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Is manual foot length measurement of comparable value to ultrasound femur and humerus measurement in anatomical studies for the assessment of foetal age?

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Contemporary anatomical studies require reliable methods for determining foetal age. Menstrual age is often found to be inadequate. A combination of several anatomical features showing age-dependency may result both in exact age approximation and pathology detection. The authors compared the manual foot length measurements with the ultrasound femur and humerus length measurements of aborted foetuses in the calculation of foetal age. The correlation between femur length and foot length as well as humerus length and foot length were statistically significant. The expected value formulae for foot length are presented. The authors conclude that foetal age assessment based on foot length metering is reliable before the 7th calendar month of pregnancy and correlates with ultrasound measurements of the humerus and femur.

Key words: foetus, gestational age, ultrasonography

INTRODUCTION

Assessment of foetal age is based mainly on: 1) gestational age — last menstrual period according to Nagele's rule, 2) direct manual measures of aborted foetuses including different morphometric features such as head circumference, crown-rump length (CRL), crown-heel length (CHL), foot length and abdominal circumference (AC) [9, 18]. Skeletal measurements are performed on dissected foetuses. Antenatal ultrasound morphometry is used during intrauterine development monitoring [1, 4, 6]. Each of these methods has its own degree of sensitivity, which may fluctuate for different trimesters or be affected by conditions like multiple pregnancy and other pregnancy-related pathologies [4, 5, 17]. Single calculations based on the last menstrual period seem to be inadequate for research purposes due to the pathologies of pregnancies that may interfere foetal age. These include oligomenorrhoea or polimenorrhoea, which cause errors in calculations, intrauterine growth retardation and delayed detection of the intrauterine death of a foetus. Contemporary methods of age assessment should involve different features and techniques in order to avoid or diminish errors [1, 2, 5].

The research analyses direct manual measurements of foot length in comparison with ultrasound measurements of the humerus and femur length. Computations were performed in order to correlate the results obtained from different studies.

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MATERIAL AND METHODS

A group of 117 spontaneously aborted human foetuses was examined (59 male and 58 female) aged from 13 to 33 weeks of gestation. The average age of the male foetuses was 21.7 weeks with SD = 4.8 and in the female group 20.9 weeks with SD = 2.5.

Only foetuses from singleton pregnancies were introduced into the study. No foetuses showing morphological malformations were allowed for analysis.

The foot length (FtL), femur length (FL) and humerus length (HL) measurements were performed after the fixation of the foetuses in a 3% aqueous formaldehyde solution. Many authors have demonstrated that formalin fixation does not affect measurements [2, 5].

The feet were measured by two different examiners independently. To obtain the foot length a certified callipering gauge "MAUB 160/0.05" SOMET was used. The callipering gauge branches were expanded between calcanear tuberosity and the tip of the first or second toe, whichever was longer.

Ultrasound measures of HL and FL were performed on the immersed foetuses by two different examiners separately with a Siemens Sonoline SL 5 MHz sector probe. The probe was set at a right angle to the humerus or femur held in its physiological (i.e. embryonic) position.

The mean values of the left and right foot length, FL, HL were calculated for each of the foetuses. Gestational age evaluation from foot length was performed according to Wigglesworth's formula [19, 20]:

If mean foot length development is assumed, gestational age = $(4.3 \times 10^{-10} \times FtL^6) + (-7.8 \times 10^{-8} \times \times FtL^5) + (1.8 \times 10^{-6} \times FtL^4) + (4.041 \times 10^{-4} \times FtL^3) + + (-0.028062 \times FtL^2) + (0.9353103 \times FtL) + 5.381448$, where FtL represents foot length in mm.

The conversion of the FL and HL into gestational age was conducted by a comparison with the tables for the Polish population compiled by Dębski et al. [4]. The comparability of the results obtained by the different examiners was tested using the F-test. The correlation indices between foot length and FL, foot length and HL and gestational age and foot length were calculated. The significance of foot length growth in subsequent calendar months of pregnancy was tested using Scheffe's test. The descriptive statistical analysis of the study group included mean values, standard deviation, median value and 25th and 75th quartiles. All calculations were performed on Statistica 5.1 software. Approximal formulae for femur length to foot length, humerus length to foot length and gestational age to foot length calculation were edited by the software.

RESULTS

In the first stage of the study a comparison of the results (the mean values of the left and right extremities) between the researchers showed the following: correlation index = 0.99 in the F-test for the manual foot length measurements, 0.99 in the F-test for the ultrasound FL measurements and 0.88 in the F-test for the ultrasound HL measurements.

The value of the correlation index between foot length and FL was 0.91 (Fig. 1), while between foot length and HL it was 0.96 (Fig. 2) and between foot length and foetal age it was 0.94 (Fig. 3). Figure 4

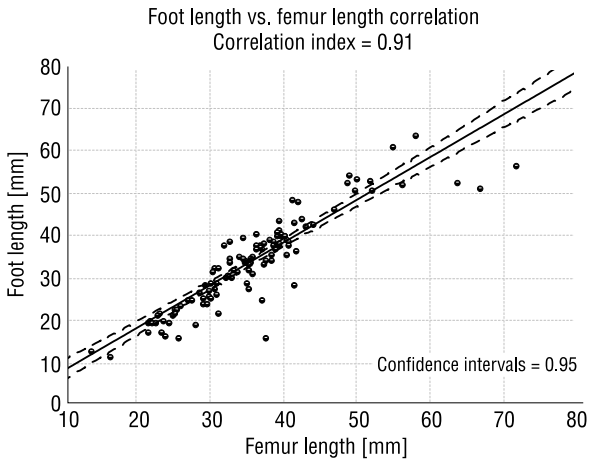

Figure 1. Correlation between foot length and femur length.

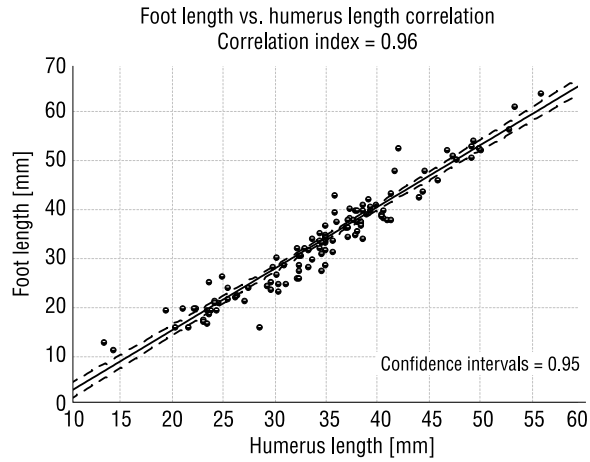

Figure 2. Correlation between foot length and humerus length.

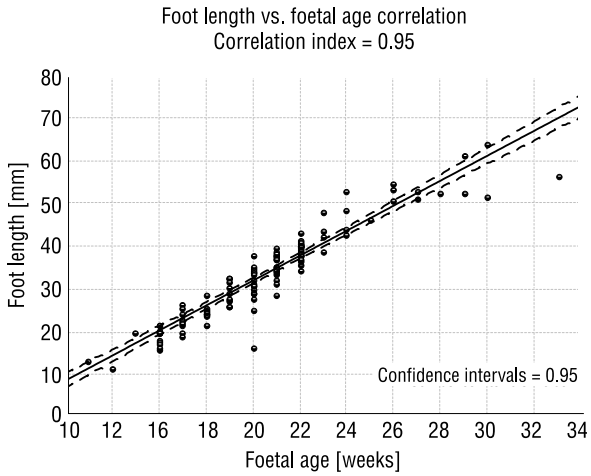

Figure 3. Correlation between foot length and foetal age.

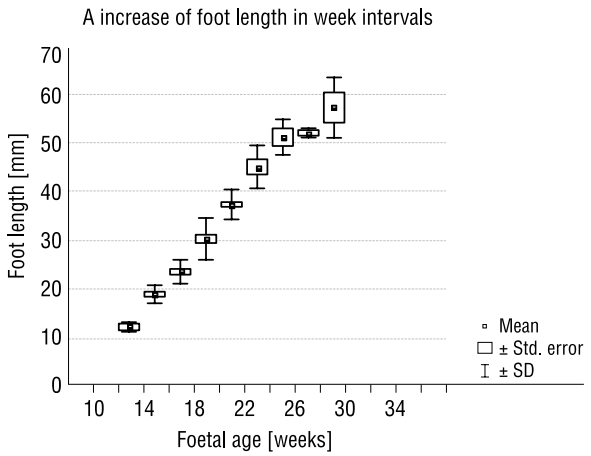

Figure 4. Increase in foot length at weekly intervals.

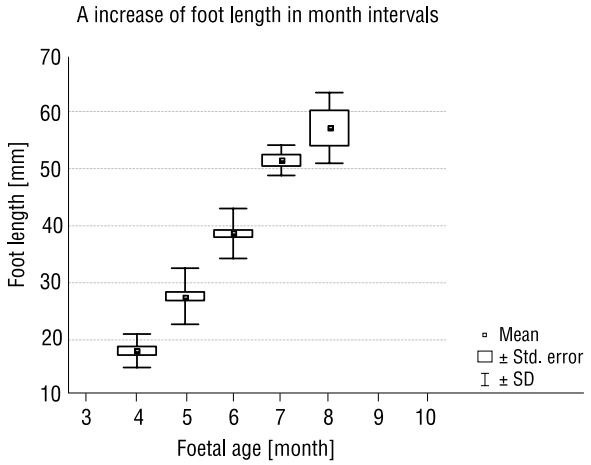

Figure 5. Increase in foot length at monthly intervals.

Table 1. Record of foot length by week

HBD	N	Mean	SD	25th Q.	Median	75th Q.
13	1	13.00				
14	1	11.63				
15	1	19.75				
16	12	18.94	1.92	17.31	19.69	20.06
17	9	22.63	2.47	21.38	22.50	24.13
18	8	24.70	1.96	23.81	24.46	25.31
19	9	29.19	2.62	27.13	29.00	31.75
20	17	30.90	4.91	29.00	31.38	33.88
21	18	35.38	2.91	34.00	35.19	37.88
22	21	39.01	2.05	38.00	39.38	40.13
23	4	43.16	3.91	40.50	42.94	45.81
24	4	46.88	4.51	43.31	46.06	50.44
25	1	46.25				
26	3	52.71	1.99	50.50	53.25	54.38
27	2	51.81	1.33	50.88	51.81	52.75
28	1	52.25				
29	2	56.75	6.01	52.50	56.75	61.00
30	2	57.50	8.84	51.25	57.50	63.75
33	1	56.50				
Total	117	33.52	10.77	25.13	34.00	39.50

Table 2. Record of foot length by calendar month

Month	N	Mean	SD	25th Q.	Median	75th Q.
4	15	18.11	2.93	16.25	19.63	20.00
5	43	27.66	4.92	24.13	27.63	31.75
6	47	38.64	4.38	35.75	38.25	40.25
7	7	51.46	2.66	50.50	52.25	53.25
8	4	57.13	6.19	51.88	56.75	62.38
9	1	56.50				
Total	117	33.52	10.77	25.13	34.00	39.50

Table 3. Scheffe's test (statistical significance $p < 0.05$)

Month	5th	6th	7th	8th	9th
4th	0.00	0.00	0.00	0.00	0.00
5th		0.00	0.00	0.00	0.00
6th			0.00	0.00	0.02
7th				0.53	0.95
8th					0.99

shows the increase in foot length at weekly intervals and figure 5 at monthly intervals. See Tables 1 and 2 for details.

In Scheffe's test foot length growth as an age indicator showed significant variability during foetal development except from the 7th to the 9th calendar months of pregnancy (Table 3, Fig. 5). On the basis of the results obtained interpolation equations for the expected values were edited with statistical software (Statistica 5.1) as follows:

— foot length in mm if right femur growth is assumed = –2.105 + 1.0085 × FL in mm;
— foot length in mm if right humerus growth is assumed = –9.777 + 1.2589 × HL in mm;
— foot length in mm if correct gestational age is assumed = –26.40 + 2.9141 × Hbd, where Hbd denotes week of gestational age.

No significant differences were observed between the sexes and between right and left side measurements.

DISCUSSION

Morphometric studies of human foetuses require an exact assessment of foetal age [2, 4–6, 8, 10, 18]. Menstrual age, the most commonly used factor and usually the only known clinical data, is often erroneous owing to menstrual period irregularity. Human foetuses which present incomplete data on age or have partially deteriorated require multiple measurements for adequate age evaluation. A combination of morphometric methods allows for more exact age assessment. Foot length measurement is an easy and available technique. Although measurement methodology is gaining popularity in anatomical studies, little information has yet been made available by other authors [3, 5, 12, 14–16]. In the present study the measurements were performed upon feet laid flat. Calculation of the foetal age from foot length was already being used in the 1920s by Streeter and continued in the 1990s by different authors [3, 13–16]. Foetal age calculated from foot length correlates strongly in our study with femur and humerus metering methods, especially for the second trimester (Fig. 1, 2). Surprisingly, in this study foot length was not a valuable factor in Scheffe's test in foetuses older then 7 calendar months (Table 3). Morphometric studies performed by Kroczek and Sobocinska [9] also show shortening of the foetal foot in both sexes at 25–28 weeks (equivalent to calendar months 5.6–6.3 of pregnancy) of gestational age compared to earlier periods. Our study did not confirm such age dependency in foot shortening, although the 7th month onward is not suitable for reliable FtL dependent age assessment. Other studies on foot length reliability have also indicated the limitations of this method, mainly in cases of disturbed growth [13, 17]. Foetal age assessment thus cannot be based on lower extremity measurements alone. Introduction of humerus length as a check allows foetuses with disturbed growth to be identified. Femur length is widely used in clinical studies to assess foetal age from the 12th week of pregnancy. Humerus length is not used as often as FL as a result of the greater difficulty in visualisation and measurement [4, 7, 11]. The difficulties of ultrasound examination of the humerus are mostly concerned with antenatal development, whereas *in vitro* measurements are of the same degree of difficulty as femur measurements. The reliability of the measurements was demonstrated by the high value of the correlation indices between the different parameters. HL correlation is the lowest ($x = 0.88$) compared to that for FL and FtL ($x = 0.99$ for both methods), although it has been found valuable by the authors. A relative lack of experience in humerus visualisation has been the supposed explanation for its poorer reliability. Humerus length is an accessory morphometric feature for sonographers and is rarely performed in comparison to routine FL measurement. Ultrasound examination performed on long bones like the femur or humerus and followed by expected value calculations is useful in excluding disturbed-growth-foetuses from a study group, especially when dissection of the extremities is not planned [12]. Foetuses affected by chondrodysplasia present pathological antenatal fractures detectable in ultrasound examination, while other anomalies result in abnormal shortening of the humerus or premature ossification of the foetal bones [17].

CONCLUSIONS

The metering methods used by team members in the study are comparable. Foot length and femur length as well as humerus length are useful indicators of foetal age calculation in normally developed foetuses. Expected value calculations create data for diagnosing the correct development of the foetuses studied.

Foot length measuring is an easy and reliable method of foetal age evaluation in anatomical studies.

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