

IS NEUTRAL REALLY NEUTRAL?

QUANTIFYING FETAL POSITION IN THE FIRST TRIMESTER USING THREE-DIMENSIONAL ULTRASOUND

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Objective

Fetal biometric assessment is essential for accurate gestational age (GA) estimation and growth monitoring. Reliable crown-rump length (CRL) measurements require the fetus to be in a neutral position. But current definitions rely on subjective visual assessment, limiting reproducibility and hindering automation of biometric measurements.

Aim: develop and validate a quantitative definition of fetal neutral position using three-dimensional (3D) ultrasound.

Methods

3D ultrasound datasets (N=133 pregnancies) were selected between **11+0 - 13+6 weeks'** GA acquired with the fetus **at rest** in the midsagittal plane.

Five anatomical **planes** were annotated by two independent raters following ISUOG guidelines (Figure 1).

Fetal flexion-extension (FFE) and lateral head deviation (LHD) were quantified using **angles** between predefined **plane pairs** (Figure 1).

FFE and LHD were also visually scored on a **0–3 scale**, with each score corresponding to a **fetal pose category** (Figure 2).

Interrater agreement was assessed using weighted Cohen's kappa (κ) for pose classification and intraclass correlation coefficients (ICCs) for angle measurements.

A **k-Nearest Neighbor (k-NN) classifier** was trained to identify the neutral position boundary (Training set n=95, Test set n=38).

The effect of fetal pose on 3D-CRL-based **GA estimation** was assessed.

Figure 2. Fetal pose classification and categories

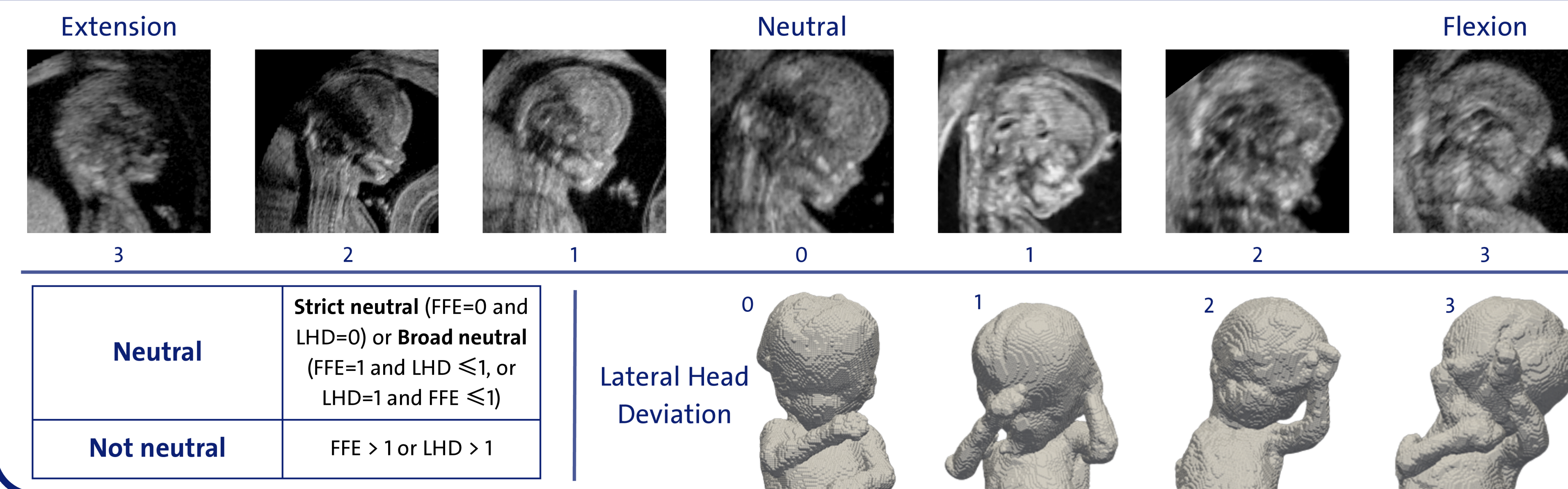
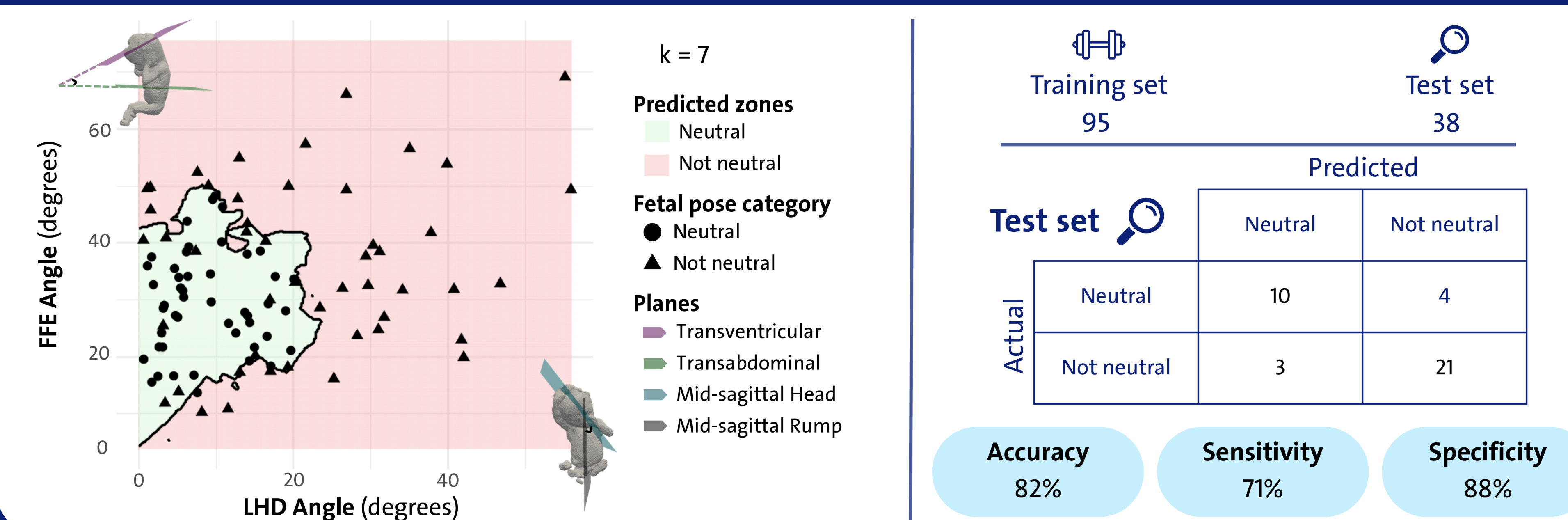


Figure 4. Performance of k-NN classifier



Conclusion

More than 50% of fetuses were in a non-neutral position at rest.

Flexion shortens the measured CRL, explaining GA underestimation. LHD appears less influential.

A quantitative definition enables standardized assessment and improves reproducibility.

This could support automation and AI-based correction of crl in non-neutral postures to improve GA estimation.

Figure 1. Annotated anatomical planes with corresponding angles

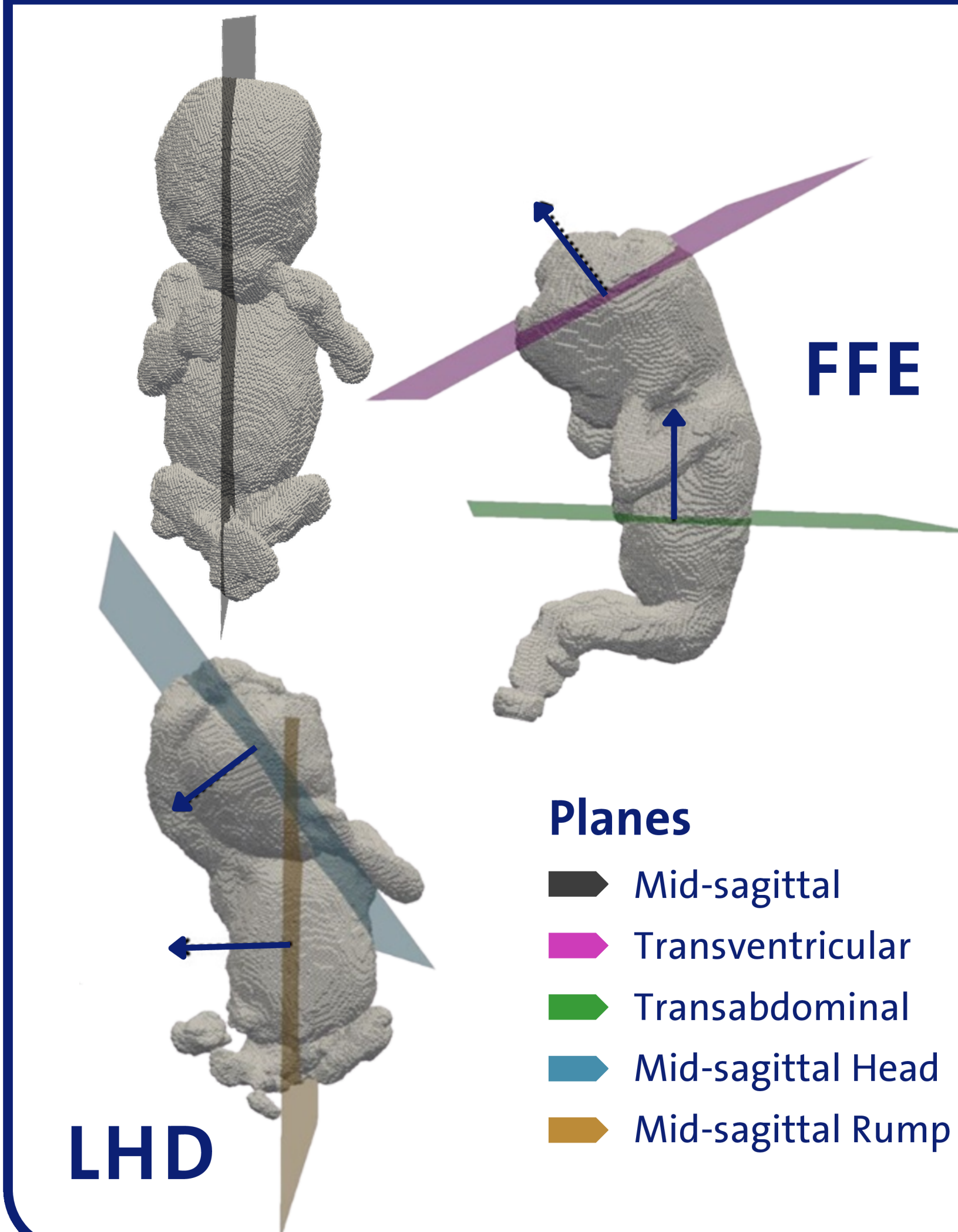
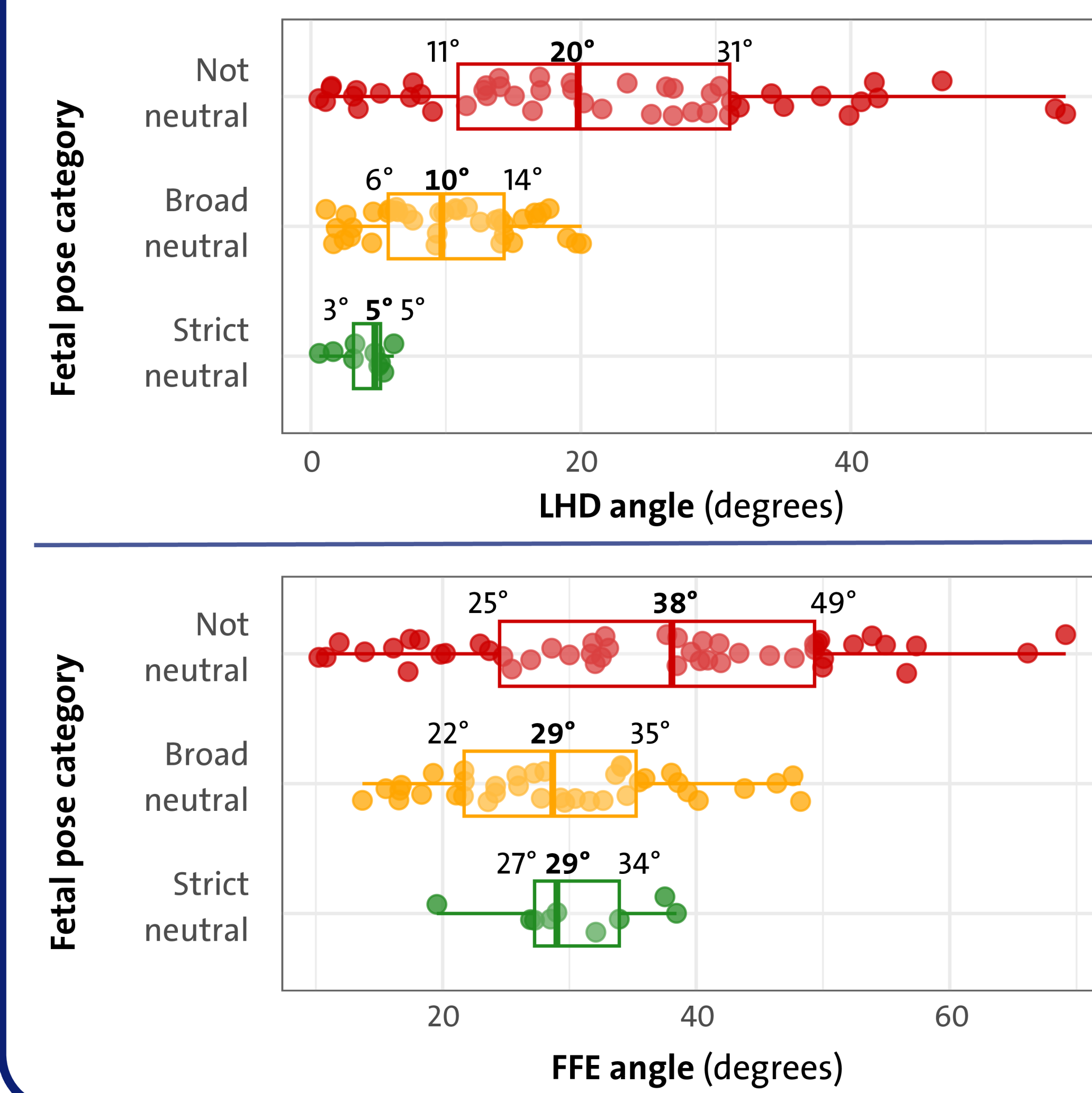


Figure 3. Relationship between fetal poses and angles



Results

>50% of fetuses were classified as **non-neutral**.

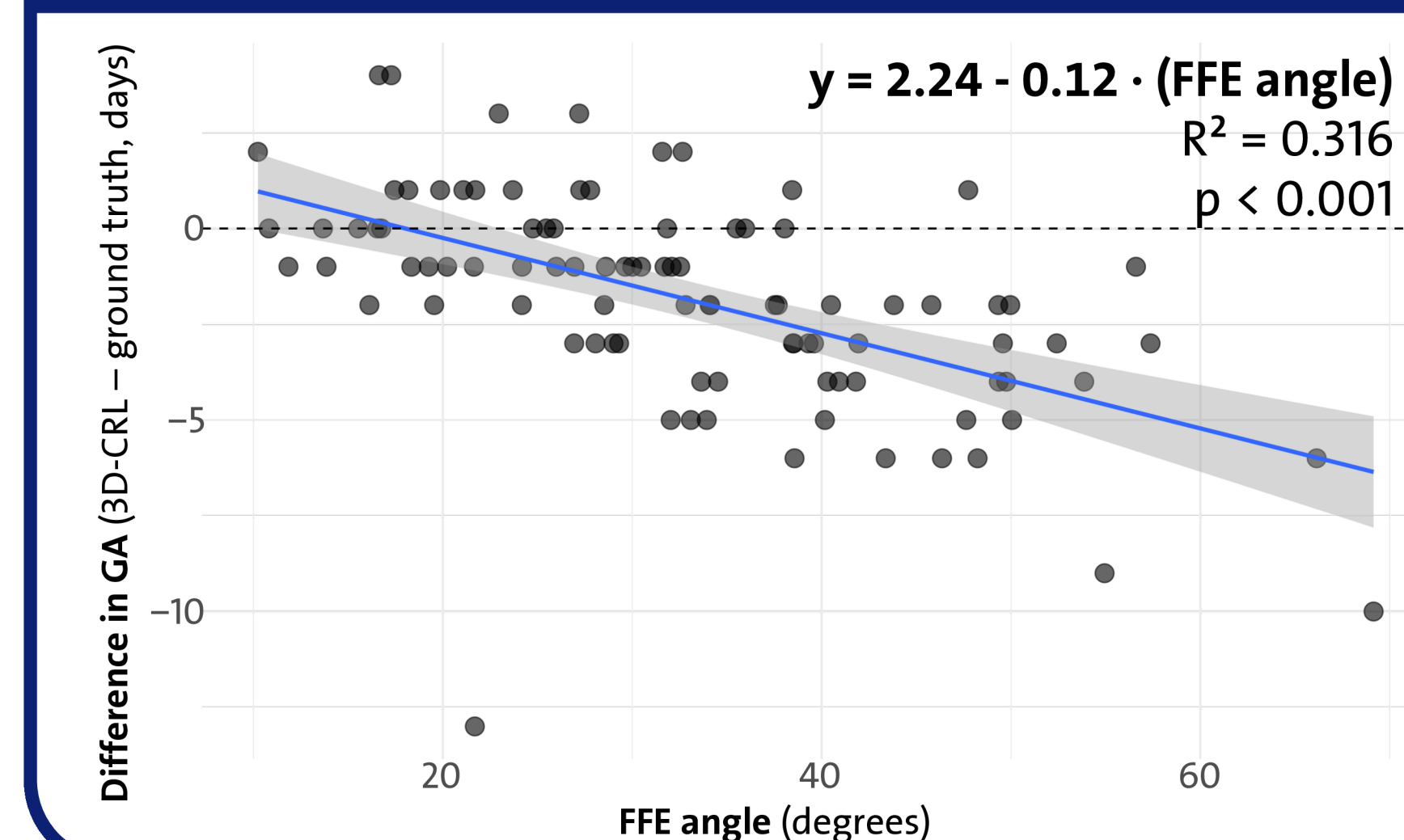
Neutral postures clustered within narrower angular ranges, while non-neutral postures showed greater variability (Figure 3).

Interrater agreement was **moderate** for fetal pose classification and **good** for both FFE and LHD.

The k-NN classifier identified neutral position with **82% accuracy** (Figure 4).

Increased fetal flexion (FFE) was significantly associated with **GA underestimation**, while LHD showed no significant association with GA estimation (Figure 5).

Figure 5. FFE and GA estimation



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