in the first trimester and to validate its feasibility for future AI applications.

Materials and Methods 2520 first-trimester fetal NT exams with 2582 CRL images (January-August 2022) were analyzed at a tertiary hospital as the pilot group. Additionally, 1418 cases with 1450 fetal CRL images (September-December 2022) were examined for validation. Three expert sonographers defined a standard for fetal positions. ∠CDH measurements, conducted by two ultrasound technicians, were validated for consistency using Bland-Altman plots and the intra-class correlation coefficient (ICC). This method allowed for categorizing fetal positions as hyperflexion, neutral, and hyperextension based on ∠CDH. Comparative accuracy was assessed against Ioannou, Wanyonyi, and Roux methods using the weighted Kappa coefficient (k value).

Results The pilot group comprised 2186 fetal CRL images, and the validation group included 1193 images. Measurement consistency was high (ICCs of 0.993; $P < 0.001$). The established 95 % reference range for ∠CDH in the neutral fetal position was 118.3 ° to 137.8 °. The ∠CDH method demonstrated superior accuracy over the Ioannou, Wanyonyi, and Roux methods in both groups, with accuracy rates of 94.5 % (k values: 0.874, 95 %CI: 0.852–0.896) in the pilot group, and 92.6 % (k values: 0.838, 95 %CI: 0.806–0.871) in the validation group.

Conclusion The ∠CDH method has been validated as a highly reproducible and accurate technique for first-trimester fetal position assessment. This sets the stage for its potential future integration into intelligent assessment models.

Introduction

The measurement of fetal crown-rump length (CRL) during early pregnancy ultrasound examinations (11–14 weeks) is crucial for accurate fetal gestational age determination [1, 2], chromosomal abnormality risk assessment [3–5], and fetal growth and development evaluation [6–8]. However, inaccuracies in CRL measurements, which are influenced by fetal position, can significantly impact clinical decision-making and potentially lead to adverse pregnancy outcomes [9]. It is well-documented that fetal hyperextension and hyperflexion can cause overestimation or underestimation of CRL measurements, respectively [10, 11].

The Fetal Medicine Foundation (FMF) defines the neutral fetal position as one where the fetal head and spine form a straight line. However, a clear definition of the CRL plane in relation to this position remains absent. The French College of Fetal Echography (CFEF) [12], the International Society of Ultrasound in Obstetrics and Gynecology (ISUOG) [13], and the INTERGROWTH-21st Project [14] advocate for CRL measurements when amniotic fluid is observable between the fetus's chin and chest to avoid hyperflexion. However, these guidelines fail to sufficiently address the hyperextension position. Studies by Wanyonyi et al. [15] and Roux et al. [16] have endeavored to assess fetal position by examining the angles formed by fetal anatomical lines. While relatively objective, these methods still demonstrate some inconsistency. Modern intelligent technologies have advanced the precision and repeatability of fetal biometric measurements [17–19]. However, in CRL assessments, these technologies often overlook the critical influence of fetal posture [20, 21]. Furthermore, the inherent subjectivity of conventional assessment methods complicates their integration into intelligent detection systems. Additionally, our study identified specific limitations in the current assessment methodologies. For instance, although amniotic fluid between the fetal chin and chest typically suggests a neutral position, anterior (▶ **Fig. 1a**) or posterior (▶ **Fig. 1b**) hip tilting may indicate a hyperflexed or hyperextended position instead. On the other hand, a lack of amniotic fluid in this area does not necessarily imply hyperflexion. The fetus might still assume a neutral posture (▶ **Fig. 1c**).

Given these challenges, it is essential to develop an innovative approach that not only meets the requirements for integration with intelligent technologies but also enhances the accuracy of fetal posture assessment. At present, research on methods suitable for integration into intelligent applications for the assessment of fetal position in early pregnancy is limited. Our study seeks to introduce, validate, and illustrate the potential of a novel quantitative method for fetal position assessment, tailored for integration into intelligent applications, thereby surmounting the limitations of current methods through improved accuracy, objectivity, and repeatability. This approach is expected to advance the field by offering a more reliable means of fetal assessment, ultimately contributing to improved clinical outcomes.

Methods

Study design and data sources

This retrospective, single-center study was conducted using ultrasound images. Between January 1 and August 31, 2022, 2,582 fetal CRL images from 2,520 early pregnancy nuchal translucency (NT) examinations at a tertiary hospital formed the pilot group. Additionally, 1,450 CRL images from 1,418 distinct cases collected between September 1 and December 31, 2022 comprised the validation group. Two experienced sonographers, each with over five years of prenatal ultrasound examination experience, selected images meeting specific quality criteria for this study. The inclusion criteria were: (1) Singleton pregnancies; (2) Fetal CRL measurements between 45mm and 84mm; (3) Absence of noticeable fetal structural anomalies and with normal NT measurements; (4) Fetal alignment with the mid-sagittal plane; (5) Clear visibility of the fetal head, buttock, and back skin. The exclusion criteria focused on low-resolution and unclear images. These sonographers did not participate in the subsequent study. The study received approval from the ethics committee of the hospital. Informed consent from patients was unnecessary because of the retrospective nature of the study. To ensure privacy, all images were anonymized by removing personal identifiers before being utilized in the research.

Evaluation of fetal position

The evaluation of fetal position was conducted by three senior sonographers (R1/R2/R3), each with over 15 years of fetal ultrasound examination experience. They independently reviewed the selected images. Due to limitations in the commonly used criteria for determining the fetal posture in the CRL plane, this study implemented the FMF's method, typically used for the NT plane, which we adapted for the CRL plane. According to this method, a neutral position is identified when the fetal head and spine form a nearly straight line without significant forward or backward curvature (▶ **Fig. 1c**). A forward curve of the fetal head and spine is categorized as hyperflexion (▶ **Fig. 1a**), while a backward curve is considered hyperextension (▶ **Fig. 1b**). In instances of divergent opinions among sonographers, a collaborative discussion ensued until a consensus on the fetal position was achieved. This consensus was then established as the reference standard for fetal position in the study's images.

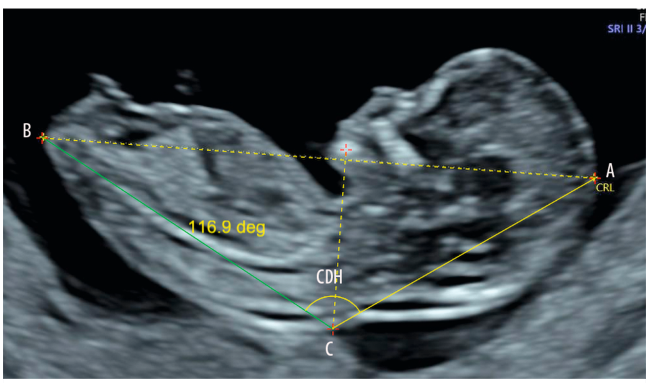
Measurement of the cranial-dorsal-hip angle (∠CDH) of the fetus

Two ultrasound technicians (M1/M2), each with over three years of prenatal ultrasound experience, independently conducted blinded measurements of the cranial-dorsal-hip angle (∠CDH) of fetuses in the images. The measurements were recorded for analysis. The specific technique used the fetal CRL measurement line, a straight line from the top of the fetal head to the bottom of the hip, to define points A (head) and B (hip). Additionally, a line perpendicular to the CRL line was drawn from the midpoint of the fetal mandible, intersecting the skin at the neck and back region, to establish point C. The ∠CDH was then measured by connecting points A, C, and B (▶ **Fig. 2**). To ensure reliability, a random 10 % sample of the selected images was re-measured by technician M1 using the same method after a two-week interval. This process aimed to assess the consistency of the measurements.

Classification of fetal position with ∠CDH method

The final value of the ∠CDH for this study was established by averaging the measurements taken by both technicians. To define the

▶ **Fig. 1** Examples that deviate from the fetal position classification methods used in previous studies. (**a**) Fetal hyperflexed position: The fetus exhibits hyperflexion, but there is amniotic fluid present between the fetal chin and chest, with the fetal hip flexed forward. (**b**) Fetal hyperextended position: The fetus is in a hyperextended position, but there is amniotic fluid present between the fetal chin and chest, with the fetal hip extended backward. (**c**) Fetal neutral position: The fetus is in a neutral position, with the head and spine nearly aligned in a straight line, but there is no amniotic fluid between the fetal chin and chest.



▶ **Fig. 2** Measurement of the cranial-dorsal-hip angle (∠CDH). The fetal CRL line allows for the determination of points A (head) and B (hip). Point C determined by drawing a line perpendicular to the CRL line from the midpoint of the fetal mandible, extending backward until it intersects with the fetal neck and back skin. The ∠CDH is defined by connecting points A, C, and B.

reference range for ∠CDH in fetuses in a neutral position, we analyzed the ∠CDH distribution within the pilot group. Based on this analysis, the 95 % reference range for a neutral position was calculated. Fetal positions were then classified according to this range: values falling below the minimum of this range were categorized as hyperflexion (overbent), and those exceeding the maximum were considered hyperextension (overextended). This classification criterion was applied to categorize the fetal positions in both the pilot and validation groups based on their ∠CDH values.

Assessment of fetal position with three established methods

To evaluate the accuracy of the ∠CDH method alongside other established methods for determining fetal positions, two experienced ultrasound sonographers (D1/D2), each with a decade of prenatal ultrasound practice, collaboratively reviewed and documented fetal positions for both image groups. They employed the techniques proposed by Ioannou et al., Wanyonyi et al., and Roux et al., herein referred to as the Ioannou, Wanyonyi, and Roux methods, respectively.

The flowchart of the study is presented in ▶ **Fig. 3**.

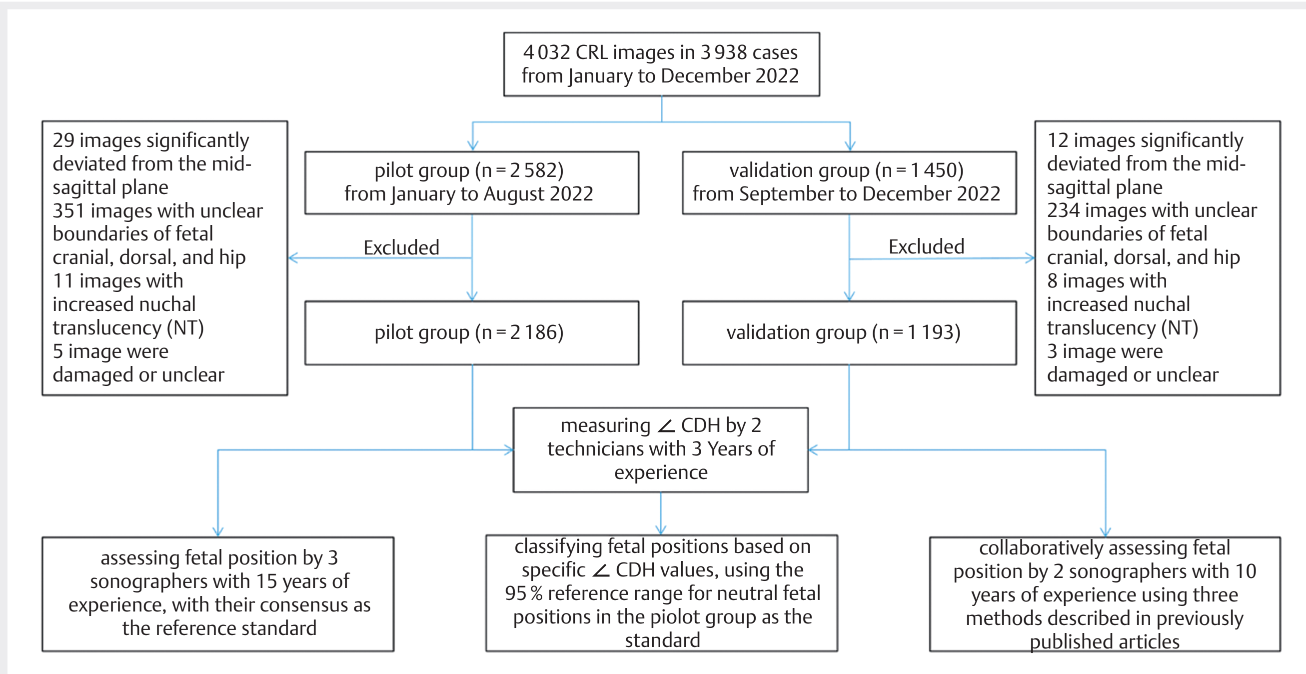
Statistical analysis

Statistical analyses were conducted using SPSS (version 26.0) software and MedCalc (version 20.0) software. Descriptive statistics for metric data include mean ± SD for normally distributed data or median (IQR) for skewed data. Categorical data are presented as counts and their respective percentages. Statistical comparisons were made among the distribution of the general characteristics using the independent Mann-Whitney U-test for continuous variables and the $\chi 2$ test for categorical variables. Bland-Altman plots with 95 % limits of agreement and intra-class correlation coefficients (ICC) were used to assess the agreement between measurements taken by M1 and M2, as well as within M1. The 95 % reference range of ∠CDH for fetal neutral position was generated using the percentile method, taking the values from both sides. The weighted Kappa value (*k* value) was employed to evaluate the concordance between each assessment method and the reference standard. The κ value was categorized as follows for interpretation: 0.01–0.20, indicating poor agreement; 0.21–0.40, denoting fair agreement; 0.41–0.60, representing moderate agreement; 0.61–0.80, signifying good agreement; and 0.81–1.0, reflecting very good agreement. A significance level of $p < 0.05$ was considered statistically significant.

Results

Participant and general characteristics

In the pilot group, 2,186 fetal CRL images were analyzed, excluding 29 images deviating significantly from the mid-sagittal plane, 351 with unclear boundaries of the head, hip, and back, 11 with increased NT, and 5 damaged images. Similarly, the validation group comprised 1,193 fetal CRL images, excluding 12 images with marked deviation from the mid-sagittal plane, 234 with indistinct boundaries, 8 with increased NT, and 3 damaged images. No significant differences were observed in the basic characteristics of the cases included in both the pilot and validation groups ($p > 0.05$). The distribution of maternal ages, gestational weeks, CRL values, fetal positions, and ∠CDH values for both groups is detailed in ▶ **Table 1**.



▶ **Fig. 3** Flowchart of the study. ∠CDH: cranial-dorsal-hip angle.

▶ **Table 1** Case Characteristics Stratified by Group.

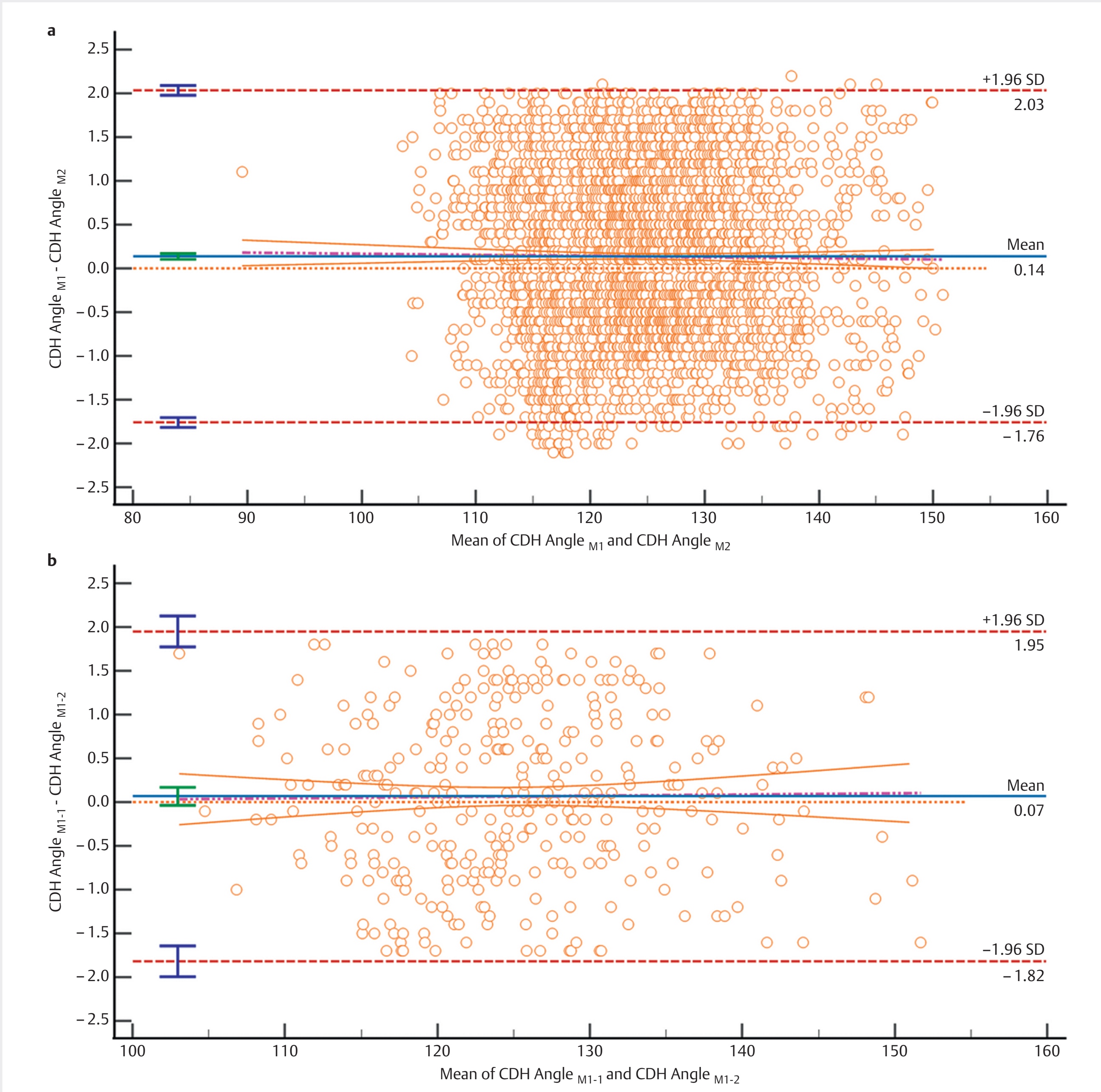
	Pilot group (n = 2186)	**Validation group (n = 1193)**	***p*-value**
Characteristic			
Maternal age (y)	30 (27.0–33.0)	30.0 (27.5–33.0)	0.460
Gestational weeks (w)	12^{+4} (12^{+2}–12^{+6})	12^{+4} (12^{+1}–12^{+6})	0.065
Fetal CRL (mm)	60.5 (56.0–64.9)	60.2 (56.0–64.3)	0.312
Fetal position			0.554
Hyperflexion	487 (22.3)	270 (22.6)	...
Neutral	1616 (73.9)	869 (72.8)	...
Hyperextension	83 (3.8)	54 (4.5)	...
∠CDH value			...
Measured by M1	124.5 (119.1–130.1)	124.5 (119.2–129.9)	0.897
Measured by M2	124.3 (119.0–129.9)	124.3 (119.1–129.7)	0.971

Data are given as n(%) and median (Q1-Q3); Abbreviations: CRL: crown-rump length; ∠CDH: cranial-dorsal-hip angle.

Inter-observer and intra-observer agreement

▶ **Fig. 4** presents Bland–Altman plots illustrating the consistency analysis of ∠CDH measurements conducted between two observers (M1/M2) and within the same observer (M1 at different times). In all cases, the mean differences in measurement closely approximated zero, indicating the absence of significant systematic measurement bias, both between different observers and within the same observer. Specifically, the average difference in ∠CDH measurements between different observers was 0.14 °, with 95 % limits of agreement (LOAs) ranging from ± 1.90 ° (▶ **Fig. 4a**). Conversely, when considering measurements within the same observer, the average difference was merely 0.07 °, and the 95 % LOAs span ± 1.88 ° (▶ **Fig. 4b**).

The absolute agreement in measurements was notably high, as evidenced by the intraclass correlation coefficient (ICC) values of 0.993 (95 %CI:0.992, 0.993; $p < 0.001$) for inter-observer measurements and 0.993 (95 %CI:0.992, 0.995; $p < 0.001$) for intra-observer measurements.

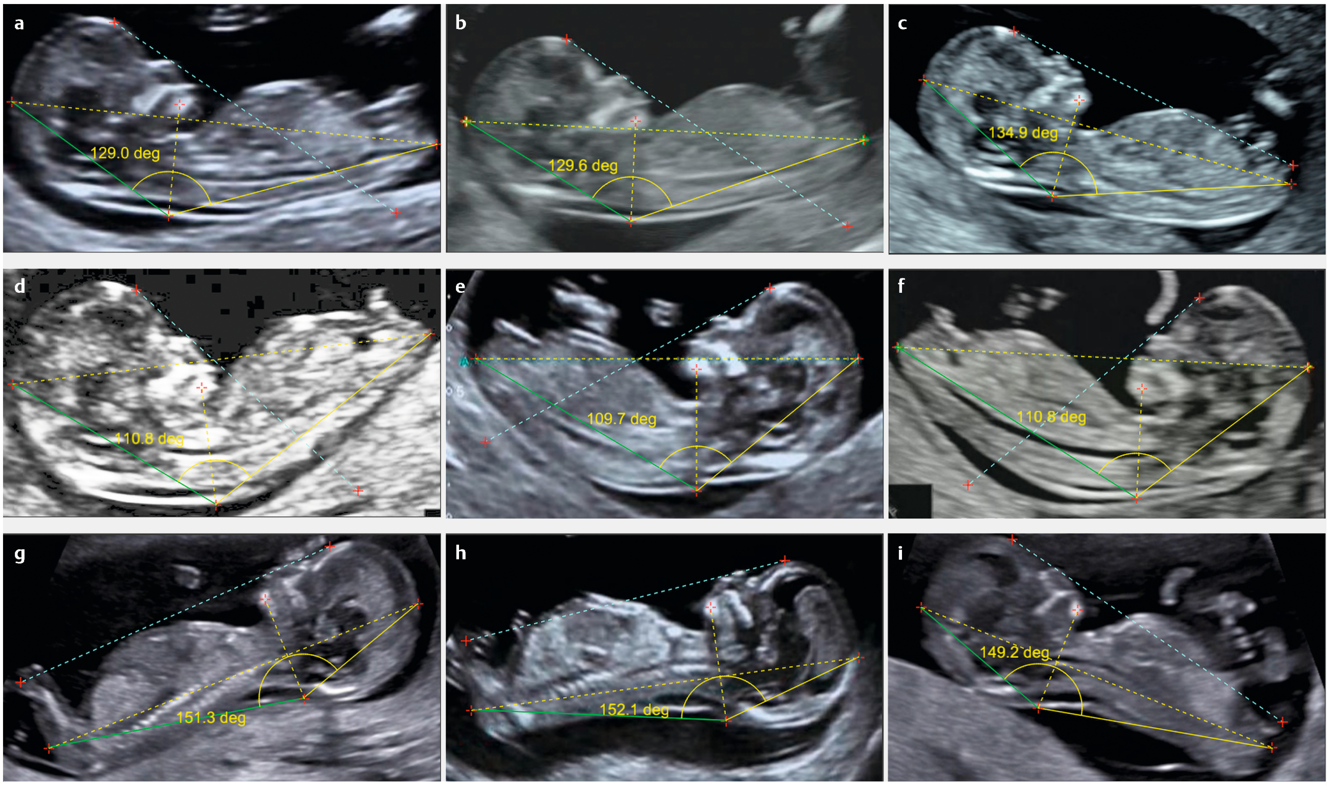


▶ **Fig. 4** Bland-Altman plots with 95 % limits of agreement (LoA) of inter-observer agreement (**a**) and intra-observer (**b**) of ∠CDH measurements. The orange dashed line represents the zero reference line, the blue solid line represents the mean difference, the green vertical lines represent the 95 % confidence interval of the mean difference, the dark brown dashed line represents the LoA line, the blue vertical lines represent the 95 % confidence interval of LoA, and the purple dashed line represents the regression line for the pair difference.

Accuracy of ∠CDH method for determining fetal position

In the pilot group, the distribution of ∠CDH values for fetuses identified in the neutral position ranged from 112.6 ° to 142.6 °, with a median of 126.5 ° and an interquartile range of 122.6 ° to 130.8 °. The 95 % reference range for neutral position ∠CDH values was established at 118.3 ° to 137.8 °. Using this range, 489 images (22.4 %) were classified as hyperflexion, 1578 images (72.2 %) as neutral, and 119 images (5.4 %) as hyperextension. The accuracy of this classification method in the pilot group was 94.5 %, demonstrating high agreement with the reference standard (k value = 0.874; 95 % CI: 0.852, 0.896; P < 0.001).

In the validation group, based on the same criteria, 266 images (22.3 %) were classified as hyperflexion, 845 images (70.8 %) as neutral, and 82 images (6.9 %) as hyperextension. The classification accuracy in the validation group was 92.6 %, with a high level of agreement with the reference standard (k value = 0.838; 95 % CI: 0.806, 0.871; P < 0.001).



▶ **Fig. 5** Examples of four methods for assessing fetal positions. (**a**) Neutral position. There is amniotic fluid between the fetal chin and chest, and both the profile line and palate form acute angles with the CRL line, ∠CDH = 129.0 °. (**b**) Neutral position. There is no amniotic fluid between the fetal chin and chest, and both the profile line and palate form acute angles with the CRL line, ∠CDH = 129.6 °. (**c**) Neutral position. There is amniotic fluid between the fetal chin and chest, the profile line does not intersect with the CRL line in front of the fetal buttock, and the palate intersects with the CRL line at an angle < 90 °, ∠CDH = 134.9 °. (**d**) Hyperflexed position. There is no amniotic fluid between the fetal chin and chest, and both the profile line and palate form acute angles with the CRL line, ∠CDH = 110.8 °. (**e, f**) Hyperflexed position. There is amniotic fluid between the fetal chin and chest, and both the profile line and palate form acute angles with the CRL line, ∠CDH = 109.7 °, 110.8 °; (**g**) Hyperextended position. There is amniotic fluid between the fetal chin and chest, the profile line is nearly parallel to the CRL line, and the palate forms a 90 ° angle with the CRL line, ∠CDH = 151.3 °. (**h, i**) Hyperextended position. There is amniotic fluid between the fetal chin and chest, the profile line is nearly parallel to the CRL line, and the palate forms an angle < 90 ° with the CRL line, ∠CDH = 152.1 °, 149.2 °. The yellow dashed line represents the CRL line, the blue dashed line represents the profile line.

Comparison between the ∠CDH method and other fetal position determination methods

In the pilot group, the ∠CDH method demonstrated superior accuracy at 94.5 %, surpassing the Ioannou, Wanyonyi, and Roux methods, which showed accuracies of 82.3 %, 82.7 %, and 85.0 % respectively. The corresponding k values were 0.874 for the ∠CDH method, and 0.461, 0.560, and 0.575 for the other methods, all with P-values < 0.001. The validation group showed a similar trend, with the ∠CDH method achieving an overall accuracy of 92.6 %, higher than the 80.5 %, 81.1 %, and 83.7 % accuracies of the Ioannou, Wanyonyi, and Roux methods, respectively. The kappa values were 0.838 for the ∠CDH method and 0.408, 0.534, and 0.550 for the others (all P < 0.05). ▶ **Fig. 5** presents some examples of fetal position assessments using these four methods. Notably, the ∠CDH method's accuracy in identifying hyperflexion positions stood out, with rates of 92.4 % in the pilot group and 88.1 % in the validation group, significantly higher than the 46.2 % and 40.4 % accuracy rates of the other three methods, as shown in ▶ **Table 2,3**.

Discussion

The principal finding of the study is the establishment of the ∠CDH as a reliable and accurate method for fetal position assessment in early pregnancy ultrasound examinations. This method was demonstrated to be highly consistent, as evidenced by ICCs of 0.993. The ∠CDH method proved to be more accurate than existing methods, with the neutral fetal position's ∠CDH range identified as 118.3 ° to 137.8 ° and exhibited an approximate 10 % increase in accuracy in both the pilot and validation groups.

A key strength of the ∠CDH method is its pioneering role in introducing a quantitative approach to fetal position assessment. Although this study did not engage in experiments using this angle for intelligent fetal position assessment, it successfully validated the method's reliability and accuracy for the first time, indisputably laying a solid foundation for future integration with intelligent technologies. Additionally, the ∠CDH method offers a more comprehensive assessment by accounting for the fetal hip's position relative to the head and spine, simplifying and directly correlating the measured angle with the corresponding posture. This innova-

▶ **Table 2** Comparison of the ∠CDH method with other methods for fetal position classification in the pilot group.

Reference standards		Method $_{Ioannou}$	Method $_{Wanyonyi}$	Method $_{Roux}$	Method $_{∠CDH}$
Neutral (n = 1616)	Neutral	1574 (97.5)	1501 (92.9)	1572 (97.3)	1537 (95.1)
	Hyperflexion	41 (2.5)	41 (2.5)	41 (2.5)	39 (2.4)
	Hyperextension	0 (0.0)	74 (4.6)	3 (0.2)	40 (2.5)
Hyperflexion (n = 487)	Hyperflexion	225 (46.2)	225 (46.2)	225 (46.2)	450 (92.4)
	Neutral	262 (53.8)	262 (53.8)	262 (53.8)	37 (7.6)
	Hyperextension	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Hyperextension (n = 83)	Hyperextension	0 (0.0)	82 (98.8)	60 (72.3)	79 (95.2)
	Neutral	82 (98.8)	0 (0.0)	22 (26.5)	4 (4.8)
	Hyperflexion	1 (1.2)	1 (1.2)	1 (1.2)	0 (0.0)
Total (n = 2186)	Correct	1800 (82.3)	1808 (82.7)	1857 (85.0)	2066 (94.5)
	Incorrect	386 (17.7)	378 (17.3)	329 (15.0)	120 (5.5)
	k-value	0.461 (0.419–0.503)	0.560 (0.522–0.599)	0.575 (0.534–0.616)	0.874 (0.852–0.896)
	p-value	--[a]	$<0.001^{b}$	$<0.001^{c}$	

Data are given as n(%); *k*-values are given as value (95%CI); in the *p*-values, [a] represents the comparison between the Ioannou method and the ∠CDH method; [b] represents the comparison between the Wanyonyi method and the ∠CDH method; [c] represents the comparison between the Roux method and the ∠CDH method.

▶ **Table 3** Comparison of ∠CDH method with other methods for fetal position classification in the validation group.

Reference standards		Method $_{Ioannou}$	Method $_{Wanyonyi}$	Method $_{Roux}$	Method $_{∠CDH}$
Neutral (n = 869)	Neutral	851 (97.9)	804 (92.5)	850 (97.8)	813 (93.6)
	Hyperflexion	18 (2.1)	18 (2.1)	18 (2.1)	28 (3.2)
	Hyperextension	0 (0.0)	47 (5.4)	1 (0.1)	28 (3.2)
Hyperflexion (n = 270)	Hyperflexion	109 (40.4)	109 (40.4)	109 (40.4)	238 (88.1)
	Neutral	161 (59.6)	161 (59.6)	161 (59.6)	32 (11.9)
	Hyperextension	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Hyperextension (n = 54)	Hyperextension	0 (0.0)	54 (100.0)	40 (74.1)	54 (100.0)
	Neutral	54 (100.0)	0 (0.0)	14 (25.9)	0 (0.0)
	Hyperflexion	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total (n = 1193)	Correct	960 (80.5)	967 (81.1)	999 (83.7)	1105 (92.6)
	Incorrect	233 (19.5)	226 (18.9)	194 (16.3)	88 (7.4)
	k-value	0.408 (0.351–0.465)	0.534 (0.482–0.587)	0.550 (0.494–0.605)	0.838 (0.806–0.871)
	p-value	--[a]	$<0.001^{b}$	$<0.001^{c}$	

Data are given as n(%); *k*-values are given as value (95%CI); in the *p*-values, [a] represents the comparison between the Ioannou method and the ∠CDH method; [b] represents the comparison between the Wanyonyi method and the ∠CDH method; [c] represents the comparison between the Roux method and the ∠CDH method.

tive approach not only fills a critical gap in existing methodologies but also enhances the method's objectivity.

Comparison with existing literature reveals the innovative nature of the ∠CDH method in evaluating fetal posture. The Ioannou method [14] is renowned for its high accuracy in identifying neutral positions, as evidenced by its impressive performance in our study: 97.5% accuracy in the pilot group and 97.9% in the validation group. However, it falls short in recognizing hyperextension, often incorrectly classifying these cases as neutral. The methods of Wanyonyi et al. [15] and Roux et al. [16], although innovative in their angular approach, fail to independently confirm the fetal neutral and hyperflexed position (in which both of these angles measure less than 90 °) and remain contingent upon the detection of amniotic fluid between the fetal chin and chest. This critical dependency may result in misclassification when faced with scenarios involving the nuanced role of hip orientation, as previously discussed. The ∠CDH method recognizes that the hip's orientation relative to the head and spine can dramatically influence fetal position and, consequently, CRL measurement. By integrating the position of the hip, this method transcends the limitations of the aforementioned methods, providing a more robust and comprehensive framework for fetal position classification. This is particularly critical in cases where traditional methods are prone to misclassification, thereby reducing the margin of error and increasing the reliability of fetal assessments in early pregnancy.

In clinical practice, it is crucial to acknowledge that images of fetuses in hyperextended positions are significantly less common compared to those in neutral or hyperflexed positions. This rarity often stems from the fact that a hyperextended fetal body frequently does not align with the mid-sagittal plane, which clinicians often prioritize over fetal posture. Consequently, if a fetus is not positioned in the mid-sagittal plane, sonographers tend not to retain the image. As a result, the classification of neutral and hyperflexed positions becomes more significant and practical in everyday clinical settings. Our findings reveal that the ∠CDH method exhibits superior accuracy in differentiating these two postures. In the pilot group, it achieved 95.1 % accuracy for the neutral position and 92.4 % for the hyperflexed stance, while in the validation group, accuracy rates were 93.6 % for the neutral posture and 88.1 % for the hyperflexed position. This precision in commonly encountered scenarios underscores the practical value of our method in clinical applications.

Our approach also acknowledges the dynamic nature of fetal movement, where positions can fluctuate during the scanning process. This consideration, which is often underemphasized in the literature, has significant clinical relevance. Utilizing the ∠CDH as a quantitative measure enables a reduction in the reliance on subjective interpretations of fetal posture. Such interpretations, which can vary depending on the sonographer's experience, may result in inconsistencies, as indicated in previous studies on similar assessment tasks [22, 23].

Insights from the field highlight a critical demand for standardization and objectivity in fetal measurements [24]. The ∠CDH method, with its quantification capabilities, not only satisfies this requirement but also harmonizes with the evolving integration of intelligent detection systems in prenatal diagnostics. The adoption of the ∠CDH method in automated measurement systems has the potential to foster significant advancements in the field, as observed by Cengiz, et al. in their study on automated CRL measurement techniques [21].

Our study has certain limitations including its single-center design and a limited sample size for hyperextended positions. This aspect could potentially affect the generalizability of our findings. Moreover, the study did not directly explore the impact of varying fetal positions on CRL measurements, highlighting an area in need of further investigation.

Conclusion

To summarize, the introduction of the ∠CDH method is a pivotal development in fetal position assessment during early pregnancy. Its ability to provide a quantitative, objective tool for this purpose holds great clinical relevance. The potential for this method's integration into automated technologies bodes well for the future of obstetric care, promising to enhance the precision of CRL measurements and improve overall clinical outcomes. Future research, particularly multi-center studies that encompass a wider variety of fetal positions, will be crucial in further validating and refining the ∠CDH method.

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Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] Napolitano R, Dhami J, Ohuma EO et al. Pregnancy dating by fetal crown-rump length: a systematic review of charts. BJOG 2014; 121: 556–565. DOI: 10.1111/1471-0528.12478

[2] Papageorghiou AT, Kennedy SH, Salomon LJ et al. International standards for early fetal size and pregnancy dating based on ultrasound measurement of crown-rump length in the first trimester of pregnancy. Ultrasound Obstet Gynecol 2014; 44: 641–648. DOI: 10.1002/uog.13448

[3] Sagi-Dain L, Peleg A, Sagi S. First-Trimester Crown-Rump Length and Risk of Chromosomal Aberrations-A Systematic Review and Meta-analysis. Obstetrical & gynecological survey 2017; 72: 603–609. DOI: 10.1097/ogx.0000000000000490

[4] Kagan KO, Hoopmann M, Baker A et al. Impact of bias in crown-rump length measurement at first-trimester screening for trisomy 21. Ultrasound Obstet Gynecol 2012; 40: 135–139. DOI: 10.1002/uog.11095

[5] Salomon LJ, Bernard M, Amarsy R et al. The impact of crown-rump length measurement error on combined Down syndrome screening: a simulation study. Ultrasound Obstet Gynecol 2009; 33: 506–511. DOI: 10.1002/uog.6371

[6] Gadsboll K, Wright A, Kristensen SE et al. Crown-rump length measurement error: impact on assessment of growth. Ultrasound Obstet Gynecol 2021; 58: 354–359. DOI: 10.1002/uog.23690

[7] Stirnemann J, Massoud M, Fries N et al. Crown-rump length measurement: a new age for first-trimester ultrasound? Ultrasound Obstet Gynecol 2021; 58: 345–346. DOI: 10.1002/uog.23692

[8] Patel S, Sarkar A, Pushpalatha K. A Prospective Study on Correlation of First Trimester Crown-Rump Length With Birth Weight. Cureus 2022; 14: e28781. DOI: 10.7759/cureus.28781

[9] Xu Y, Ni M, Zhang Q et al. Correlation between crown-rump length in the first trimester of pregnancy and neonatal outcomes. BMC pediatrics 2022; 22: 386. DOI: 10.1186/s12887-022-03426-8

[10] Jakubowski D, Salloum D, Torbe A et al. The crown-rump length measurement - ISUOG criteria and clinical practice. Ginekol Pol 2020; 91: 674–678. DOI: 10.5603/GP.a2020.0098

[11] Dhombres F, Roux N, Friszer S et al. Relation between the quality of the ultrasound image acquisition and the precision of the measurement of the crown-rump length in the late first trimester: what are the consequences? European journal of obstetrics, gynecology, and reproductive biology 2016; 207: 37–44. DOI: 10.1016/j.ejogrb.2016.10.019

[12] Fries N, Althuser M, Fontanges M et al. Quality control of an image-scoring method for nuchal translucency ultrasonography. Am J Obstet Gynecol 2007; 196: 272 e271–272 e275. DOI: 10.1016/j.ajog.2006.10.866

[13] Salomon LJ, Alfirevic Z, Bilardo CM et al. ISUOG practice guidelines: performance of first-trimester fetal ultrasound scan. Ultrasound Obstet Gynecol 2013; 41: 102–113. DOI: 10.1002/uog.12342

[14] Ioannou C, Sarris I, Hoch L et al. Standardisation of crown-rump length measurement. BJOG 2013; 120 Suppl 2: 38–41, v. DOI: 10.1111/1471-0528.12056

[15] Wanyonyi SZ, Napolitano R, Ohuma EO et al. Image-scoring system for crown-rump length measurement. Ultrasound Obstet Gynecol 2014; 44: 649–654. DOI: 10.1002/uog.13376

[16] Roux N, Dhombres F, Friszer S et al. How to assess the neutral position of the fetus for the crown-rump length measurement at the nuchal translucency scan. Gynecol Obstet Fertil 2016; 44: 146–150. DOI: 10.1016/j.gyobfe.2016.02.007

[17] Yang C, Yang Z, Liao S et al. A new approach to automatic measure fetal head circumference in ultrasound images using convolutional neural networks. Comput Biol Med 2022; 147: 105801. DOI: 10.1016/j.compbiomed.2022.105801

[18] Jang J, Park Y, Kim B et al. Automatic Estimation of Fetal Abdominal Circumference From Ultrasound Images. IEEE J Biomed Health Inform 2018; 22: 1512–1520. DOI: 10.1109/JBHI.2017.2776116

[19] Luo D, Wen H, Peng G et al. A Prenatal Ultrasound Scanning Approach: One-Touch Technique in Second and Third Trimesters. Ultrasound Med Biol 2021; 47: 2258–2265. DOI: 10.1016/j.ultrasmedbio.2021.04.020

[20] Yasrab R, Fu Z, Drukker L et al. End-to-end First Trimester Fetal Ultrasound Video Automated CRL and NT Segmentation. Proc IEEE Int Symp Biomed Imaging 2022; 2022: 9761400. DOI: 10.1109/ISBI52829.2022.9761400

[21] Cengiz S, Yaqub M. Automatic Fetal Gestational Age Estimation from First Trimester Scans. In: Simplifying Medical Ultrasound. 2021: 220–227. DOI: 10.1007/978-3-030-87583-1_22

[22] Staboulidou I, Wüstemann M, Vaske B et al. Interobserver variability of the measurement of fetal nasal bone length between 11 + 0 and 13 + 6 gestation weeks among experienced and inexperienced sonographers. Ultraschall in Med 2009; 30: 42–46. DOI: 10.1055/s-2008-1027402

[23] Salomon LJ, Bernard JP, Duyme M et al. Feasibility and reproducibility of an image-scoring method for quality control of fetal biometry in the second trimester. Ultrasound Obstet Gynecol 2006; 27: 34–40. DOI: 10.1002/uog.2665

[24] Dhombres F, Khoshnood B, Bessis R et al. Quality of first-trimester measurement of crown-rump length. Am J Obstet Gynecol 2014; 211: 672 e671–672 e675. DOI: 10.1016/j.ajog.2014.06.012