A corrected formula for uncertainty in estimations of gestational age from fetal head circumference measurements

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Numerous publications over recent years have proposed methods for estimation of gestational age (GA) from fetal measurements including biparietal diameter, head circumference, crown-rump length and others. The manuscript of Altman and Chitty[1] presented statistical modelling of data from 663 fetuses to define charts and tables for pregnancy dating based upon such measures. The resulting outputs are tables of mean GA estimates based upon each measurement, each with a corresponding standard deviation that encompasses the uncertainty in the prediction. We here address an erroneous result in the appendix of this work, associated with the uncertainty in GA prediction based upon derived head circumference measurements.

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Altman and Chitty report the following formulae for mean log-GA (in weeks) and associated standard deviation, as a function of (derived) head circumference (HC):

$$mean = 1.848 + 0.010611HC - 0.000030321HC^2 + 0.43498 \times 10^{-7}HC^3, \quad (1)$$

$$SD = 0.08024 - 0.00052635HC + 0.000014204HC^2. \quad (2)$$

Predictions for mean GA are calculated by taking the exponential of (1), and the uncertainty in these predictions is described via the 5th and 95th centiles, calculated according to

$$e^{mean \pm 1.64SD}. \quad (3)$$

The resulting values are presented in a look-up table for estimated GA based upon these (derived) HC measurements. (Table 5 in [1].) While the estimated GA aligns with (1), the quoted standard deviation in (2) gives rise to exponentially divergent 5th and 95th centiles, with a significantly greater degree of uncertainty than quoted in Altman and Chitty's look-up table (Figure 1). We stress here that the values quoted in Altman and Chitty's table do seem reflective of the data in their original study, and we do not call these into question. Indeed, these tables have been recommended for routine clinical use by the British Medical Ultrasound Society[2]. The formula in (2), however, predicts unfeasible values of GA, for large HC measurements in particular, suggesting that this formula is subject to typographical error in the original publication. We address this here due to the need for a continuous analogue to Altman and Chitty's table, to enable these predictions and uncertainty measures to be easily incorporated into commercial healthcare software currently under development.

We correct for the above anomaly as follows. Using Altman and Chitty's tabulated values at each measured HC, which we index by i, we denote the estimated gestational age by GA_i and the 5th and 95th centiles by $c_i^{\pm}$. (Note that, from (1), $GA_i = \exp(mean(HC_i).)$ Using the absolute log-difference

between the estimate and the centiles, we compute the standard deviation for each HC measurement independently, according to

$$SD_i = \frac{|\log(GA_i) - \log(c_i^{\pm})|}{1.64}, \quad i = 1, \dots, 49. \tag{4}$$

We then use a least-squares approach to fit a second-degree polynomial to the resulting data in Matlab, to obtain the following corrected formula for the standard deviation of GA as a function of (derived) HC:

$$\widehat{SD} = 9.5934 \times 10^{-2} - 6.3256 \times 10^{-4} HC + 1.7103 \times 10^{-6} HC^2 \tag{5}$$

The predictions resulting from this adjusted formula are shown in Figure 2, in which the mean GA is calculated as above and the centiles are calculated by replacing SD by $\widehat{SD}$ in (3). As Figure 2 demonstrates, the corrected formula in (5) accurately reproduces the tabulated results of [1] for the full range of HC measurements. This formula is readily amenable to implementation within clinical software alongside the remainder of Altman and Chitty's results.

References:

1. Altman DG and Chitty LS. New charts for ultrasound dating of pregnancy. *Ultrasound Obstet. Gynecol.* 1997; 10: 174-191.

2. Loughna P, Chitty L, Evans T and Chudleigh, T. Fetal size and dating: charts recommended for clinical obstetric practice. *Ultrasound* 2009; 17(3): 160-166.

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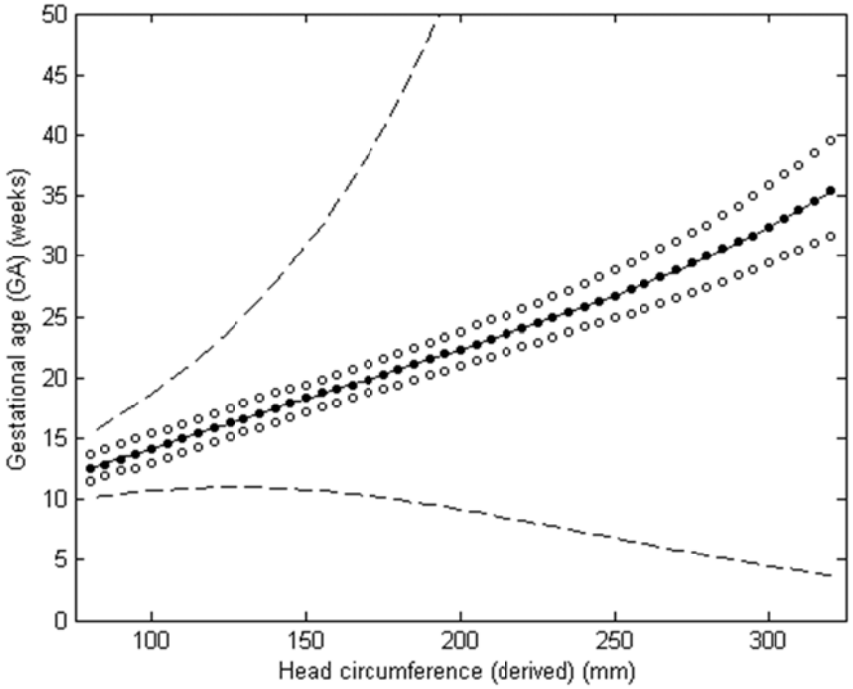

Figure 1 Tabulated estimates of mean gestational age (black circles) and 5th and 95th centiles (white circles) from Table 5 of Altman and Chitty, together with the predictions of (1) and (2): mean (solid line) and centiles (dashed lines).

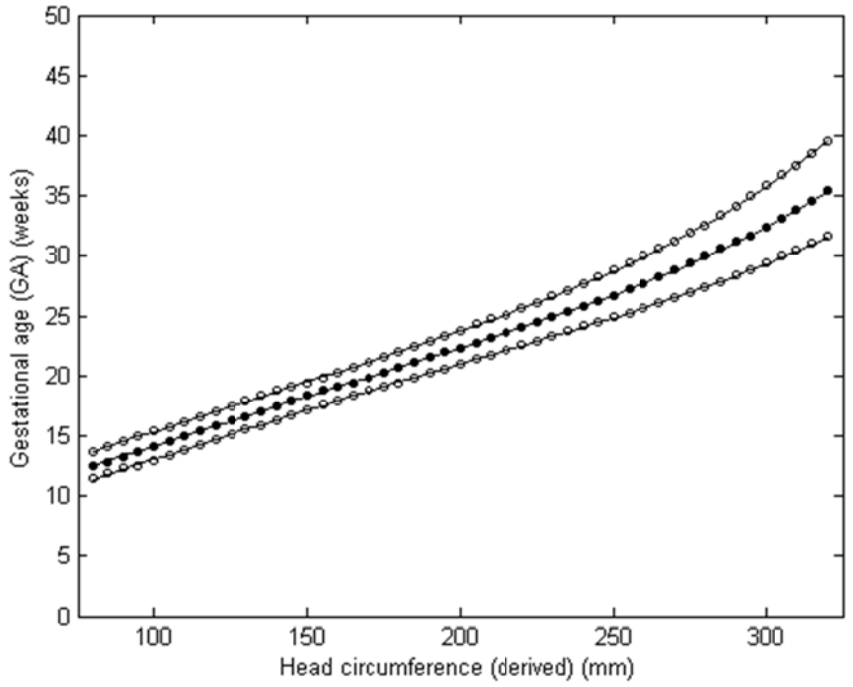

Figure 2 Predictions of gestational age with corrected 5th and 95th centiles based upon $\widehat{SD}$ (solid lines), together with the tabulated estimates of Altman and Chitty (mean, black circles; centiles, white circles).