Partial dependence of ultrasonically estimated fetal weight on individual biometric variables

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Contribution

What are the novel findings of this work?
Through a systematic analysis, it emerges that the contribution of ultrasonically measured parameters on fetal weight estimation varies based on the formula and the gestation age. In particular, the importance of some parameters changes drastically throughout the gestation, while others remain insignificant.

What are the clinical implications of this work?
This work enables a sonographer to ascertain which measurement plays the biggest role during the estimation of fetal weight, depending on their choice of formula and the gestation age. In many cases, fewer than the intended measurements are sufficient for a similar estimation.

Abstract

Objectives: To assess the contribution of sonographically measured parameters, namely head circumference, biparietal diameter, abdominal circumference, and femur length, to fetal weight estimation formulas.
Methods: The Sobol' method is employed for the global sensitivity analysis of the biometric parameters.
Results: The Sobol' sensitivity indices for the parameters of 32 known formulas are presented and discussed.
Conclusions: Depending on the formula, the indices of some parameters show substantial fluctuations, while others are insignificant for fetal weight estimation.

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Introduction

For the sonographic assessment of fetal weight, a formula that incorporates certain biometric parameters is required. Many formulas have been proposed, with standard biometric parameters being the head circumference (HC), biparietal diameter (BPD), abdominal circumference (AC), and femur length (FL).

There exist many studies comparing the accuracy of different formulas[1–9]. However, there are none that systematically assess the contribution of the involved parameters of each formula.

The scope of the present study is to evaluate the effect of the biometric parameters of various formulas on the estimation of fetal weight. Our approach does not rely on statistical analysis, rather than on an unbiased global sensitivity analysis scheme, known as the Sobol' method.

Methods

Sensitivity analysis

The Sobol' method, a global sensitivity analysis technique, is a variance-based approach employed to evaluate how changes in parameter inputs influence the outputs of a mathematical model. The method operates by partitioning the variance of the outputs generated by the model into distinct contributions from individual input parameters and their respective interactions. Assuming that f is the mathematical formula used for fetal weight estimation and X is the vector of the parameters of f, then by the Hoeffding decomposition, the total variance of the formula can be written as:

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

where d represents the length of vector X, V_i represents the variance due to the main effect of parameter i, V_{ij} represents the variance due to the interaction between parameters i and j, and so on.

Sobol' sensitivity indices are normalized metrics that correspond to the aforementioned representations. The first-order sensitivity indices are defined as

$$S_i = \frac{V_i}{\mathrm{Var}[f(\mathrm{X})]}.$$

A high first-order index indicates that the parameter has a significant direct influence on the output.

The second-order sensitivity indices are defined as

$$S_{i,j} = \frac{V_{i,j}}{\mathrm{Var}[f(\mathrm{x})]}.$$

A high second-order index indicates that the combined effects of the two parameters are not merely additive. Both the first- and second-order indices range from 0 to 1.

The Julia package GlobalSensitivity.jl[10] was employed for the calculation of the Sobol' indices.

Sampling

In order to eliminate bias from the dataset and at the same time investigate the whole parameter space uniformly (i.e., more evenly), low-discrepancy synthetic data were generated. A quasi-random low-discrepancy sequence of numbers was generated in the interval between the 5th and the 95th percentile of each parameter, utilizing the Sobol' sampling method, which is described in Sobol[11]. The Julia package QuasiMonteCarlo.jl was employed to generate a Sobol' sequence of 1,000,000 numbers for each parameter.

Data

The lower and upper bounds for the parameters were taken from Kurmanavicius *et al.*[12] and Kurmanavicius *et al.*[13]. In Kurmanavicius *et al.*[12], 6,217 fetal BPDs and 5,462 fetal HCs were measured. In Kurmanavicius *et al.*[13], 5,807 fetal ACs and 5,860 fetal FLs were measured. In both studies, the measurements were taken between 12 and 42 weeks of each fetus gestational age, from pregnant women of various ethnicities. Additionally, the 5th and 95th percentile charts were calculated for all parameters. In the present study, the 5th and 95th percentiles are considered as the lower and upper bounds, respectively, for each parameter.

Formulas

The formulas under investigation, which take into account more than one independent parameter, are presented in Table 1.

Source	Formula
Combs (1993)[20]	$0.23718(\mathrm{AC})^2(\mathrm{FL}) + 0.03312(\mathrm{HC})^3$
Ferrero (1994)[21]	$10^{0.77125+0.13244(\mathrm{AC})-0.12996(\mathrm{FL})-1.73588(\mathrm{AC})^2/1000+3.09212(\mathrm{AC})(\mathrm{FL})/1000+2.18984(\mathrm{FL})/(\mathrm{AC})}$
Hadlock (1984)[22]	$10^{1.1134+0.05845(\mathrm{AC})-0.000604(\mathrm{AC})^2+0.007365(\mathrm{BPD})^2+0.000595(\mathrm{BPD})(\mathrm{AC})+0.1694(\mathrm{BPD})}$
Hadlock I (1985)[23]	$10^{1.304+0.05281(\mathrm{AC})+0.1938(\mathrm{FL})-0.004(\mathrm{AC})(\mathrm{FL})}$
Hadlock II (1985)[23]	$10^{1.335-0.0034(\mathrm{AC})(\mathrm{FL})+0.0316(\mathrm{BPD})+0.0457(\mathrm{AC})+0.1623(\mathrm{FL})}$
Hadlock III (1985)[23]	$10^{1.326-0.00326(\mathrm{AC})(\mathrm{FL})+0.0107(\mathrm{HC})+0.0438(\mathrm{AC})+0.158(\mathrm{FL})}$
Hadlock IV (1985)[23]	$10^{1.3596+0.00061(\mathrm{BPD})(\mathrm{AC})+0.424(\mathrm{AC})+0.174(\mathrm{FL})+0.0064(\mathrm{HC})-0.00386(\mathrm{AC})(\mathrm{FL})}$

Source	Formula
Halaska (2006)[24]	$10^{0.64041(BPD)-0.03257(BPD)^2+0.00154(AC)(FL)}$
Hsieh (1987)[25]	$10^{2.1315+0.0056541(BPD)(AC)-0.00015515(BPD)(AC)^2+0.000019782(AC)^3+0.052594(BPD)}$
INTERGROWTH-21 (2017)[26]	$e^{5.084820-54.06633((AC)/100)^3-95.80076((AC)/100)^3\ln((AC)/100)+3.136370(HC)/100}$
Jordaan I (1983)[27]	$10^{-1.1683+0.0377(AC)+0.095(BPD)-0.0015(BPD)(AC)}$
Jordaan II (1983)[27]	$10^{0.9119+0.0488(HC)+0.0824(AC)+0.001599(AC)(HC)}$
Merz (1988)[28]	$3200.40479+157.07186(AC)+15.90391(BPD)^2$
Ott (1986)[29]	$10^{-2.0661+0.04355(HC)+0.05394(AC)-0.0008582(AC)(HC)+1.2594(AC)(FL)(AC)}$
Roberts (1985)[30]	$10^{1.6758+0.01707(AC)+0.042478(BPD)+0.05216(FL)+0.01604(HC)}$
Schild (2004)[31]	$5381.193+150.324(HC)+2.069(FL)^3+0.0232(AC)^3-6235.478\log(HC)$
Shepard I (1982)[32]	$10^{-1.599+0.144(BPD)+0.032(AC)-0.000111(AC)(BPD)^2}$
Shepard II (1982)[32]	$10^{-1.7492+0.166(BPD)+0.046(AC)-0.002646(BPD)(AC)}$
Thurnau (1983)[33]	$9.337(BPD)(AC)-229$
Vintzileos I (1987)[34]	$10^{1.879+0.084(BPD)+0.026(AC)}$
Vintzileos II (1987)[34]	$10^{2.082+0.004(HC)(FL)+0.0018(AC)-0.00000001509((HC)(FL))^3}$
Warsof (1977)[35]	$10^{-1.599+0.144(BPD)+0.032(AC)-0.000111(BPD)^2(AC)}$
Warsof (1986)[36]	$e^{2.792+0.108(FL)+0.000036(AC)^2-0.00027(AC)(FL)}$
Weiner I (1985)[37]	$10^{1.6961+0.02253(HC)+0.01645(AC)+0.06439(FL)}$
Weiner II (1985)[37]	$10^{1.6575+0.04035(HC)+0.01285(AC)}$
Woo (1986)[38]	$1.4(BPD)(AC)(HC)-200$
Woo I (1985)[39]	$10^{1.54+0.15(BPD)+0.00111(AC)^2-0.0000764(BPD)(AC)^2+0.5(FL)-0.000992(AC)(FL)}$
Woo II (1985)[39]	$10^{1.14+0.16(BPD)+0.05(AC)-2.8(BPD)(AC)/1000+0.04(FL)-4.9(AC)(FL)/10000}$
Woo III (1985)[39]	$10^{1.13+0.18(BPD)+0.05(AC)-3.35(BPD)(AC)/1000}$
Woo IV (1985)[39]	$10^{1.63+0.16(BPD)+0.00111(AC)^2-0.0000859(BPD)(AC)^2}$
Woo V (1985)[39]	$10^{0.59+0.08(AC)+0.28(FL)-0.00716(AC)(FL)}$

Table 1: List of the formulas under investigation.

Ten of the most commonly used formulas in practice are Hadlock (1984), Hadlock I – IV (1985), Halaska (2006), INTERGROWTH-21 (2017), Schild (2004), Shepard II (1982), and Warsof (1986)[2,14].

Results

Second order Sobol' indices for all the tested formulas were found to be small enough (<0.01). This fact confirms the lack of interactions between the involved parameters, which are indeed independent. Therefore, all the formulas under investigation are well-defined and only the first order Sobol' indices are left to be examined.

In Table 2 through Table 7 the first order Sobol' indices for all the tested formulas are presented. For brevity, only the indices of the following four hallmark gestational intervals are portrayed:

- 11th – 14th week: first-trimester ultrasound scan[15].
- 18th – 22nd week: second-trimester ultrasound scan[16].
- 22nd – 24th week: fetal viability threshold[17].
- 32nd – 34th week: fetal lung maturity threshold[18].

The complete list of indices for every formula, along with the code implementation, can be found at https://github.com/TsilidisV/partial-dependence-of-estimated-fetal-weight.

In particular, the case of the most commonly used formulas is presented for the whole gestation in Figure 1.

		First-trimester			**Second-trimester**				**Fetal viability**			**Fetal lung maturity**		
Formula	**Parameter**	**12**	**13**	**14**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**32**	**33**	**34**
Ferrero (1994)	AC	0.47	0.57	0.67	0.9	0.92	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97
	FL	0.53	0.43	0.33	0.1	0.08	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.03
Hadlock I (1985)	AC	0.57	0.56	0.57	0.59	0.59	0.6	0.61	0.63	0.65	0.66	0.77	0.78	0.79
	FL	0.43	0.43	0.43	0.41	0.41	0.4	0.39	0.37	0.35	0.34	0.23	0.22	0.21
Warsof (1986)	AC	0	0	0	0	0	0	0	0	0	0	0	0	0
	FL	1	1	1	1	1	1	1	1	1	1	1	1	1
Woo V (1985)	AC	0.6	0.6	0.6	0.63	0.64	0.65	0.66	0.68	0.7	0.71	0.84	0.86	0.87
	FL	0.39	0.4	0.4	0.37	0.36	0.35	0.34	0.32	0.3	0.29	0.16	0.14	0.13

Table 2: First order indices of formulas involving exclusively AC and FL. The intensity of the color of each cell highlights the magnitude of the index.

		First-trimester			Second-trimester				Fetal viability			Fetal lung maturity		
Formula	Parameter	12	13	14	18	19	20	21	22	23	24	32	33	34
Hadlock (1984)	BPD	0.65	0.65	0.66	0.7	0.7	0.71	0.73	0.74	0.75	0.76	0.83	0.84	0.85
	AC	0.35	0.34	0.34	0.3	0.29	0.28	0.26	0.25	0.25	0.24	0.16	0.15	0.14
Hsieh (1987)	BPD	0.88	0.86	0.83	0.74	0.72	0.7	0.69	0.67	0.65	0.64	0.51	0.49	0.47
	AC	0.11	0.14	0.17	0.26	0.28	0.3	0.31	0.33	0.35	0.36	0.49	0.51	0.53
Jordaan I (1983)	BPD	0.44	0.42	0.4	0.33	0.32	0.31	0.3	0.29	0.28	0.27	0.2	0.19	0.18
	AC	0.56	0.58	0.6	0.66	0.68	0.69	0.7	0.71	0.72	0.73	0.8	0.81	0.82
Merz (1988)	BPD	0.02	0.03	0.03	0.06	0.07	0.07	0.08	0.09	0.09	0.1	0.13	0.14	0.14
	AC	0.98	0.97	0.97	0.94	0.93	0.93	0.92	0.91	0.91	0.9	0.87	0.86	0.86
Shepard I (1982)	BPD	0.72	0.7	0.68	0.62	0.61	0.59	0.58	0.57	0.55	0.54	0.44	0.42	0.41
	AC	0.28	0.3	0.32	0.38	0.39	0.41	0.42	0.43	0.44	0.46	0.56	0.58	0.59
Shepard II (1982)	BPD	0.64	0.62	0.6	0.56	0.55	0.53	0.53	0.52	0.51	0.51	0.45	0.45	0.44
	AC	0.36	0.38	0.4	0.44	0.45	0.46	0.47	0.48	0.49	0.49	0.55	0.55	0.56
Thurnau (1983)	BPD	0.47	0.46	0.45	0.41	0.4	0.39	0.39	0.38	0.38	0.37	0.35	0.34	0.35
	AC	0.52	0.53	0.55	0.59	0.59	0.61	0.61	0.61	0.62	0.63	0.65	0.65	0.65
Vintzileos I (1987)	BPD	0.57	0.54	0.52	0.47	0.46	0.44	0.44	0.43	0.41	0.41	0.35	0.35	0.34
	AC	0.43	0.45	0.47	0.53	0.54	0.56	0.56	0.57	0.58	0.59	0.65	0.65	0.65
Warsof (1977)	BPD	0.72	0.7	0.68	0.62	0.61	0.59	0.58	0.57	0.55	0.54	0.44	0.42	0.41
	AC	0.28	0.3	0.32	0.38	0.39	0.41	0.42	0.43	0.44	0.46	0.56	0.58	0.59
Woo III (1985)	BPD	0.64	0.62	0.6	0.56	0.55	0.54	0.54	0.53	0.52	0.52	0.47	0.46	0.46
	AC	0.36	0.38	0.39	0.44	0.45	0.46	0.46	0.47	0.48	0.48	0.53	0.54	0.54
Woo IV (1985)	BPD	0.97	0.95	0.93	0.84	0.82	0.79	0.77	0.75	0.72	0.7	0.53	0.51	0.49
	AC	0.03	0.05	0.07	0.16	0.18	0.21	0.23	0.25	0.28	0.3	0.47	0.49	0.51

Table 3: First order indices of formulas involving exclusively BPD and AC. The intensity of the color of each cell highlights the magnitude of the index.

		First-trimester			Second-trimester				Fetal viability			Fetal lung maturity		
Formula	Parameter	12	13	14	18	19	20	21	22	23	24	32	33	34
INTERGROWTH-21 (2017)	AC	0.22	0.34	0.47	0.77	0.81	0.84	0.86	0.88	0.9	0.9	0.93	0.93	0.93
	HC	0.78	0.66	0.53	0.22	0.19	0.16	0.14	0.12	0.1	0.09	0.07	0.07	0.07
Jordaan II (1983)	AC	0.72	0.74	0.76	0.83	0.84	0.86	0.87	0.88	0.9	0.91	0.99	0.99	1
	HC	0.27	0.25	0.23	0.17	0.16	0.14	0.13	0.12	0.1	0.09	0.01	0.01	0
Weiner II (1985)	AC	0.08	0.08	0.09	0.11	0.11	0.12	0.12	0.12	0.13	0.13	0.16	0.16	0.16
	HC	0.92	0.92	0.91	0.89	0.89	0.88	0.88	0.87	0.87	0.87	0.84	0.84	0.83

Table 3: First order indices of formulas involving exclusively AC and HC. The intensity of the color of each cell highlights the magnitude of the index.

		First-trimester			Second-trimester				Fetal viability			Fetal lung maturity		
Formula	**Parameter**	**12**	**13**	**14**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**32**	**33**	**34**
Combs (1993)	AC	0.09	0.14	0.18	0.31	0.33	0.35	0.37	0.39	0.41	0.43	0.55	0.56	0.57
	FL	0.09	0.1	0.1	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.09	0.09	0.09
	HC	0.81	0.76	0.71	0.58	0.56	0.53	0.52	0.5	0.48	0.47	0.36	0.35	0.34
Hadlock III (1985)	AC	0.56	0.55	0.55	0.57	0.58	0.58	0.59	0.61	0.62	0.63	0.72	0.72	0.73
	FL	0.4	0.41	0.41	0.38	0.38	0.37	0.36	0.34	0.32	0.31	0.2	0.19	0.18
	HC	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.08	0.08	0.08
Ott (1986)	AC	0.07	0.08	0.1	0.2	0.23	0.26	0.28	0.31	0.34	0.36	0.53	0.54	0.56
	FL	0.59	0.54	0.49	0.32	0.3	0.27	0.25	0.23	0.21	0.19	0.12	0.11	0.11
	HC	0.33	0.38	0.41	0.47	0.47	0.47	0.46	0.46	0.45	0.45	0.36	0.34	0.33
Schild (2004)	AC	0	0	0	0.14	0.34	0.48	0.46	0.41	0.38	0.35	0.42	0.43	0.45
	FL	0	0	0	0.13	0.33	0.49	0.47	0.41	0.36	0.34	0.29	0.29	0.28
	HC	1	1	1	0.74	0.33	0.03	0.07	0.18	0.26	0.31	0.3	0.28	0.27
Vintzileos II (1987)	AC	0.05	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	FL	0.8	0.77	0.75	0.7	0.7	0.69	0.69	0.68	0.66	0.66	0.59	0.59	0.58
	HC	0.14	0.19	0.22	0.28	0.29	0.29	0.3	0.31	0.33	0.33	0.4	0.4	0.41
Weiner I (1985)	AC	0.24	0.24	0.25	0.28	0.29	0.3	0.31	0.32	0.33	0.33	0.4	0.4	0.41
	FL	0.23	0.24	0.25	0.27	0.27	0.27	0.26	0.26	0.25	0.25	0.2	0.2	0.2
	HC	0.53	0.51	0.49	0.45	0.44	0.43	0.43	0.42	0.42	0.42	0.4	0.39	0.39

Table 5: First order indices of formulas involving exclusively AC, FL and HC. The intensity of the color of each cell highlights the magnitude of the index.

		First-trimester			Second-trimester				Fetal viability			Fetal lung maturity		
Formula	**Parameter**	**12**	**13**	**14**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**32**	**33**	**34**
Hadlock II (1985)	BPD	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.07
	AC	0.57	0.56	0.56	0.59	0.59	0.6	0.61	0.62	0.64	0.65	0.74	0.75	0.76
	FL	0.39	0.4	0.4	0.38	0.37	0.36	0.35	0.33	0.32	0.31	0.2	0.19	0.17
Halaska (2006)	BPD	1	1	1	1	0.99	0.99	0.99	0.99	0.98	0.97	0.73	0.64	0.54
	AC	0	0	0	0	0	0	0	0.01	0.01	0.01	0.16	0.21	0.28
	FL	0	0	0	0	0	0	0.01	0.01	0.01	0.01	0.11	0.14	0.18
Siemer (2007)	BPD	0	0	0	0	0	0.01	0.01	0.01	0.02	0.02	0.1	0.11	0.12
	AC	1	1	1	0.98	0.98	0.97	0.95	0.94	0.93	0.91	0.75	0.73	0.7
	FL	0	0	0	0.01	0.02	0.03	0.04	0.04	0.05	0.06	0.15	0.16	0.17
Woo (1986)	BPD	0.15	0.18	0.2	0.22	0.22	0.22	0.23	0.23	0.23	0.23	0.24	0.24	0.24
	AC	0.16	0.21	0.24	0.32	0.33	0.34	0.35	0.37	0.38	0.39	0.45	0.46	0.46
	FL	0.68	0.6	0.55	0.45	0.44	0.43	0.42	0.4	0.38	0.38	0.3	0.3	0.29
Woo I (1985)	BPD	0.15	0.13	0.12	0.1	0.09	0.09	0.09	0.08	0.08	0.08	0.05	0.05	0.05
	AC	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04
	FL	0.84	0.85	0.86	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.89	0.9	0.9
Woo II (1985)	BPD	0.56	0.54	0.53	0.48	0.47	0.46	0.46	0.45	0.44	0.44	0.39	0.39	0.38
	AC	0.42	0.43	0.45	0.49	0.5	0.51	0.51	0.52	0.53	0.53	0.58	0.59	0.59
	FL	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

Table 6: First order indices of formulas involving exclusively BPD, AC and FL. The intensity of the color of each cell highlights the magnitude of the index.

		First-trimester			Second-trimester				Fetal viability			Fetal lung maturity		
Formula	**Parameter**	**12**	**13**	**14**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**32**	**33**	**34**
Hadlock IV (1985)	BPD	0	0	0	0	0	0	0	0	0.01	0.01	0.02	0.02	0.02
	AC	0.52	0.52	0.52	0.55	0.56	0.57	0.58	0.6	0.62	0.63	0.75	0.75	0.76
	FL	0.46	0.46	0.46	0.43	0.42	0.41	0.4	0.38	0.36	0.34	0.21	0.2	0.18
	HC	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03
Roberts (1985)	BPD	0.23	0.21	0.21	0.18	0.18	0.17	0.17	0.17	0.17	0.17	0.15	0.15	0.15
	AC	0.29	0.3	0.31	0.35	0.36	0.37	0.38	0.39	0.4	0.41	0.47	0.48	0.48
	FL	0.17	0.18	0.19	0.2	0.2	0.2	0.2	0.19	0.19	0.18	0.15	0.15	0.14
	HC	0.31	0.3	0.29	0.26	0.26	0.25	0.25	0.24	0.24	0.24	0.22	0.22	0.22

Table 7: First order indices of formulas involving exclusively BPD, AC, FL and HC. The intensity of the color of each cell highlights the magnitude of the index.

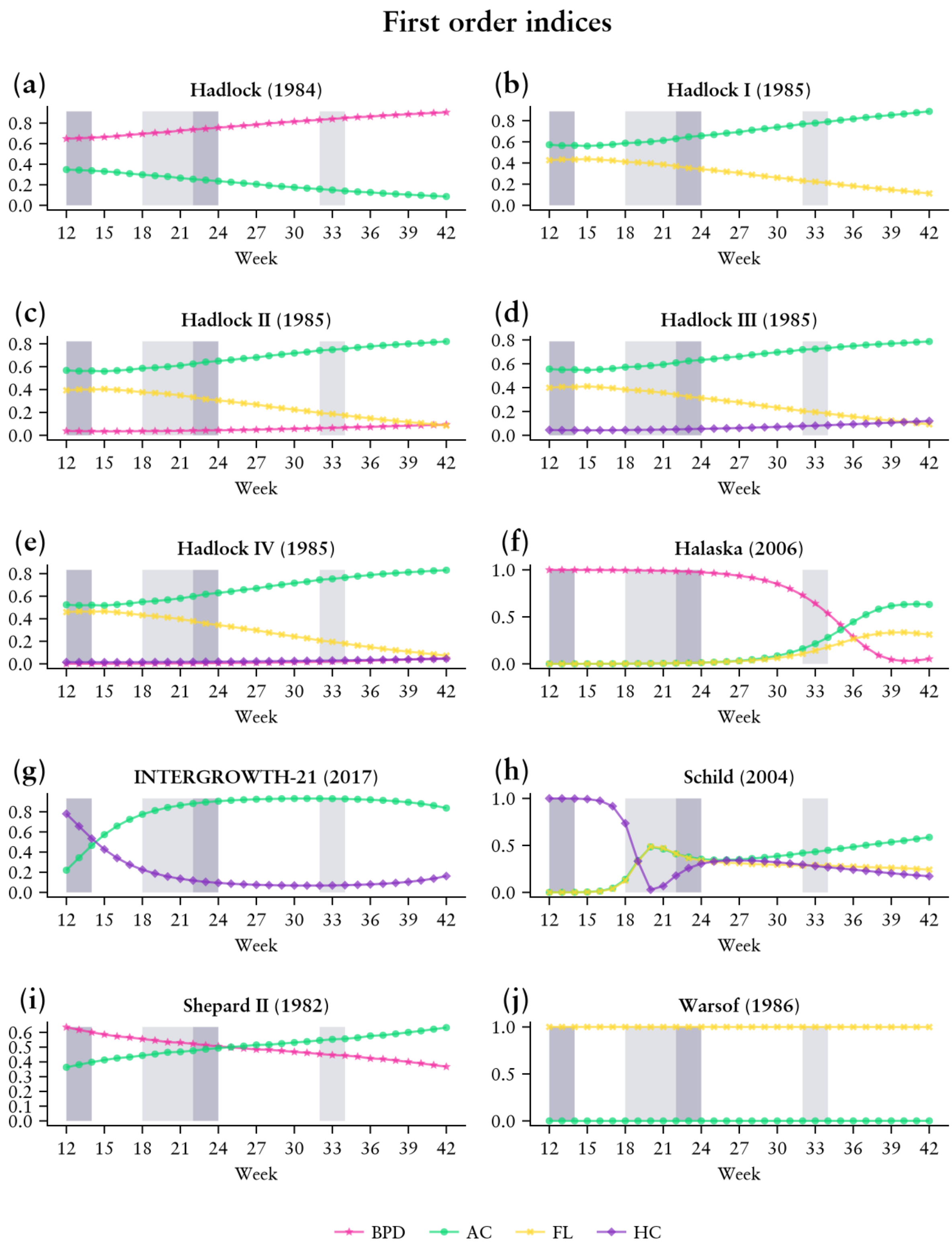

Figure 1: Sobol' indices for ten of the most commonly used fetal weight estimation formulas. The four hallmark gestational intervals are highlighted in gray.

Concerning the case of Figure 1, the indices of most formulas not only do they fluctuate, but they also exhibit qualitative changes. Namely, in Shepard (1982) the graphs cross each other at the 22nd – 24th week interval; in Hadlock (1984) and Hadlock I – IV (1985) two indices start at almost the same level, but end up at significantly different values. Moreover, the indices of some formulas remain small throughout the gestation. Namely, HC is insignificant in all the Hadlock formulas in which it appears.

Discussion

As far as a general overview of the results is concerned, the indices of almost all studied formulas are strictly monotone, with notable exceptions being Schild (2004) and Ott (1986). Additionally, for most formulas, the range of index values is large, with only 25% of the formulas retaining a range less than 0.3. Moreover, the indices of 44% of the formulas cross each other clearly, at some point during the pregnancy.

Regarding the importance of each parameter, 46% of the formulas has at least one insignificant index, with values less than 0.3 throughout the gestation. Specifically, the presence of HC is insignificant in 27% of the formulas that it appears in, BPD in 42%, AC in 13%, and FL in 22%. On the contrary, only 16% of the formulas has a dominant index, with values greater than 0.7 throughout the gestation.

Finally, AC is generally considered to be a crucial parameter in fetal weight estimation. After all, it is included in all of the studied formulas. However, our results indicate that the importance of AC, just like all the tested parameters, depends on both the choice of the formula and the gestation age.

Conclusions

The above analysis leads to the following two conclusions:

1. The behavior of certain parameters of some formulas is subject to qualitative variation during pregnancy, as the values of the corresponding indices change dramatically. Therefore, each sonographer should take into account the gestational age in relation to the formula used for the fetal weight assessment.

2. Certain parameters of some formulas are insignificant throughout pregnancy, which has been confirmed in previous statistical studies[19], such as the HC of Hadlock III (1985). Since fewer parameters are generally preferred (especially in a crude estimation on an emergency basis), some commonly used formulas should be reassessed in this context.

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