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A Contemporary Amniotic Fluid Volume Chart for the United States: The NICHD Fetal Growth Studies-Singletons

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Abstract

Background—Amniotic fluid is essential to normal fetal development and is estimated clinically with ultrasound to identify pregnancies at risk for poor perinatal outcome,

Objectives: Our goal was to develop a United States standard for amniotic fluid volume estimated by the amniotic fluid index and single deepest pocket.

Study Design—We performed a planned secondary analysis of a multicenter observational study of 2334 low-risk women with normal singleton gestations from one of 4 self-reported racial-ethnic groups. Eligible women had confirmed first-trimester dating criteria with health status, lifestyles and medical and obstetric histories associated with normal fetal growth. Consenting women underwent serial (up to 5) sonographic evaluations of amniotic fluid between 15 and 40 weeks' gestation after being randomly assigned to one of 4 gestational age observation schedules. Twelve

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U.S. perinatal centers participated, and all sonograms were performed by credentialed sonographers using identical, high-resolution equipment; caregivers were unaware of results but were notified for oligohydramnios. Women (N=597) subsequently found to have clinically significant antepartum complications were excluded. Racial-ethnic-specific nomograms for amniotic fluid index and single deepest pocket across gestation were developed using linear mixed models with cubic splines, while racial-ethnic differences were evaluated both with global and between-group tests. Median, 3rd, 5th, 10th, 90th, 95th and 97th percentile values were also estimated. We further considered the possible confounding effects of selected maternal characteristics and the estimated fetal weight at each sonogram.

Results—A total of 1719 pregnant women met inclusion criteria and had available data. These included 480 non-Hispanic white, 418 non-Hispanic black, 485 Hispanic and 336 Asian women. Both the amniotic fluid index and the single deepest pocket varied across gestation with maximal values at 26 and 33 weeks respectively. Statistically significant differences were observed by maternal race-ethnicity. The between-group differences observed at 17–22 weeks' and 35–40 weeks' gestation remained statistically significant after adjusting for maternal characteristics and estimated fetal weight. These between-group racial-ethnic differences were most prominent after 35 weeks' gestation and at the extremes of dispersion (3rd and 97th percentiles). All 3rd and 97th percentile amniotic fluid index values were within the range of commonly used cutoffs to define oligohydramnios (< 5 cm) and polyhydramnios (> 25 cm). However, 3rd percentile values ranged between 5.9 cm at 40 weeks and 10.1 cm at 25–27 weeks, while the 97th percentile values ranged between 24.8 cm at 38 weeks and 15.7 cm at 15 weeks.

Conclusions—Sonographic amniotic fluid volume estimates vary by racial-ethnic group, but the absolute differences appear to be small and may not be clinically significant. Selected maternal characteristics and estimated fetal weight did not affect the racial-ethnic differences. Between-group differences are maximal after 35 weeks and at the extremes of the upper and lower dispersion estimates. Given the observed variability in extreme (3rd and 97th percentile) dispersion values over gestation, use of single cutoffs to define out-of-range measurements may not be clinically appropriate. These data might form a contemporary United States standard for amniotic fluid estimation using the amniotic fluid index and the single deepest pocket.

ClinicalTrials.gov Identifier for parent study: NCT00912132

Keywords

Amniotic fluid volume estimate; Amniotic fluid index; Largest vertical pocket; Single deepest pocket; Fetal growth; Estimated fetal weight; Low-risk; Ethnic; Racial

INTRODUCTION

Amniotic fluid is essential to normal fetal development, particularly the pulmonary and musculoskeletal systems; it also provides umbilical cord protection¹. Since amniotic fluid volume (AFV) abnormalities are associated with perinatal pathology, estimation of AFV is a standard part of obstetric sonography². As an indicator of fetal well-being, it is commonly used as a part of antepartum fetal surveillance as a component of both the modified and complete biophysical profile³. It is also used in the evaluation of pregnancies for complications such as premature membrane rupture, twin-twin transfusion syndrome and

fetal congenital anomalies. Well-established methods for estimating AFV include the 4-quadrant amniotic fluid index (AFI) and the single deepest pocket (SDP), both reproducible semi-quantitative techniques, although the visual subjective estimate of an experienced sonographer has also been utilized².

To date there has been no published sonographic AFV standard for U.S. women. Previously published nomograms of sonographically estimated AFV across gestation^{4–15} have been limited by retrospective, cross-sectional design or uneven representation of measurements across gestation^{4,10,14,15}, small sample size which affects precision, especially of dispersion estimates^{5,11,14}, and study populations not representative of the current diverse U.S. population^{5–8, 11–13}. Essentially all nomograms were developed from sonographers who were aware of women's clinical status, while indications for the examinations may not have been specifically for AFV estimation; both are factors which could bias the observations. Most reports also lacked simultaneous estimates of both AFI and SDP which prevent a comparison of these 2 techniques, especially at the extremes of fluid volumes. Moreover, although ultrasound technology has improved markedly in the past 2 decades there have been few recent evaluations of AFV across gestation. The possible confounding effects of selected maternal characteristics and estimated fetal size on AFV measurements have also not been well-studied^{16–19} and not included in the development of essentially all published^{4–15}. Finally, current nomograms were not developed from populations selected to have maternal characteristics associated with normal fetal growth, and reasonably, amniotic fluid production.

Our primary goal was to develop standard AFI and SDP charts for U.S. women and secondarily to assess the association of race-ethnicity with these values, while also estimating the association of other maternal characteristics and fetal weight.

MATERIALS and METHODS

This is a planned secondary analysis of the NICHD Fetal Growth Studies-Singletons, a large-scale, multi-center prospective observational cohort study whose primary goal was to develop U.S. racial-ethnic standards for fetal growth from 10 to 41 weeks' gestation²⁰. Investigators at the 12 clinical sites enrolled 2334 gravidas between July, 2009 and January, 2013, from 4 self-reported racial-ethnic groups with optimal characteristics for normal fetal growth. These characteristics included maternal age 18–40 years, body mass index 19–29.9 kg/m², and normal obstetric and medical histories. Human subjects' approval was obtained from all clinical sites and women gave informed consent prior to data collection. After enrollment, only women with uncomplicated pregnancies were retained and analyzed for the growth standard and also for this analysis (N=1737). Additional specific details about inclusion and exclusion criteria are detailed in the primary report of the parent study²⁰ along with a complete description of the cohort's design and methodology²¹.

Before consent, all participants underwent a first trimester ultrasound that confirmed a certain last menstrual period (LMP) date. The ultrasound estimate of gestation had to be between 8 + 0 weeks and 13 + 6 weeks and also match the LMP-based gestational age within 5 days for women between 8 + 0 and 10 + 6 weeks, within 6 days for those between

11 + 0 weeks and 12 + 6 weeks and within 7 days for participants between 13 + 0 and 13 + 6 weeks for continued participation in the study. With these criteria satisfied, the project gestational age was based on the menstrual date. Women were then assigned at random to one of 4 sonography schedules as shown in the box to ensure that data were available at each (± 1) week of gestation without subjecting women to weekly obstetrical ultrasounds between 16 and 26 weeks and at each week of gestation starting at 28 weeks:

Sonology

At each study sonogram, credentialed sonographers measured standard fetal biometrics used for the fetal growth standard and also measured the AFV using both the 4-quadrant AFI²² and the SDP techniques²³ using Voluson E8 machines (GE Healthcare, Milwaukee, WI) and multifrequency curvilinear transducers (real-time abdominal 4–8 MHz). Because AFV measurements began at < 20 weeks, the sonographers were trained to divide the uterus into 4 quadrants along the sagittal plane and a point half-way to the fundus¹⁰. The face of the ultrasound transducer was aligned parallel to the floor with the patient supine. Additional fetal biometric measurements were obtained and estimated fetal weight (EFW) was calculated using the measured fetal head circumference, abdominal circumference, and femoral length with a Hadlock formula²⁴.

All study protocol examinations were performed independent of any clinically-indicated scans, which also may have been performed per usual clinical practice by the managing physicians. Findings from the study protocol examinations were revealed to managing physicians in cases of severe oligohydramnios, defined as a SDP < 2 cm or an AFI < 5 cm. All images and measurement data were captured in *Viewpoint* (GE Healthcare, Milwaukee, WI) and electronically transferred to the data coordinating center. Prior to and during the trial, ultrasound quality was assessed by ante hoc training and credentialing of all site sonographers and a protocol for post hoc quality assurance that included a central review of a random sample of all scans²⁵.

Statistics

Baseline and clinical data were compared for participants by women's self-reported race-ethnicity using Chi-square or t-tests for categorical and continuous data, respectively. AFI and SDP percentiles (3rd, 5th, 10th, median, 90th, 95th, and 97th) were estimated using linear mixed models with cubic splines as fixed effects and cubic terms as random effects corresponding to gestational age. Cubic splines were used to provide a very flexible representation of the trajectories of AFI and SDP across gestational age²⁶. Three knot points were chosen for the cubic splines at gestational ages that evenly split the distributions (25th, 50th and 75th percentiles). We a priori chose the knots at the three quartile cut points based on each biomarker distribution, as this yields an equal number of measurements within each region separated by the knot points. We chose three since our experience has suggested that the underlying trajectories were rather smooth over gestational age and choosing a larger number of knots resulted in unstable trajectories. Both AFI and SDP values were log-transformed to stabilize variances across gestational age and to improve normal approximations for the error structures. Percentiles were estimated based on the assumed normal distribution of the random effects and error structure. Estimated percentile AFI and

SDP curves were first developed across gestation from the 15th to the 40th weeks of gestation for the entire population.

Because of the statistically significant racial-ethnic differences in fetal growth observed in the entire study population²⁰, we next evaluated whether AFI and SDP differed by maternal race-ethnicity (4 groups). We further controlled for the effects of selected maternal characteristics and we finally considered the potential effect of the log-transformed estimated fetal weight (EFW) at each examination. Selected maternal covariates were assessed as a group and included: age, height, weight, parity, full time employment versus student status, marital status (married, living as married versus not), insurance (private, managed versus Medicaid versus other), income, education, and infant sex (male versus female). Annual income and education were analyzed categorically: income <\$30,000; \$30,000-\$39,999; \$40,000-\$49,999; \$50,000-\$74,999; \$75,000-\$99,999; \$100,000 and education: < high school, high school or equivalent, some college or associate degree, bachelor degree versus master's or higher degree.

Differences among the race-ethnicity groups were evaluated with a global test (i.e. likelihood-ratio test) that examined whether there were any differences in the longitudinal mean fluid volume profiles across the 4 groups. These tests were conducted separately for AFI and SDP, where the global p-value was used to identify any statistically significant differences using the threshold of $p < 0.05$. If the global p-value was found to be statistically significant, we further identified gestational-age-week-specific differences using Wald tests which compared differences among race-ethnic groups at each week of gestation. The Wald tests were first conducted by comparing means across all four groups, and then by forming pairwise tests to compare differences between the racial-ethnic groups at each week of gestation.

All analyses were done with and without collective covariate adjustments (covariates listed previously). We used multiple imputations to account for missing covariate information²⁷. We empirically assessed model validity using simulation analysis to ensure unbiased percentile estimates and compared different mixed model cubic splines, cubic polynomials and second order fractional polynomials, individual-specific interpolation and smoothing methods^{28–29}. All analyses were implemented using SAS (version 9.4, SAS Institute, Inc., Cary, North Carolina) or R (version 3.1.2, <http://www.R-project.org>).

RESULTS

Due to missing AFV data, 1,719 of the 1,737 (99.6%) pregnancies included in the fetal growth standard²⁰ were included in the AFV standard analyses. The final study population included 480 non-Hispanic white (NHW), 418 non-Hispanic black (NHB), 485 Hispanic (H) and 336 Asian (A) women. Maternal characteristics are shown in Table 1. Asian women had the highest mean maternal age, and Hispanic women had the highest prepregnancy BMI and the highest rate of multiparity. The observed differences in gestational ages at the initial and final ultrasound, though statistically significant, were not clinically important. Notably, birth gestational ages were similar across the 4 groups. Marital status, family income, medical insurance and employment showed significant intergroup differences with NHW having the

highest rates of marriage, college education, high income, private insurance and full-time employment in comparison to other racial-ethnic groups of mothers.

Unadjusted overall population AFI and SDP standard nomograms by gestational week are shown in Figures 1 & 2 respectively. Median AFI increased from 15 weeks, peaked at 26 weeks, and then underwent a slight but steady decrease through 40 weeks. In contrast, median SDP steadily increased until 33 weeks, remaining relatively constant from 33 to 37 weeks, after which there was a slight decline. Unadjusted overall population median and percentile AFI and SDP values by gestational week are also presented in Tables 2 & 3 respectively. We confirmed that the variances did not vary by GA on the log-transformed scale utilized³⁰. Further, our percentiles explicitly accounted for the estimation done in the random effects models by increasing the variability accordingly.

Figure 3 is a graph that depicts the relative magnitude of median AFI and SDP weekly changes throughout gestation from 15 to 40 weeks as estimated by the weekly percent change. Note that small percent changes (near zero on the Y-axis) might not be obviously reflected in tables 2 & 3 because of rounding. For AFI, median values increased at an accelerated rate until approximately 17 weeks when the weekly increase began to slow and level off at approximately 26 weeks marking its peak. After this time, median AFI began to decrease slowly with a more pronounced decrease beginning at approximately 35 weeks. Compared to AFI, changes in the SDP demonstrated a similar overall pattern, but with a delayed timing of the changes. For example, the AFI percent change reached zero at 26 weeks compared to the initial SDP zero change at 27 weeks. However, the SDP underwent another slight increase between 27 and 33 weeks with a second stable peak between 33 and 37 weeks.

As shown in Table 2, the 5th percentile for AFI was above 7 cm until 40 weeks when it fell to 6.4 cm. The 95th percentile for AFI was always below 23 cm and it stayed between 21 and 22 cm for 11 weeks from 24 to 34 weeks. When we assessed the most extreme values for AFI, the 3rd percentile remained 6 or greater through 39 weeks falling to 5.9 cm at 40 weeks. Conversely, the 97th percentile AFI values increased over gestation attaining values of 24.7 cm at 39 weeks and 24.1 cm at 40 weeks. Depicted in Table 3, the 3rd percentile for SDP was at least 2 cm for every gestational week studied. The 97th percentile for SDP increased from 5.1 cm at 15 weeks to 8.8 cm at 39 weeks; at 40 weeks it fell slightly to 8.7 cm.

Median AFI curves (Figure 4) differed by race-ethnicity (global $P < 0.001$), with week-specific differences at 17–22 weeks' and 35–40 weeks' (all $P < 0.05$) that remained significant after adjusting for maternal characteristics and EFW (all Wald p-values < 0.05). Similarly, as depicted in Figure 5, race-ethnicity affected SDP (global $P < 0.001$), with week-specific differences at 16–21 weeks' and 36–40 weeks' (all Wald p-values < 0.05). Although statistically significant inter racial-ethnic differences were observed, the absolute median differences were generally very small. For example in the 35–40 week range the greatest difference was observed at 40 weeks where NHW had the largest (13.4 cm) and NHB the smallest (11.9 cm) unadjusted median AFI values, but the absolute difference was only 1.5

cm. In the 17–22 week range, the maximum differences among the cohorts were no more than 1.1 cm.

Graphs of median and both extreme (3rd and 97th) percentiles of AFI and SDP for each racial-ethnic group by gestational week are shown in Figures 4 & 5 respectively. For both AFI and SDP the racial-ethnic associations on the median and extreme dispersion values were most pronounced after 35 weeks, where maximum intergroup differences at the 3rd and especially the 97th percentiles were almost 5 cm by 40 weeks. Overall the 3rd percentile values demonstrated less variation in absolute AFI and SDP values compared to the 97th percentiles; NHW patients had the highest 97th percentile AFI values after 27 weeks but only after 37 weeks did their 97th percentile SDP values exceed the other groups. Conversely, NHB patients had larger 97th percentile AFI and SDP values from 16 to 25 weeks.

Adding the maternal characteristics, as described above, to the AFI and SDP models which informed figures 1–5 and tables 1–2, had no appreciable effect on the racial-ethnic differences, since the global p-values remained significant and the week-specific differences were essentially unchanged (data not shown). Similarly, additionally adjusting for EFW had no discernable effect on the observed racial-ethnic differences (data not shown), indicating that these AFI differences were not explained by previously identified racial-ethnic differences in fetal growth over gestation²¹.

COMMENT

Principal findings

We present AFI and SDP median, percentiles and graphical nomograms based on controlled data observed in a large contemporary multiracial-ethnic cohort of U.S. women with low-risk singleton gestations. Study participants underwent serial sonographic measurements of AFI and SDP from 15–40 weeks' gestation using up-to-date, high resolution ultrasound equipment. Women included in the analysis were selected initially to have characteristics that would be anticipated to support normal fetal growth and reasonably, amniotic fluid production. The population was further refined by the exclusion of pregnancy complications. We observed statistically significant differences in both AFI and SDP across the 4 racial-ethnic groups, even after adjustment for selected maternal characteristics and the sonographic estimated fetal weight. The 3rd percentile for AFI was greater than 5.0 cm and for SDP it was greater than 2.0 cm at every gestational week. Conversely, while polyhydramnios is often defined as 24 cm or SDP > 8 cm, in our cohort the 97th percentile for AFI was less than 24 cm through 35 weeks of gestation and for SDP it was less than 8.0 cm through 33 weeks of gestation. Perhaps the most pervasive observation is that the 97th percentile in normal pregnancies varies markedly across gestation: 16 cm at 15 weeks versus 24 cm after 35 weeks.

There was observed racial-ethnic variance in the 3rd percentile values notable after 35 weeks, although the absolute differences were smaller than those seen at the 97th percentile. Hispanic and NHW women had values closest to the overall mean, while NHB women had

approximately a one cm smaller value, and NHB women had a one cm greater value; this represented the largest race-ethnic differences, which was maximal at 40 weeks.

The best interpretation of the small observed differences in weekly percent changes between the AFI & SDP (figure 3) is unclear. The one week delay in the initial SDP “zero” change compared to the AFI is likely of no biologic relevance and could easily represent inherent differences in AFV estimation. Single deepest pocket is akin to a one-dimensional estimate, whereas AFI may be more analogous to a two-dimensional measurement. Thus one might not expect perfect concordance between the two estimates. As a single dimensional estimate, SDP may also be more influenced by the enlarging fetal size which would affect its estimate to a larger degree than a 4-quadrant estimate; this might explain its second (though modest increase in its peak value) between 33 and 37 weeks.

Meaning of the findings/Clinical implications

We believe that our data should not be used to establish absolute clinical thresholds which define pathologically diminished or increased amniotic fluid volumes because they were derived from a normal, referent population. Our findings of marked differences in the extremes of AFV across gestation may belie the use of a single AFV estimate to define oligohydramnios or polyhydramnios; while all AFI values at < 35 weeks were below the commonly used cutoff of 24 cm², there were marked differences in the 97th percentiles across gestation. Similarly, the 3rd percentile values varied across gestation but with a much smaller range in absolute measurement differences.

An important question is whether our observed racial-ethnic differences in amniotic fluid volume, most evident at the percentile extremes, near or at term, are clinically important. Considering the upper 97th percentile, at term, NHW women exceeded the other group values by several cm, while H and A women had the lowest measurements. These racial-ethnic differences, though not as pronounced, were also evident in the GVP. The etiology for the racial-ethnic differences in AFV is unclear, but, surprisingly, was not explained by observed racial-ethnic differences in fetal growth as estimated using sonographic fetal weight. Thus, use of race-ethnic-specific values, while feasible, might not improve the value of surveillance and might represent an unnecessary burden to implement in clinical practice.

Strengths and weaknesses

Major strengths of the study include the ability to report measured AFI and SDP medians and other percentiles in a low-risk cohort comprised of 4 racial-ethnic groups representative of the current U.S. population. Moreover, women were subsequently excluded if clinically significant pregnancy complications that were known to affect growth were discovered based on a priori criteria applied before the study results were released. Only experienced, credentialed sonographers made these measurements; AFV was a specific parameter required for credentialing. All sonograms were performed for research purposes and the findings were not used for clinical management; however, in cases of severe oligohydramnios, this was reported. This may have led to a repeat measurement and other testing or interventions by the managing providers. Regardless, the measured AFV values from that scan would have been included in our analysis.

As with any measurement protocol, interobserver variation can affect the findings; however this concept has been investigated and considered to be small^{10,32} and consistent across studies³³. Although inter-rater and intra-rater reliability for AFV was not formally tested in the Fetal Growth Study accreditation process²⁵, it was deemed excellent for the fetal biometrics. Thus we have no reason to believe that this would have been different for AFV measurement. Although interobserver variability is a well-recognized limitation to essentially all biologic research where more than one observer measures a biometric parameter, use of multiple sonographers would increase the external validity of our study compared to a single observer. Nevertheless, the variability in SDP estimation may be greater as compared to AFI³⁴ while the use of sonographic estimates to accurately diagnose oligohydramnios remain a concern¹.

Measurements were performed at perinatal centers well-known for clinical investigations; the ultrasound equipment was also standardized across the 12 clinical centers. The AFV measurement procedures were well-defined in the original study protocol, and these techniques have been well-standardized and in common clinical use for nearly 3 decades. Participants were randomly assigned to one of 4 different sonography schedules to ensure that measurements across the entire gestational range were performed and available for analysis. We utilized statistical models that optimized the utility of these repeated measures and further considered possible covariate effects beyond race-ethnicity.

Conclusion with future research implications

Although various cut-points to define abnormal AVF (i.e. oligo- or polyhydramnios) have been published, the best cut-points to identify pregnancies with increased risk of neonatal morbidity, especially in cases of isolated oligohydramnios, remain uncertain³¹. Therefore, investigators should first establish reference charts in a low risk, diverse population of patients selected to have characteristics associated with normal fetal growth and fetal urine production. The observed racial-ethnic differences could not be explained by selected maternal characteristics or estimated fetal weight. We believe that these differences should not be considered clinically relevant until further investigation demonstrates that inclusion of these differences as part of clinical management leads to measurable improvements in pregnancy outcomes.

In summary, compared to previous studies of amniotic fluid volume estimates using the AFI and GVP across gestation, we believe that the strengths of our study design, execution and analysis overcome essentially all of the limitations present in previous reports of sonographically estimated amniotic fluid volume across gestation and thus could represent a legitimate U.S. standard for sonographic amniotic fluid volume. Importantly, these values should not necessarily dictate clinical action points, but rather we suggest that they inform future research into the clinical implications and management of suspected amniotic fluid abnormalities. For example, the finding of an AFV estimate at the extreme might reasonably indicate the need for closer fetal surveillance that might include a subsequent (specialized) evaluation or the institution of more formal fetal surveillance (e.g. biophysical profile). Also given the observed variation in the dispersion extremes across gestation, use of single value

cutoffs to define out-of-range measurement estimates may not be appropriate, although this possibility will require further investigation as well.

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Condensation

Sonographic amniotic fluid volume estimates vary by gestational age and racial-ethnic group; selected maternal characteristics and estimated fetal weight did not affect the racial-ethnic differences.

AJOG at a Glance:

A. To develop a United States standard for sonographic estimation of amniotic fluid volume using the amniotic fluid index and single deepest pocket.

B. A total of 1,719 low-risk women from 4 self-reported racial-ethnic groups and with normal pregnancy outcomes, underwent serial assessments of amniotic fluid from 15–40 weeks' gestation as part of an NICHD-funded, multicenter prospective observational study. Small but statistically significant racial-ethnic differences were identified. After controlling for selected maternal characteristics and estimated fetal weight, these racial-ethnic differences persisted, but may not be clinically relevant.

C. Compared to previously developed amniotic fluid-gestational age nomograms, these data represent significant improvements in multiple aspects of study design and execution and could represent a legitimate U.S. standard.

Fig. 1.
Unadjusted amniotic fluid index (AFI) values and percentiles by weeks of gestation
(combined race-ethnicities)

Fig. 2. Unadjusted single deepest pocket (SDP) values by weeks of gestation (combined race-ethnicities).

Fig 3.
Percent weekly change in amniotic fluid index (AFI) and single deepest pocket (SDP) values

Fig 4. Unadjusted median amniotic fluid index (AFI) values and extreme (3rd and 97th) percentiles by weeks of gestation, overall and by race-ethnicity.

Fig 5. Unadjusted median single deepest pocket (SDP) values and extreme (3rd and 97th) percentiles by weeks of gestation, overall and by race-ethnicity.

Table 1.

Selected characteristics among racial-ethnic groups of NICHD Fetal Growth Study

	Non-Hispanic White n = 480	Non-Hispanic Black n = 418	Hispanic n = 485	Asian & Pacific Islander n = 336	All N = 1719	P-value
Maternal age, years - mean, $\pm$ SD	30.3 (4.3)	25.5 (5.4)	27.0 (5.4)	30.5 (4.4)	28.2 (5.4)	<.0001
Height ^a , cm - mean $\pm$ SD	165.7 (7.1)	164.4 (6.8)	160.1 (6.2)	160.5 (6.0)	162.8 (7.0)	<.0001
Weight ^{a,c} , kg - mean $\pm$ SD	63.5 (9.0)	64.8 (9.8)	62.2 (9.1)	57.0 (8.2)	62.2 (9.5)	<.0001
Pregnancy BMI ^{a,b,c} , kg/m ² - mean $\pm$ SD	23.1 (2.8)	23.9 (3.2)	24.3 (3.0)	22.2 (2.6)	23.5 (3.0)	<.0001
Parity, n (%)						<.0001
0	257 (53.5%)	205 (49.0%)	188 (38.8%)	173 (51.5%)	823 (47.9%)	
1	162 (33.8%)	135 (32.3%)	185 (38.1%)	130 (38.7%)	612 (35.6%)	
2	61 (12.7%)	78 (18.7%)	112 (23.1%)	33 (9.8%)	284 (16.5%)	
Infant sex, n (%)						0.5691
Male	260 (54.2%)	210 (50.2%)	243 (50.1%)	174 (51.8%)	887 (51.6%)	
Female	220 (45.8%)	208 (49.8%)	242 (49.9%)	162 (48.2%)	832 (48.4%)	
GA at initial AFV assessment, weeks - mean, $\pm$ SD	20.1 (2.7)	20.4 (3.5)	20.6 (3.4)	20.9 (3.2)	20.5 (3.2)	0.0042
GA at final AFV assessment, weeks - mean, $\pm$ SD	37.5 (2.0)	37.0 (2.5)	37.1 (2.5)	36.8 (3.2)	37.2 (2.5)	<.0001
GA at delivery weeks - mean, $\pm$ SD	39.6 (1.0)	39.5 (1.0)	39.6 (1.0)	39.5 (1.1)	39.5 (1.0)	0.0731
Marital status ^c , n (%)						<.0001
Not married	28 (5.8%)	215 (51.6%)	131 (27.0%)	29 (8.6%)	403 (23.5%)	
Married or living with partner	451 (94.2%)	202 (48.4%)	354 (73.0%)	307 (91.4%)	1314 (76.5%)	
Education, n (%)						<.0001
< High school	4 (0.8%)	46 (11.0%)	106 (21.9%)	18 (5.4%)	174 (10.1%)	
High school/equivalent	22 (4.6%)	118 (28.2%)	113 (23.3%)	40 (11.9%)	293 (17.0%)	
Some college/associate	88 (18.3%)	151 (36.1%)	181 (37.3%)	66 (19.6%)	486 (28.3%)	
Bachelors' degree	203 (42.3%)	65 (15.6%)	67 (13.8%)	103 (30.7%)	438 (25.5%)	
Postgraduate degree	163 (34.0%)	38 (9.1%)	18 (3.7%)	109 (32.4%)	328 (19.1%)	
Family income ^c , n(%)						<.0001

	Non-Hispanic White n = 480	Non-Hispanic Black n = 418	Hispanic n = 485	Asian & Pacific Islander n = 336	All N = 1719	P-value
<\$30,000	17 (3.7%)	175 (48.2%)	156 (38.8%)	42 (16.5%)	390 (26.3%)	
\$30,000-\$39,999	14 (3.0%)	25 (6.9%)	67 (16.7%)	16 (6.3%)	122 (8.2%)	
\$40,000-\$49,999	16 (3.5%)	45 (12.4%)	41 (10.2%)	16 (6.3%)	118 (8.0%)	
\$50,000-\$74,999	59 (12.7%)	33 (9.1%)	55 (13.7%)	32 (12.6%)	179 (12.1%)	
\$75,000-\$99,999	88 (19.0%)	38 (10.5%)	30 (7.5%)	53 (20.9%)	209 (14.1%)	
\$100,000 or more	269 (58.1%)	47 (12.9%)	53 (13.2%)	95 (37.4%)	464 (31.3%)	
Insurance, n (%)						<.0001
Other	26 (5.4%)	205 (49.0%)	293 (60.4%)	52 (15.5%)	576 (33.5%)	
Private or managed care	454 (94.6%)	213 (51.0%)	192 (39.6%)	284 (84.5%)	1143 (66.5%)	
Full-time employment/student status ^c , n (%)						<.0001
No	82 (17.1%)	104 (24.9%)	188 (38.8%)	114 (33.9%)	488 (28.4%)	
Yes	398 (82.9%)	314 (75.1%)	297 (61.2%)	222 (66.1%)	1231 (71.6%)	

^aPrepregnancy, self-reported;^bBMI = Body Mass Index, based on self-reported height and weight.^cNot included in the totals are missing data: Weight (n=4), BMI (n=15), GA at final AFV (n=1), Marital status (n=2), Income (n=237, 17 from Non-Hispanic White, 55 from Non-Hispanic Black, 83 from Hispanic, 82 from Asian & Pacific Islander).

GA=gestational age; AFV=amniotic fluid volume

Table 2.

Unadjusted population percentiles for amniotic fluid index (cm) by gestational age in normal pregnancies

Gestational age, weeks	Percentiles							Number of scans
	3rd	5th	10th	50th	90th	95th	97th	
15	6.9	7.3	7.9	10.4	13.8	14.9	15.7	66
16	7.3	7.7	8.3	10.9	14.4	15.6	16.4	113
17	7.6	8.0	8.7	11.4	15.1	16.3	17.1	177
18	8.0	8.4	9.1	12.0	15.8	17.0	17.9	222
19	8.4	8.8	9.5	12.6	16.5	17.8	18.8	228
20	8.8	9.2	10.0	13.1	17.2	18.6	19.6	218
21	9.2	9.6	10.4	13.7	17.9	19.4	20.4	219
22	9.5	10.0	10.8	14.2	18.6	20.1	21.1	207
23	9.8	10.3	11.1	14.6	19.1	20.7	21.7	170
24	10.0	10.5	11.3	14.9	19.6	21.1	22.2	207
25	10.1	10.6	11.5	15.1	19.8	21.4	22.5	201
26	10.1	10.6	11.5	15.2	20.0	21.6	22.7	218
27	10.1	10.6	11.4	15.1	20.0	21.6	22.7	227
28	9.9	10.5	11.3	15.0	19.9	21.5	22.7	379
29	9.7	10.3	11.1	14.8	19.8	21.4	22.6	353
30	9.5	10.1	10.9	14.7	19.7	21.4	22.6	388
31	9.3	9.9	10.7	14.5	19.6	21.4	22.6	347
32	9.1	9.7	10.5	14.4	19.7	21.5	22.8	356
33	8.9	9.4	10.3	14.3	19.8	21.7	23.0	407
34	8.6	9.2	10.1	14.2	19.9	21.9	23.3	385
35	8.4	8.9	9.9	14.1	20.1	22.2	23.7	423
36	8.0	8.6	9.6	13.9	20.3	22.6	24.2	435
37	7.7	8.2	9.2	13.7	20.4	22.8	24.6	431
38	7.2	7.8	8.7	13.3	20.4	22.9	24.8	421
39	6.6	7.2	8.1	12.7	20.0	22.7	24.7	315
40	5.9	6.4	7.4	11.9	19.3	22.1	24.1	61

Table 3.

Unadjusted population percentiles for single deepest pocket (cm) by gestational age in normal pregnancies.

Gestational age, weeks	Percentile							Number of scans
	3rd	5th	10th	50th	90th	95th	97th	
15	2.2	2.3	2.5	3.4	4.5	4.9	5.1	66
16	2.3	2.4	2.6	3.5	4.7	5.1	5.3	113
17	2.4	2.5	2.8	3.7	4.9	5.3	5.6	177
18	2.5	2.7	2.9	3.8	5.1	5.5	5.8	222
19	2.6	2.8	3.0	4.0	5.3	5.7	6.0	228
20	2.8	2.9	3.1	4.2	5.5	6.0	6.3	218
21	2.9	3.0	3.3	4.3	5.7	6.2	6.6	219
22	3.0	3.1	3.4	4.5	6.0	6.5	6.8	207
23	3.1	3.2	3.5	4.6	6.2	6.7	7.0	170
24	3.1	3.3	3.6	4.8	6.3	6.8	7.2	207
25	3.2	3.4	3.7	4.8	6.4	7.0	7.3	201
26	3.2	3.4	3.7	4.9	6.5	7.1	7.4	218
27	3.2	3.4	3.7	4.9	6.6	7.1	7.5	227
28	3.2	3.4	3.7	4.9	6.6	7.1	7.5	379
29	3.2	3.4	3.7	4.9	6.6	7.2	7.6	353
30	3.2	3.4	3.7	4.9	6.6	7.2	7.6	388
31	3.2	3.3	3.6	4.9	6.7	7.3	7.7	347
32	3.1	3.3	3.6	4.9	6.7	7.4	7.8	356
33	3.1	3.3	3.6	5.0	6.8	7.5	7.9	407
34	3.1	3.3	3.6	5.0	7.0	7.6	8.1	385
35	3.0	3.2	3.6	5.0	7.1	7.8	8.3	423
36	3.0	3.2	3.5	5.0	7.2	8.0	8.5	435
37	2.9	3.1	3.4	5.0	7.3	8.1	8.7	431
38	2.8	3.0	3.3	4.9	7.3	8.2	8.8	421
39	2.6	2.8	3.2	4.8	7.2	8.1	8.8	315
40	2.4	2.6	2.9	4.6	7.1	8.0	8.7	61