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Unveiling the Drivers of Fetal Weight Estimation

Which Ultrasound Measurements Matter Most?

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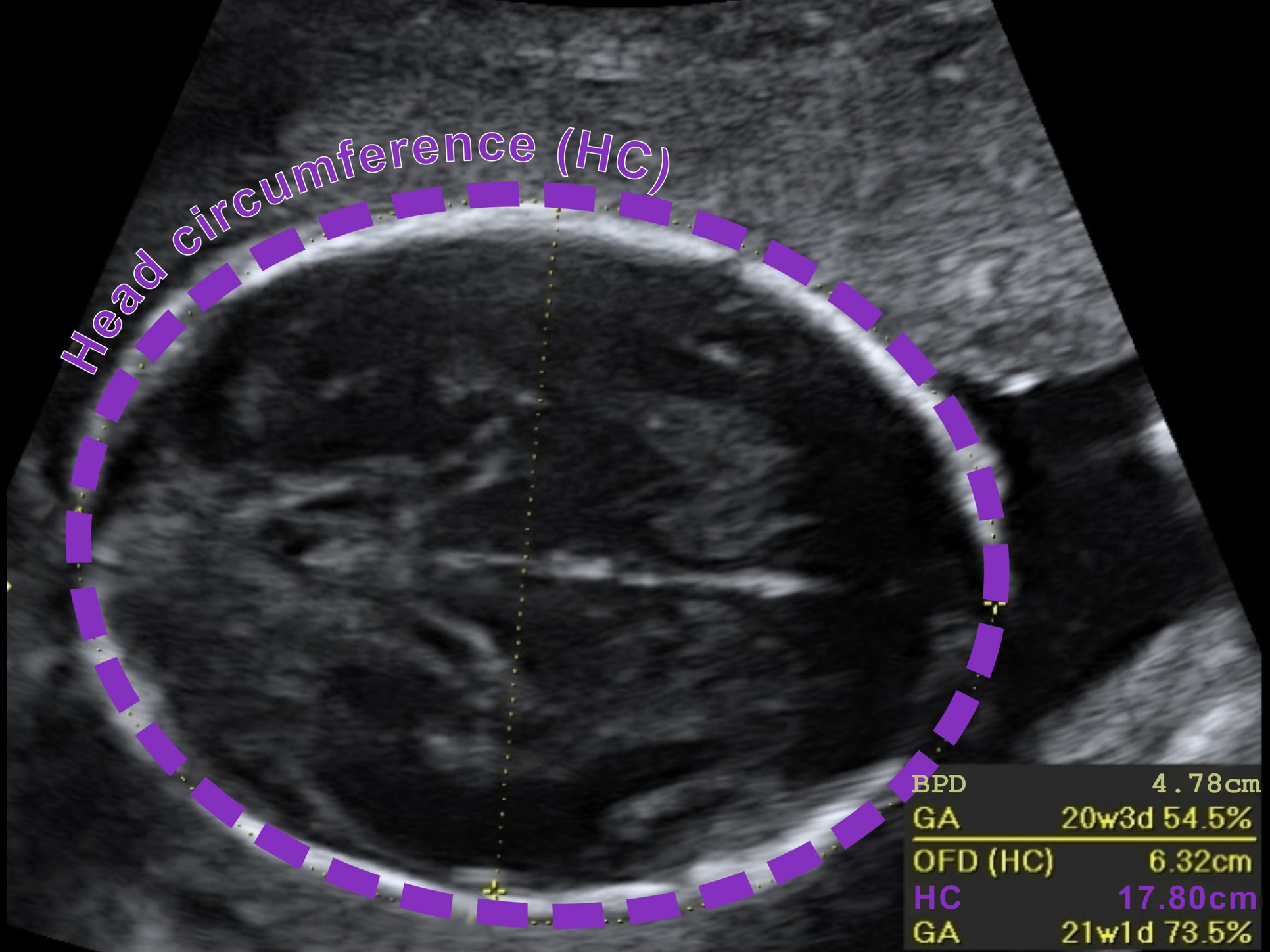
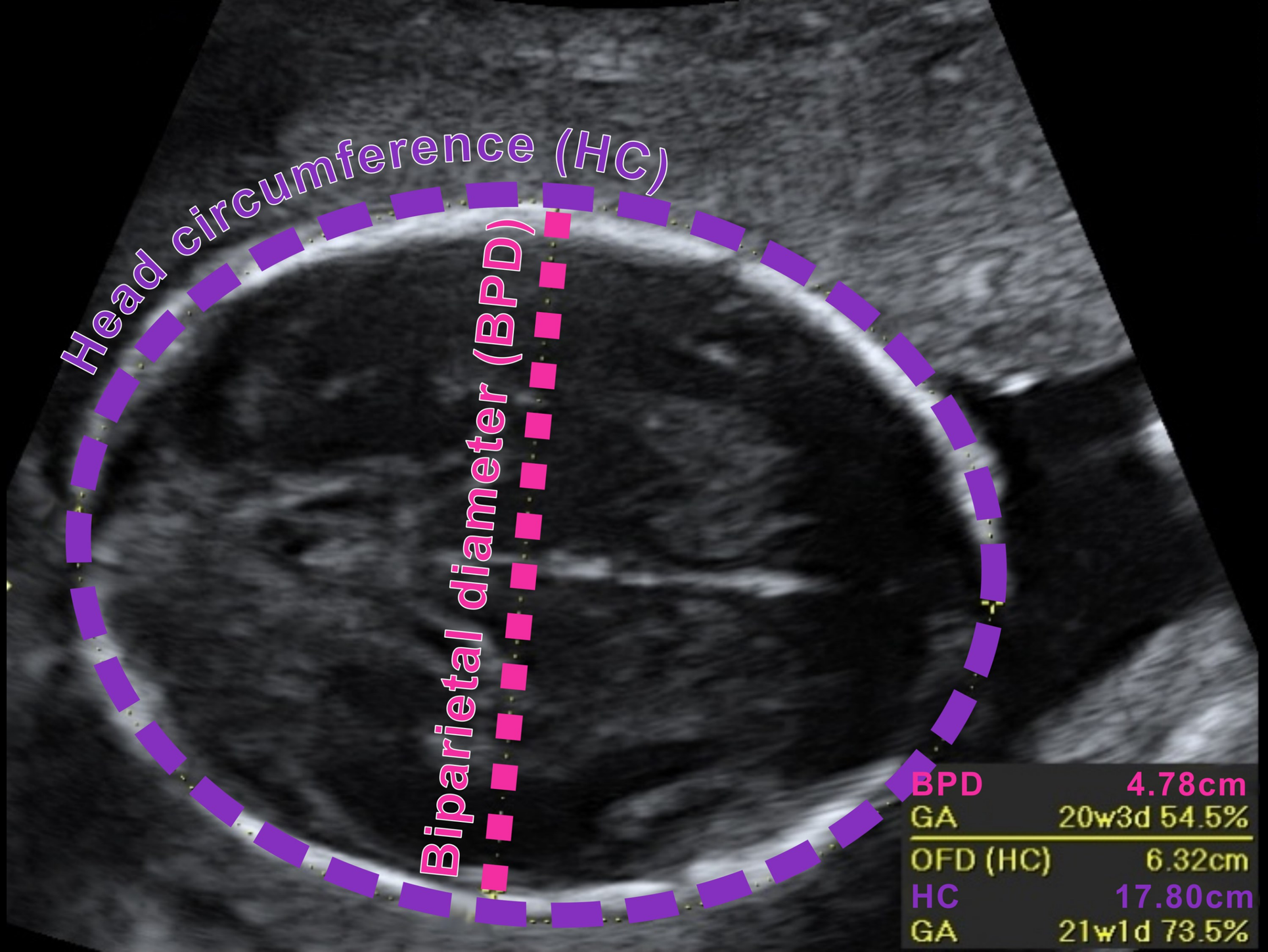
Joint work with **V. Bitsouni** (UPatras) & **N. Gialelis** (NKUA)

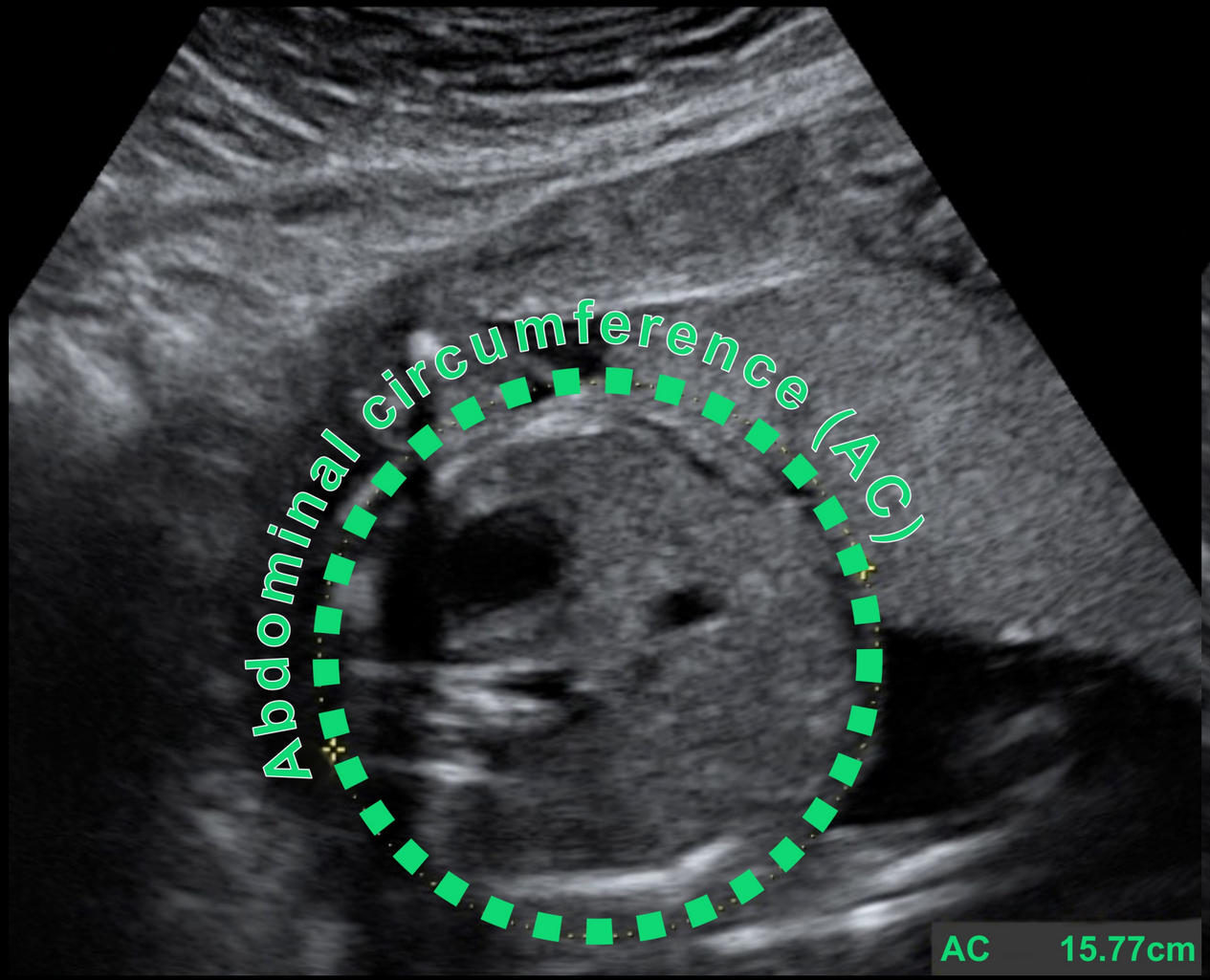
15 July, 2025

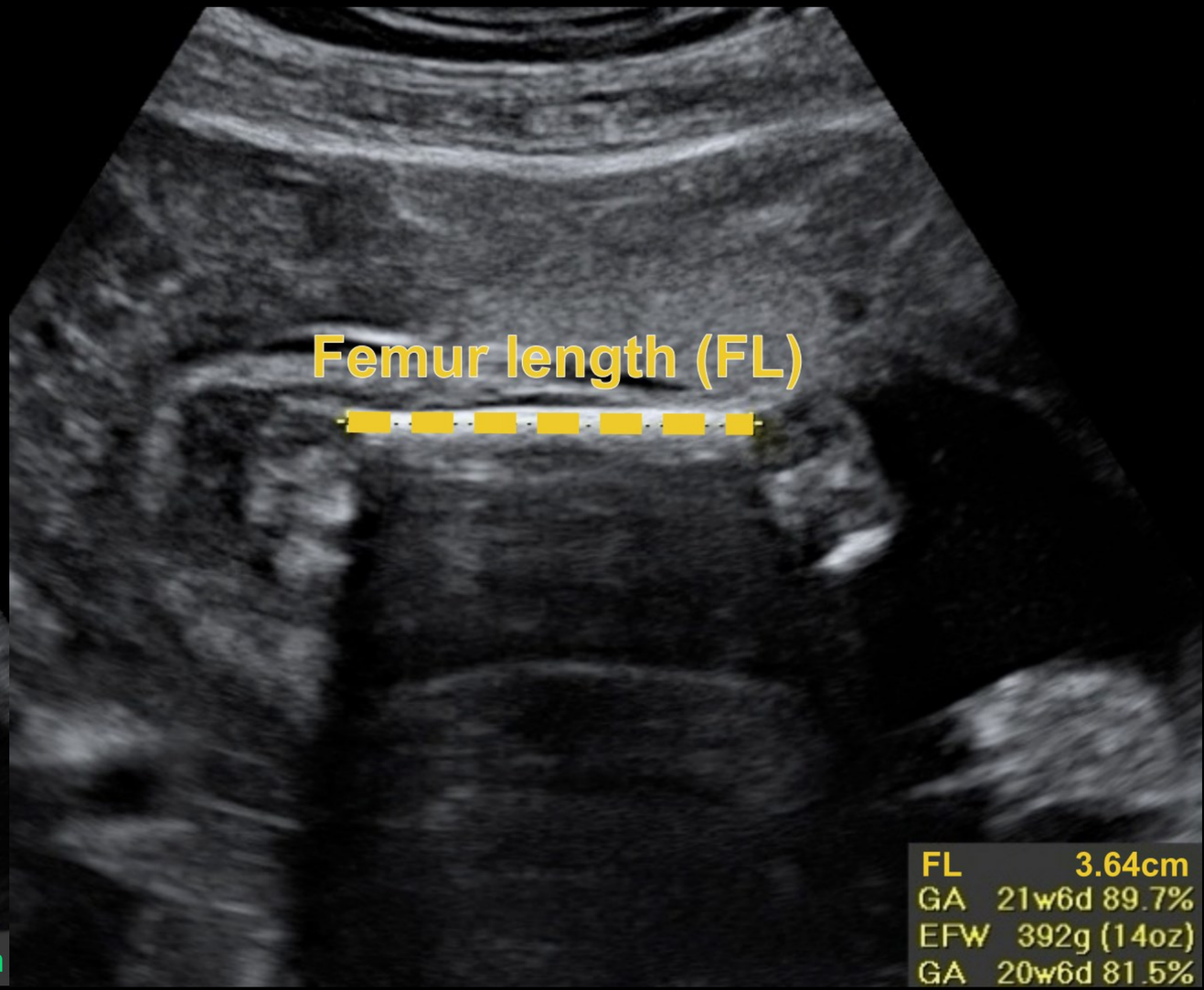

Voluson
Expert 22

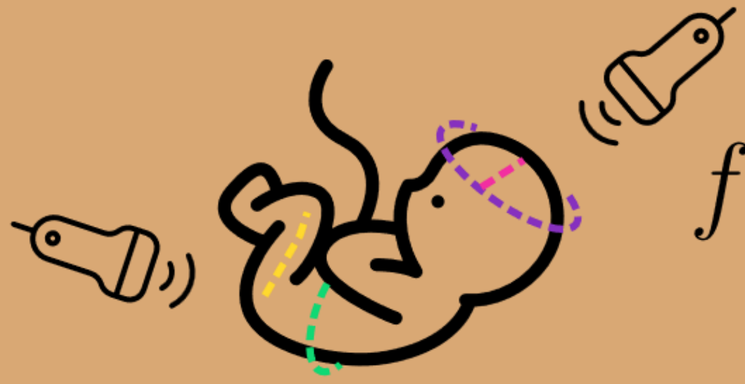

HC
BPD
BPD 4.78cm
GA 20w3d 54.5%
OFD (HC) 6.32cm
HC 17.80cm
GA 21w1d 73.5%


Head circumference (HC)
BPD 4.78cm
GA 20w3d 54.5%
OFD (HC) 6.32cm
HC 17.80cm
GA 21w1d 73.5%

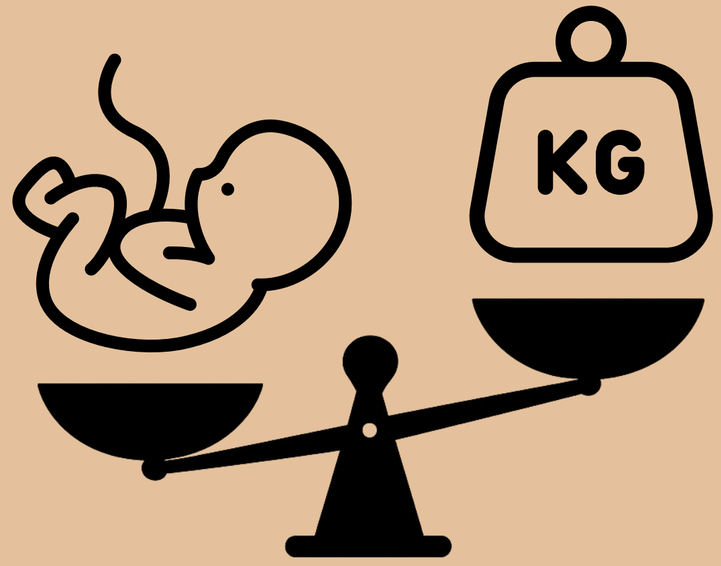

Head circumference (HC)
Biparietal diameter (BPD)
BPD 4.78cm
GA 20w3d 54.5%
OFD (HC) 6.32cm
HC 17.80cm
GA 21w1d 73.5%

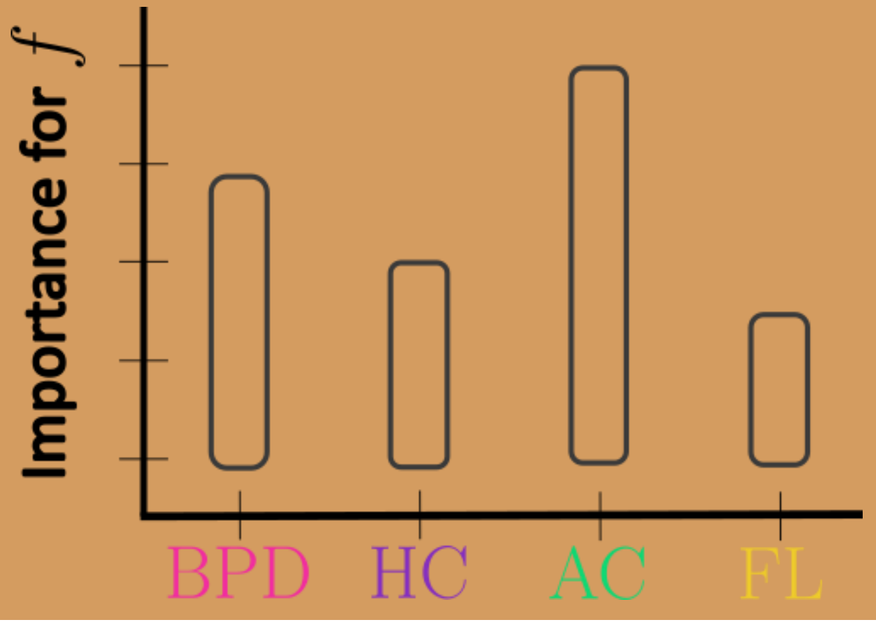

Abdominal circumference (AC)
AC 15.77cm


Femur length (FL)
FL 3.64cm
GA 21w6d 89.7%
EFW 392g (14oz)
GA 20w6d 81.5%



$$f\,(\ldots,\mathrm{BPD},\mathrm{HC},\mathrm{AC},\mathrm{FL},\ldots) =$$





Agenda Overview

A Methodology

- A1 Formulas
- A2 Sensitivity Analysis
- A3 Data
- A4 Framework

B Results

- B1 Findings
- B2 Summary of key findings
- B3 Implications

A Methodology

A1

Formulas

Hadlock III (1985)

$$10^{1.326-0.00326(\mathrm{AC})(\mathrm{FL})+0.0107(\mathrm{HC})+0.0438(\mathrm{AC})+0.158(\mathrm{FL})}$$

Shepard II (1982)

$$10^{-1.7492+0.166(\mathrm{BPD})+0.046(\mathrm{AC})-0.002646(\mathrm{BPD})(\mathrm{AC})}$$

Schild (2004)

$$5381.193 + 150.324\,(\mathrm{HC}) + 2.069\,(\mathrm{FL})^3 + 0.0232\,(\mathrm{AC})^3 - 6235.478\log(\mathrm{HC})$$

INTERGROWTH-21 (2017)

$$e^{5.084820-54.06633((\mathrm{AC})/100)^3-95.80076((\mathrm{AC})/100)^3\ln((\mathrm{AC})/100)+3.136370(\mathrm{HC})/100}$$

A2 Sensitivity Analysis

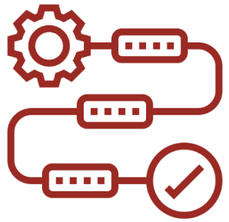
Our tool of choice for answering the question of how exactly the ultrasonically measured biometric parameters influence the estimated fetal weight for each formula

What is it?

Determines how changes in input parameters affect the output of a mathematical model or system

Why use it?

Informs which parameters have the greatest influence, improves model development, prioritizes further research, etc.



How to use it?

Local: Changes one parameter(s) at a time, while holding other parameters fixed

Global: Varys of all parameters simultaneously over their plausible ranges

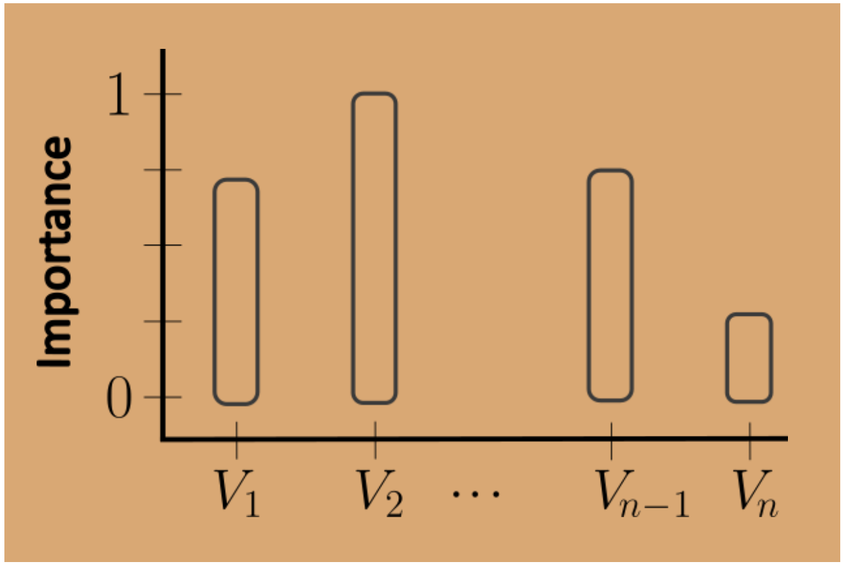
Sobol' Method

First order Sobol' indices

Let f be a function and $\mathbf{X} = (X_1, X_2, \ldots, X_n)$ its parameter vector

$$\mathrm{Var}[f(\mathbf{X})] = \sum_{i=1}^{n} V_i + \sum_{i<j}^{n} V_{i,j} + \cdots + V_{1,2\ldots,n}\,,$$

where
V_i is the contribution of the main effect of parameter X_i to $\mathrm{Var}[f(\mathbf{X})]$,
$V_{i,j}$ is the contribution of the interactions of parameter X_i and X_j to $\mathrm{Var}[f(\mathbf{X})]$.



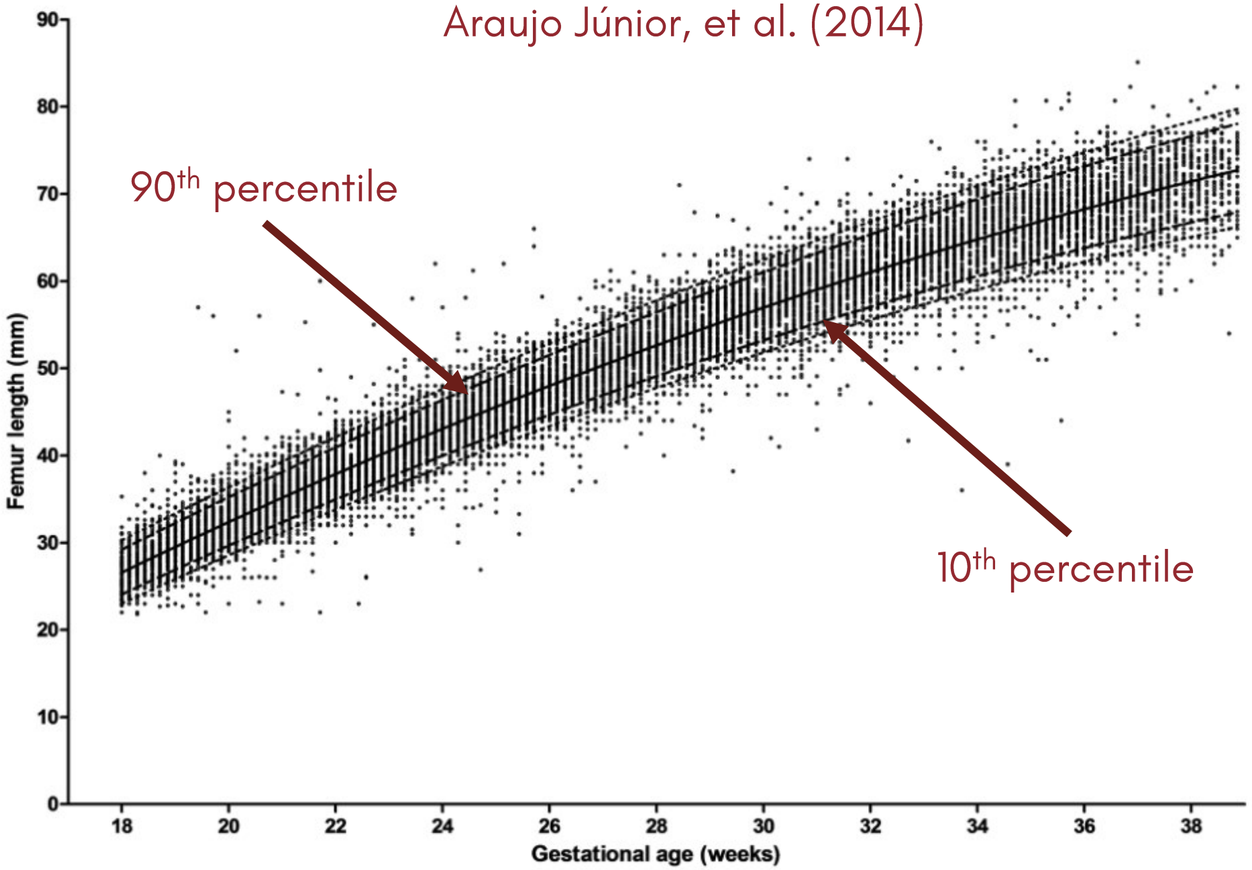
Global methods consider the sensitivity of the output over an entire range of parameters

We need ranges = We need data!

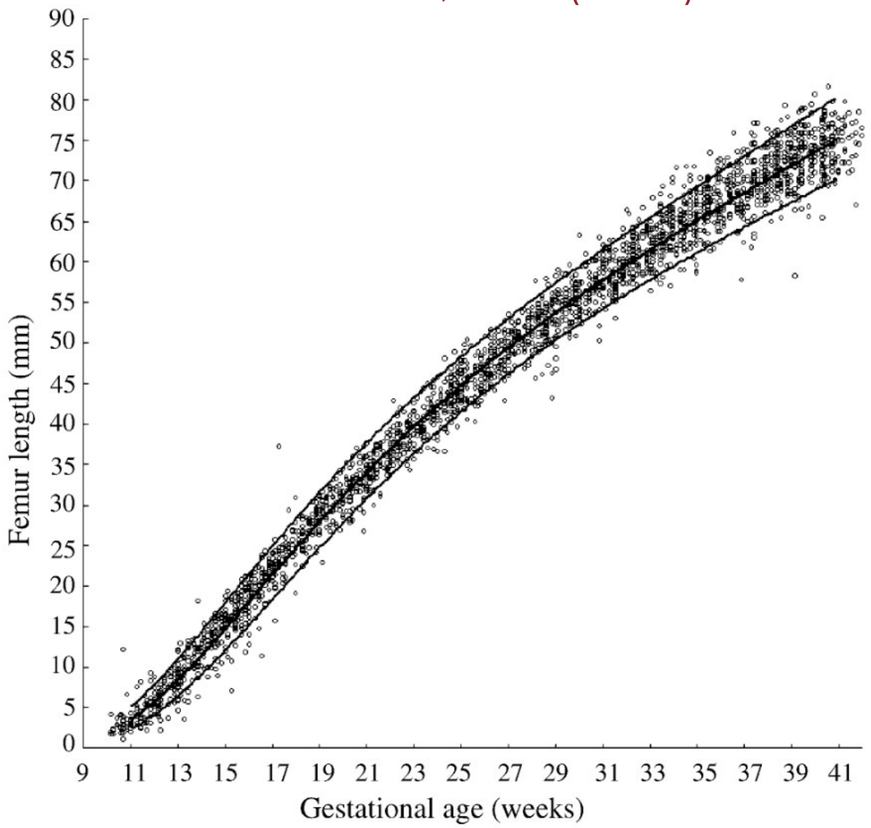
A3 Data

Growth Charts

Araujo Júnior, et al. (2014)



Johnsen, et al. (2004)



26 datasets from published studies spanning diverse populations and gestational ages were analysed, incorporating measurements of BPD, AC, HC and FL

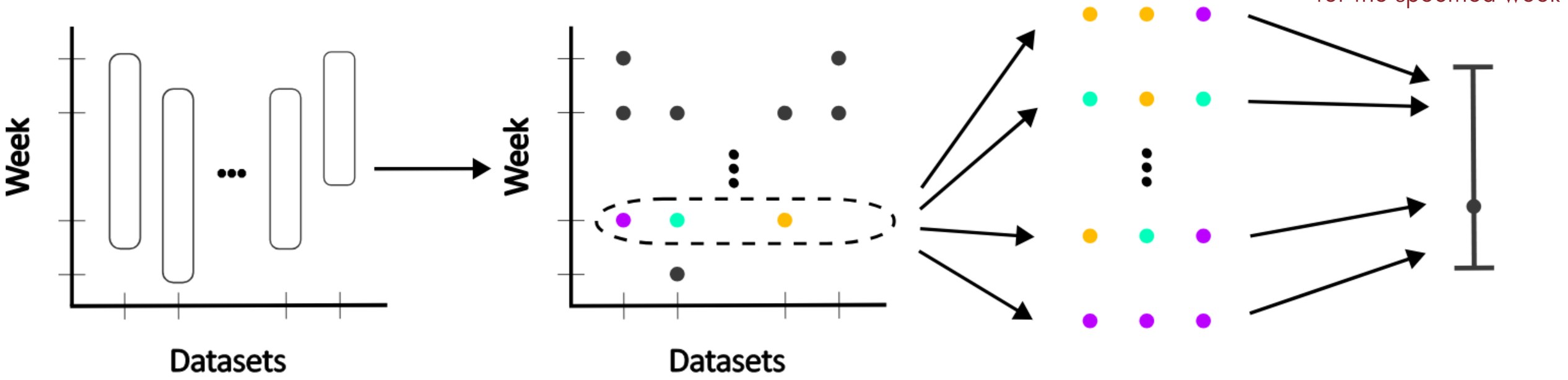
A4 Framework

Collect datasets
for the four biometric parameters
throughout the gestation

Compute Sobol' indices
for a specific formula
for all available weeks
in each dataset

Resample all indices
computed for a single week
and calculate their mean

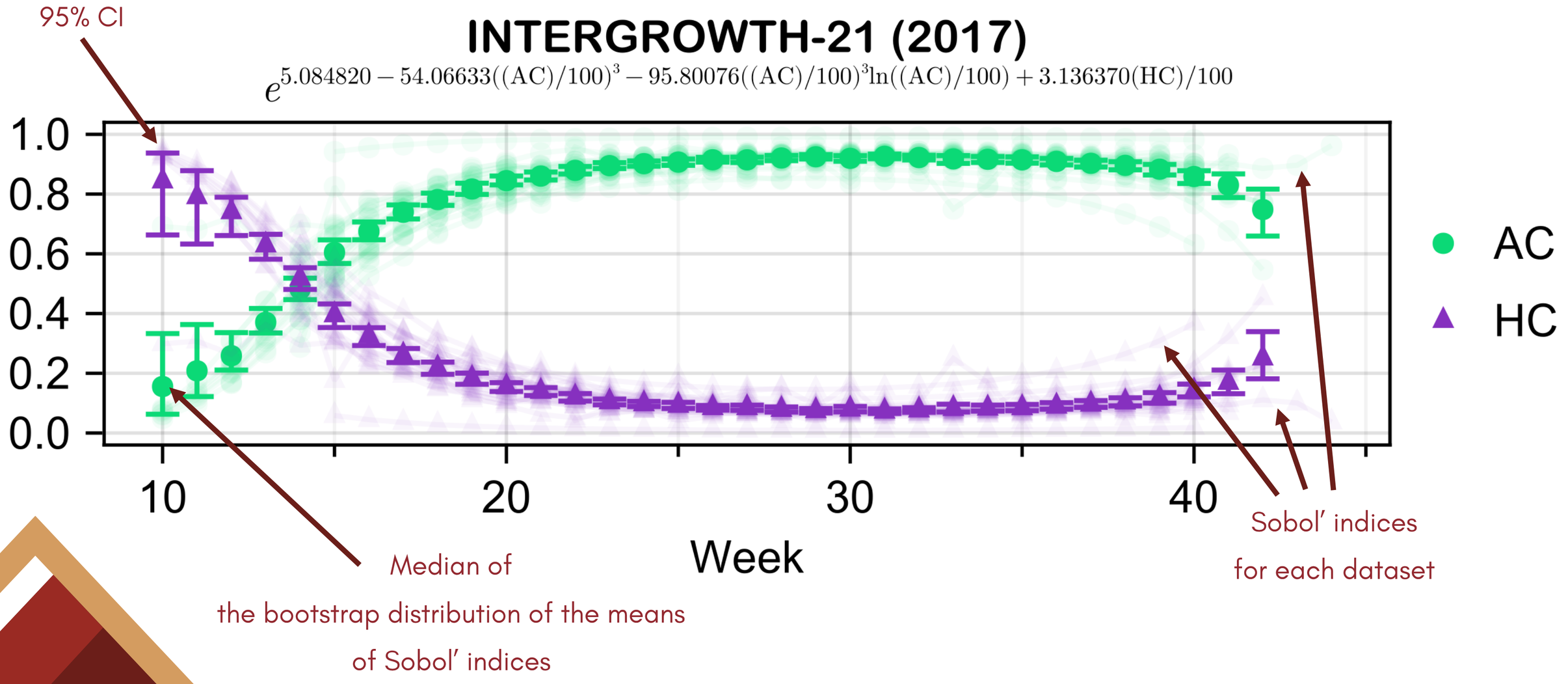
Estimate median
and 95% CI
of the bootstrap
distribution
of the mean Sobol' index
for the specified week

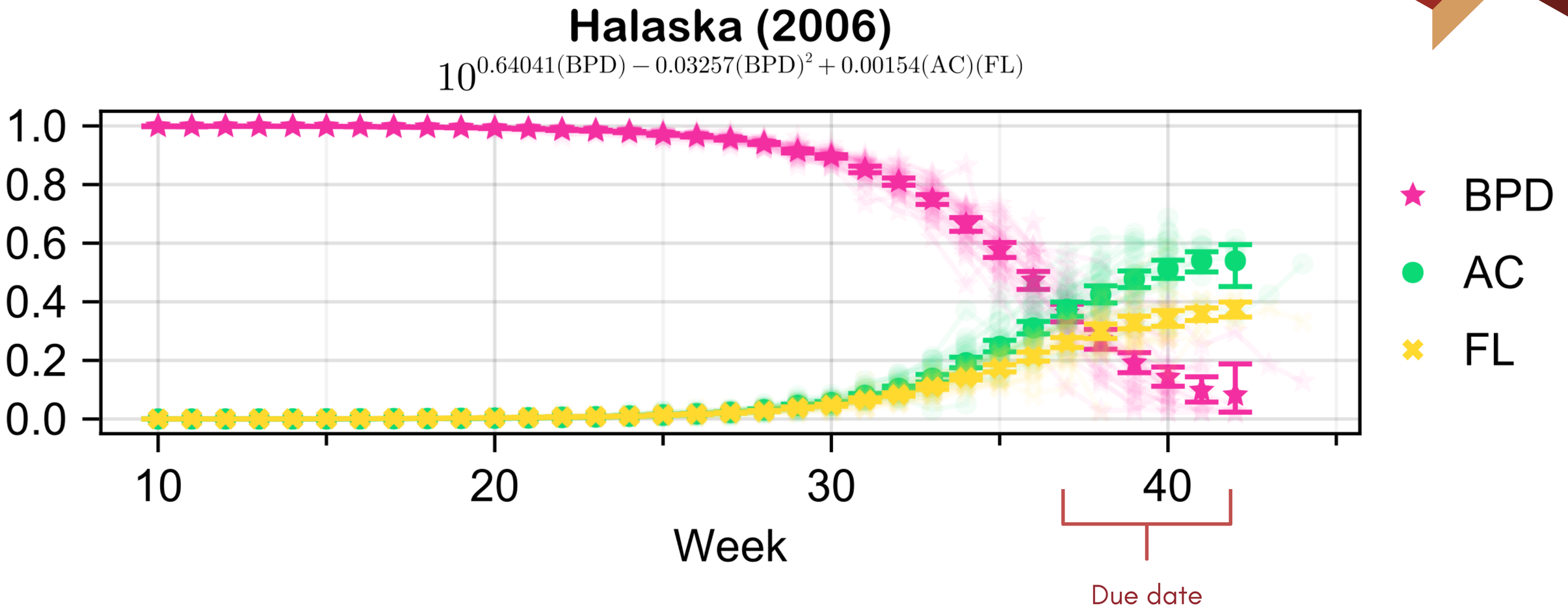


B Results

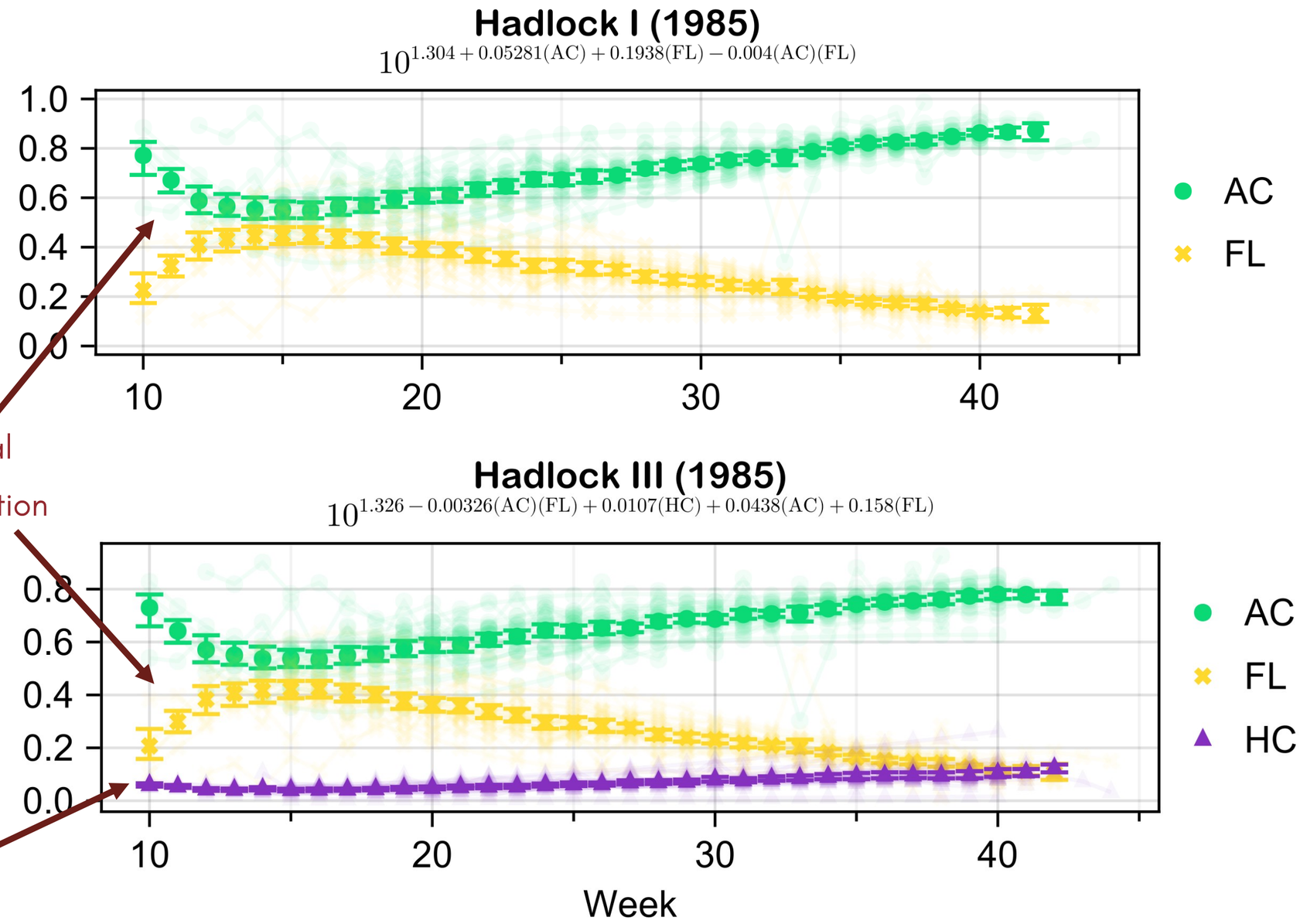
B1

Findings


95% CI
INTERGROWTH-21 (2017)
$e^{5.084820 - 54.06633((AC)/100)^3 - 95.80076((AC)/100)^3\ln((AC)/100) + 3.136370(HC)/100}$
1.0
0.8
0.6
0.4
0.2
0.0
10
20
30
40
Week
AC
HC
Median of
the bootstrap distribution of the means
of Sobol' indices
Sobol' indices
for each dataset


Halaska (2006)
$10^{0.64041(\mathrm{BPD}) - 0.03257(\mathrm{BPD})^2 + 0.00154(\mathrm{AC})(\mathrm{FL})}$
1.0
0.8
0.6
0.4
0.2
0.0
10
20
30
40
Week
Due date
BPD
AC
FL

Parsimony



AC and FL are almost identical throughout the gestation

HC is insignificant throughout the whole gestation

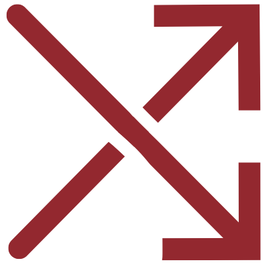
B2 Summary of key findings

Half of the formulas include at least one parameter with minimal contribution

AC is insignificant in 4% of the formulas that it appears in (HC: 20%, BPD: 33%, and FL: 37%)

Only two of the formulas have a dominant parameter throughout the gestation

AC is considered a crucial parameter
in fetal weight estimation
however, its contribution depends on
both the choice of the formula and the gestation age



66% of the formulas exhibit a crossover in parameter importance
over the course of gestation
i.e., some transition from low-to-high significance,
while others decline from high to low

B3 Implications

Clinicians should select formulas based on gestational age, measurement reliability and fetal characteristics

Estimates made with fewer than the intended parameters can be viable in emergencies

The refinement of existing formulas and the development of improved fetal weight estimation models can be achieved through the proposed methodology

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ΕΛΚΕ
ΕΙΔΙΚΟΣ ΛΟΓΑΡΙΑΣΜΟΣ ΚΟΝΔΥΛΙΩΝ ΕΡΕΥΝΑΣ
ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ

ΠΡΟΓΡΑΜΜΑ "ΜΕΔΙΚΟΣ*"

Thank You!

V. Bitsouni, N. Gialelis, and V. Tsilidis,
Partial dependence of ultrasonically estimated fetal weight on biometric parameters,
Royal Society Open Science (2025)