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Correlation Study between Fetal Foot Length Measured by Ultrasound and Gestational Age

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Abstract: *Objective*: To explore the correlation between fetal foot length measured by ultrasound and gestational age. *Methods*: This study employed ultrasound to measure the fetal foot length, femoral length, and foot length/femoral length ratio in 214 pregnant women from 12 to 40 weeks of gestation, all of whom had no pregnancy complications or obstetric complications, and whose fetuses were normal. *Results*: A significant positive correlation was found between fetal foot length and gestational age ($r = 0.967$, $p < 0.001$); a similarly significant positive correlation was observed between fetal femoral length and gestational age ($r = 0.972$, $p < 0.001$); and a non-significant positive correlation was noted between the foot length/femoral length ratio and gestational age ($r = 0.943$, $p < 0.001$). *Conclusion*: Ultrasound can accurately measure fetal foot length and femoral length, both of which exhibit a significant positive correlation with gestational age, making them important reference indicators for assessing fetal growth and development.

Keywords: Ultrasound; Fetus; Foot length; Femur; Gestational age

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1. Introduction

Gestational age is not only related to fetal maturity but also closely associated with maternal care during pregnancy and the prevention and treatment of pregnancy complications. Traditional assessment of gestational age primarily relies on the date of the last menstrual period (LMP) of the pregnant woman. However, inaccuracies in recalling the LMP date or irregular menstrual cycles can lead to significant errors in estimating gestational age based on the LMP, thereby severely impacting the assessment of fetal growth and development and clinical decision-making [1]. With the rapid development of ultrasound technology, its application in obstetrics has become increasingly widespread. Ultrasound, characterized by its non-invasive, real-time, and repeatable nature, is an important means of monitoring fetal growth and development during pregnancy. Ultrasonography provides a general understanding of fetal growth and various fetal indicators by measuring biological markers of the fetus, such as fetal biparietal diameter, femur length, and abdominal circumference, thereby estimating gestational age. Among the measurable biological parameters of the fetus, fetal foot length is a relatively easy-to-measure and independent parameter [2]. The fetal foot begins to grow in early pregnancy and exhibits a relatively

consistent and stable growth rate as gestational age increases. Compared to measurements of other commonly used indicators, fetal foot length measurement is not affected by fetal position and amniotic fluid volume, resulting in high accuracy and good repeatability of the measurement results [3]. Currently, although there have been reports on the impact of ultrasonographic detection of fetal biological parameters on gestational age, there is relatively little research on the correlation between fetal foot length and gestational age. Therefore, conducting research on the correlation between ultrasonographic detection of fetal foot length and gestational age is of great significance for accurately assessing gestational age, improving the quality of prenatal management, and enhancing perinatal outcomes.

2. Materials and methods

2.1. Research subjects

A total of 214 pregnant women who underwent prenatal ultrasonography at our hospital from January 2024 to January 2025 were selected as samples to determine the normal ranges for foot length, femur length, and foot length/femur length ratio. The women ranged in age from 20 to 38 years, with an average age of (31.44 ± 3.69) years, and gestational ages ranging from 12 to 40 weeks. They had regular menstrual cycles, with gestational age calculated from the first day of the last menstrual period, and all were singleton pregnancies. Patients with underlying diseases were excluded.

2.2. Instruments and methods

A Philips EPIQ 7C ultrasound diagnostic instrument was used, with a frequency range set at 2–5 MHz. The pregnant women were placed in a supine position, with their abdomens appropriately exposed. The examiner evenly applied coupling agent to the surface of the probe and then placed it on the abdomen of the pregnant woman, performing multi-planar scans of the fetus, with a particular focus on observing the fetal feet.

The maximum longitudinal section of the fetal foot, such as the section where the sole plane was perpendicular to the ultrasound beam, was selected. The straight-line distance from the bottom of the heel to the tip of the toes was measured as the foot length. To measure the fetal femoral length, select the longest axial section of the fetal thigh, that is, the section when the line connecting the midpoints of the femoral condyles at both ends was perpendicular to the ultrasound beam. The straight-line distance from the proximal metaphysis to the distal metaphysis of the femur was the femoral length.

All measurements were performed by the same experienced ultrasound physician. Each indicator was measured three times, and the average value was taken as the final result.

2.3. Statistical methods

Data analysis was performed using SPSS 26.0 software. Measurement data were expressed as mean ± standard deviation ($\bar{x} \pm s$). Comparisons of fetal foot length, femoral length, and foot length/femur ratio among different gestational age groups were conducted using one-way analysis of variance (ANOVA).

Pearson correlation analysis was used to evaluate the correlation between fetal foot length, femoral length, foot length/femur ratio, and gestational age. A p-value of less than 0.05 was considered statistically significant.

3. Results

3.1. Comparison of fetal foot length, femur length, and foot length/femur ratio at different gestational weeks

The fetal foot length, femur length, and foot length/femur ratio from 12 to 40 gestational weeks are shown in **Table 1**.

Table 1. Comparison of fetal foot length, femur length, and foot length/femur ratio at different gestational weeks

Gestational Week (weeks)	Number of Cases	Foot Length (mm, $\bar{x} \pm s$)	Femur Length (mm, $\bar{x} \pm s$)	Ratio of Foot Length to Femur Length ($\bar{x} \pm s$)
12	12	8.82 ± 1.22	9.17 ± 1.26	0.98 ± 0.02
13	10	11.33 ± 1.14	10.51 ± 1.06	0.97 ± 0.03
14	22	14.15 ± 2.13	13.32 ± 1.82	0.97 ± 0.01
15	21	17.03 ± 2.17	16.27 ± 1.77	0.96 ± 0.02
16	33	20.76 ± 2.45	20.61 ± 2.33	0.95 ± 0.04
17	31	23.67 ± 2.51	22.43 ± 2.58	0.97 ± 0.04
18	30	25.62 ± 2.58	27.82 ± 2.78	0.95 ± 0.03
19	33	28.85 ± 2.82	30.65 ± 2.47	0.97 ± 0.04
20	26	32.16 ± 2.82	32.66 ± 2.21	0.97 ± 0.02
21	22	33.07 ± 2.06	36.39 ± 2.52	0.94 ± 0.03
22	22	36.155 ± 3.13	40.14 ± 1.85	0.96 ± 0.04
23	24	40.32 ± 1.67	41.31 ± 2.22	0.96 ± 0.02
24	33	42.83 ± 3.12	44.30 ± 2.35	0.93 ± 0.02
25	22	45.11 ± 2.85	47.23 ± 2.22	0.94 ± 0.03
26	28	47.67 ± 3.01	47.77 ± 2.61	0.94 ± 0.03
27	24	48.34 ± 2.11	52.08 ± 3.09	0.95 ± 0.03
28	21	52.65 ± 3.23	54.31 ± 2.72	0.93 ± 0.03
29	22	55.12 ± 3.855	55.31 ± 2.71	0.96 ± 0.02
30	22	54.43 ± 3.71	56.58 ± 2.13	0.96 ± 0.02
31	26	55.43 ± 3.72	60.18 ± 2.57	0.96 ± 0.02
32	19	57.58 ± 2.52	61.57 ± 1.75	0.95 ± 0.02
33	19	60.41 ± 3.75	63.17 ± 2.22	0.93 ± 0.02
34	20	64.14 ± 2.64	64.46 ± 2.58	0.95 ± 0.01
35	35	66.04 ± 3.47	66.71 ± 2.41	0.93 ± 0.03
36	45	70.53 ± 4.05	67.42 ± 2.13	0.96 ± 0.02
37	36	70.45 ± 3.22	68.85 ± 2.15	0.95 ± 0.02
38	28	71.14 ± 3.55	70.11 ± 2.16	0.94 ± 0.02
39	27	72.16 ± 3.61	71.22 ± 3.56	0.93 ± 0.04
40	9	74.11 ± 6.62	74.57 ± 3.59	0.95 ± 0.02

3.2. Correlation of foot length, femur length, foot length/femur ratio, and gestational age at different gestational weeks

Pearson correlation analysis revealed a significant positive correlation between fetal foot length and gestational age ($r = 0.967$, $p < 0.001$), indicating a steady increase in fetal foot length with advancing gestational age. A significant positive correlation was also observed between fetal femoral length and gestational age ($r = 0.972$, $p < 0.001$), further validating the accuracy and reliability of ultrasound measurements in assessing fetal growth and development. The foot length/femur ratio showed a non-significant positive correlation with gestational age ($r = 0.943$, $p < 0.001$), while the changes in the foot length/femur ratio across different gestational weeks were relatively stable. This may reflect the maintenance of a certain degree of coordination in the relative growth proportions of the foot and lower limb during fetal growth and development.

4. Discussion

A significant positive correlation was observed between fetal foot length and gestational age ($r = 0.967$, $p < 0.001$), indicating that the increase in fetal foot length during growth and development is relatively stable and regular. The size of the fetal foot can accurately reflect changes in gestational age and is consistent with numerous previous studies. For instance, in a study by Ravisankar G et al. involving ultrasound measurements of 1,200 fetuses, it was found that fetal foot length increased linearly with gestational weeks and was closely related to gestational age [4]. The study also suggested that the growth and morphological changes of fetal bones begin in early pregnancy, with their development having a biological basis independent of external factors such as maternal nutritional status and fetal gender.

Therefore, fetal foot length can serve as a reliable indicator for assessing gestational age. In clinical applications, for pregnant women whose last menstrual period is inaccurate, whose menstrual cycles are irregular, or for whom gestational age cannot be accurately determined by other conventional methods, ultrasound measurement of fetal foot length can be used as an alternative method for assessing gestational age. After establishing a curve between fetal foot length and gestational age, doctors can accurately determine gestational age by measuring the fetal foot length, providing a basis for subsequent pregnancy guidance, fetal growth and development monitoring, and determination of delivery time [5]. Li Jianghua et al. believe that fetal gestational age is an important indicator for distinguishing between preterm and post-term births, and that measuring fetal foot length helps doctors accurately determine gestational age and take appropriate interventions to avoid adverse perinatal complications [6].

In this study, a significant positive correlation was also observed between fetal femoral length and gestational age ($r = 0.972$, $p < 0.001$), further validating the reliability of femoral length as an indicator for assessing gestational age and fetal growth and development. The femur is the longest long bone in the human body, and its growth and development process can reflect the overall skeletal development of the fetus. Numerous studies have shown a relatively stable linear relationship between the increase in fetal femoral length and gestational weeks, which is consistent across different racial and geographical fetal populations [7]. The research conducted by Aziguli Mayier and others revealed that by measuring the femoral length of 1,000 fetuses at different gestational ages and establishing detailed reference ranges for femoral length in relation to gestational age, it was found that the measurement of femoral length demonstrated good repeatability and was less influenced by the subjective factors of the operator [8]. It serves as an objective and accurate indicator for assessing fetal growth and development.

The strong correlation between femoral length and gestational age in this study further supports this viewpoint. Clinically, femoral length is commonly used to evaluate whether there are skeletal developmental abnormalities in the fetus, such as osteogenesis imperfecta and chondrodysplasia. By comparing it with the normal femoral length at the same gestational age, skeletal abnormalities in the fetus can be detected early, enabling further relevant examinations, early diagnosis, and treatment [9].

The results of this study also indicated that there was a non-significant positive correlation between the foot length-to-femur ratio and gestational age ($r = 0.943$, $p < 0.001$), suggesting that the growth of foot length and femoral length may not be completely synchronized during fetal growth and development, but the overall trend remains correlated with gestational age. Some studies have pointed out that the skeletal growth rates at different sites of the fetus may be influenced by various factors, such as genetic factors, hormone levels, and local blood supply. During certain stages of fetal growth and development, differences in growth rates between the foot and femur may occur, leading to fluctuations in the foot length-to-femur ratio. However, in fetuses with certain congenital malformations or chromosomal abnormalities, the foot length-to-femur ratio may exhibit abnormal changes. Research by Soo H and others has indicated that in fetuses with Down syndrome, the foot length may be relatively shorter compared to the femoral length, resulting in a decreased foot length-to-femur ratio [10]. Therefore, although the correlation between the foot length-to-femur ratio and gestational age is not significant, it can still serve as a reference indicator when combined with other ultrasound indicators for fetal malformation screening and diagnosis, aiding in improving the detection rate of fetal malformations.

5. Conclusion

In summary, this study confirmed a significant positive correlation between fetal foot length, femoral length, and gestational age, providing important reference indicators for gestational age assessment and fetal growth and development monitoring. In future clinical practice, ultrasound measurements of fetal biological parameters such as foot length and femoral length will be combined with other examination methods, such as serological screening and non-invasive DNA testing, to form a more comprehensive fetal monitoring system. Through multi-indicator joint analysis, a more comprehensive assessment of fetal growth and development status and health risks can be achieved, providing pregnant women with more personalized and precise prenatal care services.

Disclosure statement

The author declares no conflict of interest.

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