National Health Statistics Reports

Number 21 ■ March 1, 2010

Biological Variation of Laboratory Analytes Based on the 1999–2002 National Health and Nutrition Examination Survey

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Abstract

Objective—Biological variation consists of within-person (WP) and between-person (BP) variation. These components of biological variation are used to set analytical goals for imprecision and bias, evaluate serial changes for individual analytes, and assess the clinical utility of population-based reference intervals. Estimates of WP coefficients of variation (CV_w) and BP coefficients of variation (CV_g) for laboratory analytes were estimated from the 1999–2002 National Health and Nutrition Examination Survey (NHANES).

Methods—NHANES is a survey of the noninstitutionalized civilian U.S. population that uses a stratified, multistage probability design to collect a nationally representative sample. Between- and within-person variations were estimated for 34 laboratory analytes, including general biochemical, nutritional, and environmental analytes. Between-person variation was estimated taking into account the complex sample design of NHANES by Taylor series linearization. For WP variation, a nonrandom sample was obtained with an average of 18.8 days (range: 3–51 days) between two analyte measurements. Data outliers were excluded using Tukey's method to obtain more stable estimates of variation.

Results—The BP and WP variations were estimated on as many as 18,761 and 853 sample persons, respectively. When compared with the BP sample, the WP sample was older (mean age: 39 compared with 30 years) and had more non-Hispanic white (45% compared with 37%) and fewer Mexican-American (19% compared with 30%) persons. There was no statistically significant difference in gender proportions between the BP and WP samples. Serum sodium had the lowest CV_g (1.8%) and the lowest CV_w (1.0%). The index of individuality (CV_w/CV_g) ranged from 0.20 for blood lead to 0.76 for serum iron. The CV_g exceeded the analytical method coefficient of variation for all analytes. Within-person variation was also compared between males and females, and several analytes revealed significant differences ($p<0.01$). Serum ferritin had the greatest difference for CV_w (males, 17.9% compared with females, 28.8%).

Keywords: within-person differences • between-person differences • laboratory tests • survey

Introduction

Laboratory analytes for individuals are subject to several sources of variation, including biological, preanalytical (specimen collection), analytical (bias and imprecision), and postanalytical variation (reporting of results). Laboratory analytical bias is the closeness of an analyte result to the "true value" of the result, and the true value of a laboratory result is established by a "gold standard" method using standard reference materials. Bias is a measure of the systematic error of laboratory measurements. Precision is the repeatability of an analyte result if the same sample is tested many times, and the imprecision of an analyte is a measure of random errors. Biological variation consists of within-person (WP) and between-person (BP) variations, which are used to set analytical goals for bias and imprecision, assess serial changes in individual analytes, and gauge the clinical utility of population-based reference intervals.

The goals of imprecision and bias for a laboratory analyte differ depending on its intended use in screening, diagnosis, or monitoring the course of diseases in patients. For example, the WP variation, a component of

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imprecision, should be smaller than BP variation when monitoring serial changes of laboratory analyte values in an individual. Ideally, desirable goals for imprecision (I) and bias (B) have been related to the WP coefficient of variation (CV_w) and the BP coefficient of variation (CV_g) of laboratory analytes (1–3). Between-person variation has been studied extensively for demographic differences including age, sex, and, occasionally, race and ethnicity. The WP variation has rarely been evaluated by demographic characteristics.

Imprecision should ideally be less than one-half of the CV_w, and bias should be less than $0.25[(CV_w)^2 + (CV_g)^2]^{1/2}$ (2). The total error of a laboratory measurement reflects the underlying bias and imprecision of an analyte. The goal for total error should be less than $kI + B$, where $k = 1.65$ at $\alpha = 0.05$ (2). Analytical variation includes the imprecision and changes in bias (for example, changes in method calibration), which are usually negligible. Hence, the analytical coefficient of variation (CV_a) is estimated by the method imprecision coefficient of variation (CV_i). The total coefficient of variation (CV_t) of a laboratory analyte can be estimated assuming that all sources of error are measured at the same analyte mean and that preanalytical and postanalytical sources of variation are negligible. The CV_t is calculated as $[(CV_a)^2 + (CV_w)^2]^{1/2}$ (2).

The WP and BP variations have been reported for selected analytes from the Third National Health and Nutrition Examination Survey (NHANES III) conducted from 1988–1994 (4). In the present study, BP and WP variations for selected laboratory analytes are presented for a nationally representative sample based on the 1999–2002 National Health and Nutrition Examination Survey (NHANES). Gender differences for the WP variation are compared.

Methods and Procedures

Estimates of CV_w and CV_g for laboratory analytes were calculated from the 1999–2002 NHANES (5,6), a cross-sectional survey that collected data on the civilian noninstitutionalized U.S. population through questionnaires and medical examinations, including laboratory analytes. NHANES 1999–2002 used a stratified, multistage probability design to collect a nationally representative sample. Laboratory methods for NHANES 1999–2002, including imprecision, have been described (5,6).

The BP and WP means, standard deviations, and coefficients of variation (CVs) for 34 general biochemical, nutritional, and environmental analytes are shown in Table 1. The BP variations were estimated on 18,761 sample participants from NHANES 1999–2002. The WP variations were estimated for a convenience sample of 853 individuals based on NHANES 2000–2002 data. In NHANES 1999–2002, different age groups were selected for the various analytes and the minimum age was 1 year (5,6). The WP sample participants were recruited for a second analyte measurement. The WP participants were not selected randomly but recruited according to several criteria, including approximately equal proportions of males and females with an approximately uniform age distribution of 16–69 years. Participants also were recruited to obtain about equal numbers of Mexican-American and non-Hispanic black and white persons. The target size of the WP sample was 5% of those participants who had phlebotomy during the initial visit to the NHANES mobile examination center. The WP participants were asked to return for a second phlebotomy no sooner than 8 days after their initial blood draw. Compared with the BP sample, the WP sample was older (mean age: 39 compared with 30 years) and had more non-Hispanic white (45% compared with 37%) and fewer Mexican-American (19% compared with 30%) persons. There was no statistically significant difference in sex proportions when comparing the BP and WP samples.

The BP variation was estimated taking into account the complex design of NHANES by Taylor series linearization (7). The BP standard deviation was calculated as $(SE^2 + SD_{srs}^2)^{1/2}$, where SE is the standard error of the mean obtained from the complex design and SD_{srs}^2 is the square of the standard deviation assuming a simple random sample. The WP variation was estimated from a nonrandom, unweighted sample with a mean of 18.8 days (range: 3–51 days) between two analyte measurements. The CV_w was calculated as $[(CV_t)^2 - (CV_a)^2]^{1/2}$. The distributions of several analytes were nongaussian, and extreme outliers were excluded to obtain an approximately gaussian distribution with more stable estimates of variation. Outliers were eliminated by use of Tukey's method, which defines outliers as three interquartile ranges below the 25th percentile or above the 75th percentile (8). Male and female WP variations were compared. Ninety-five percent confidence intervals were estimated for the CV_w using software developed by Verrill (9). A likelihood ratio test was performed to determine if the CV_w for males and females for a laboratory analyte were equal (10). Statistical analyses were carried out with SAS for Windows software (SAS Institute) and SUDAAN software (Research Triangle Institute).

Results and Discussion

The BP and WP means, standard deviations, and CVs for 34 laboratory analytes are shown in Table 1. The CV_w and CV_g exceeded the laboratory CV_i for all laboratory analytes. For most laboratory analytes, the mean BP and WP analyte values were similar despite some demographic differences between the two groups. Analytical goals for imprecision and bias can be judged by use of the CV_w and CV_g. For example, the observed serum total calcium imprecision of 1.1% was less than the precision goal of one-half of CV_w (2.3%), or 1.15%. The bias for serum total calcium should ideally be $<0.25[(CV_w)^2 + (CV_g)^2]^{1/2}$, or $0.25[(0.023)^2 + (0.042)^2]^{1/2}$, or 1.2%. The total error is estimated as B + 1.65(I), or 1.2% + 1.65(1.15%), or 3.1%. Thus, the total-error serum total calcium estimated at the BP mean of 9.47 mg/dL (Table 1) was 0.29 mg/dL (9.47 mg/dL multiplied by 0.031). This is less than 1.0 mg/dL, the total error goal set by the Clinical Laboratory

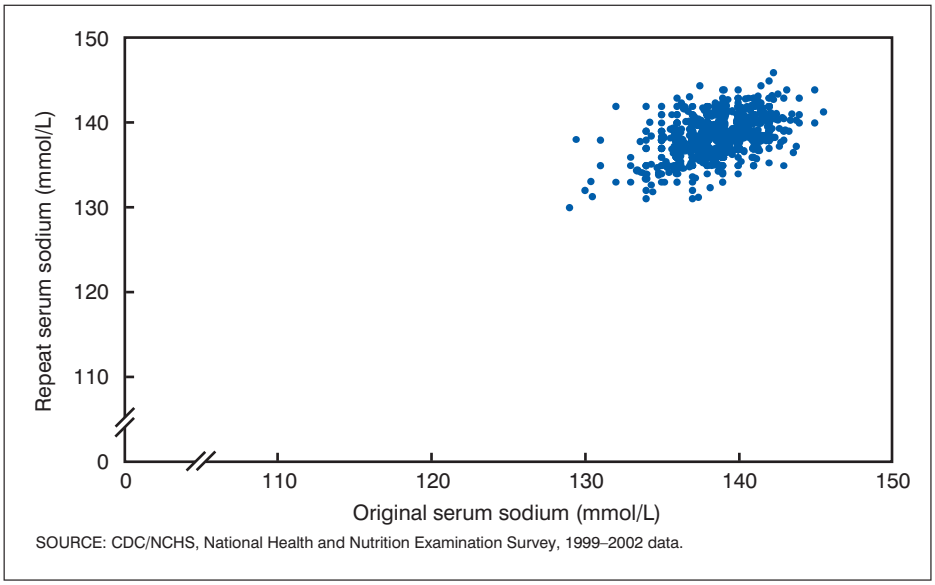

Figure 1. Original serum sodium compared with repeat serum sodium for sample persons

Improvement Amendments (CLIA) of 1988 (11).

Serum sodium had the lowest BP CV (1.8%) and lowest WP CV (1.0%), as seen in Figure 1. For NHANES III, serum sodium also had the lowest CV_g (1.6%) and the lowest CV_w (1.3%) (4). This reflects the narrow homeostatic range for sodium that the body maintains. High CV_w and CV_g values were seen for several analytes, which could result from natural population or individual variations due to sex, dietary intake, diurnal variations, disease, outlying analyte values, or relatively low analyte values. Serum iron (Figure 2) had the highest WP CV (31.9%), reflecting its large diurnal variation (12). Serum ferritin had the highest BP CV (89.8%). The BP and WP variations for most analytes were similar to corresponding variations seen in NHANES III (4).

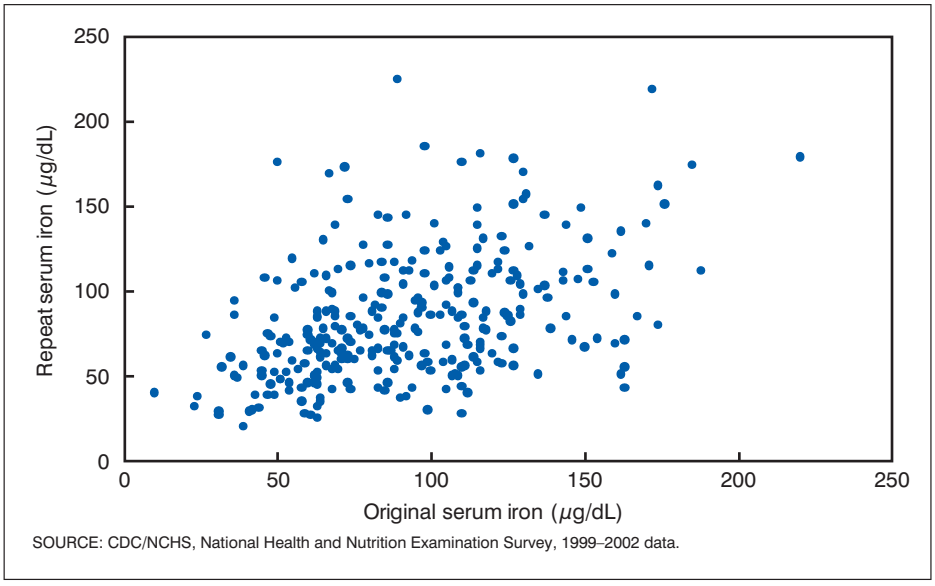

Figure 2. Original serum iron compared with repat serum iron for sample persons

The ratio of CV_w to CV_g, also known as the index of individuality, is important in determining the use of population-based reference (normal) intervals in detecting changes of disease status in individuals (13,14). When the index of individuality is low (less than 0.6), the individual results stay within a narrow range compared with the population reference interval. Hence, a low index suggests the utility of evaluating serial changes in analyte values in an individual, but population-based reference intervals would be of limited use. A high index (greater than 1.4) suggests that the population-based reference interval is appropriate when interpreting an individual's laboratory anlayte value. The index of individuality ranged from 0.20 for blood lead to 0.76 for serum iron (Table 1).

The BP and WP variations were analyzed by sex. The means, standard deviations, and CVs for 34 laboratory analytes are presented for males (Table 2) and females (Table 3). Several laboratory analytes had significant differences ($p<0.01$) in the WP CV when males and females were compared. Females had higher CV_w than males for blood lead, red blood cell folate, serum ferritin, homocysteine, methylmalonic acid, albumin, alanine aminotransferase, creatinine, gamma glutamyl transferase, and potassium. Males had higher CV_w than females for serum lactate dehydrogenase and phosphorus. For ferritin (Figure 3), the higher CV_w for females may have resulted from the lower average WP ferritin (61 ng/mL for females compared with 131 ng/mL for males), with approximately the same WP standard deviation for males and females. Lower ferritin levels in females reflect lower body iron storage, and females can have more variable ferritin due to blood loss during menstruation or increased iron utilization during pregnancy. Borel et al. also noted greater WP variation for ferritin among females compared with males (15). Feinleib et al. noted that increased WP variances could lead to overestimates of the prevalence of disease (16). The WP variance alters the BP distribution of analyte values if they are based on a single measurement.

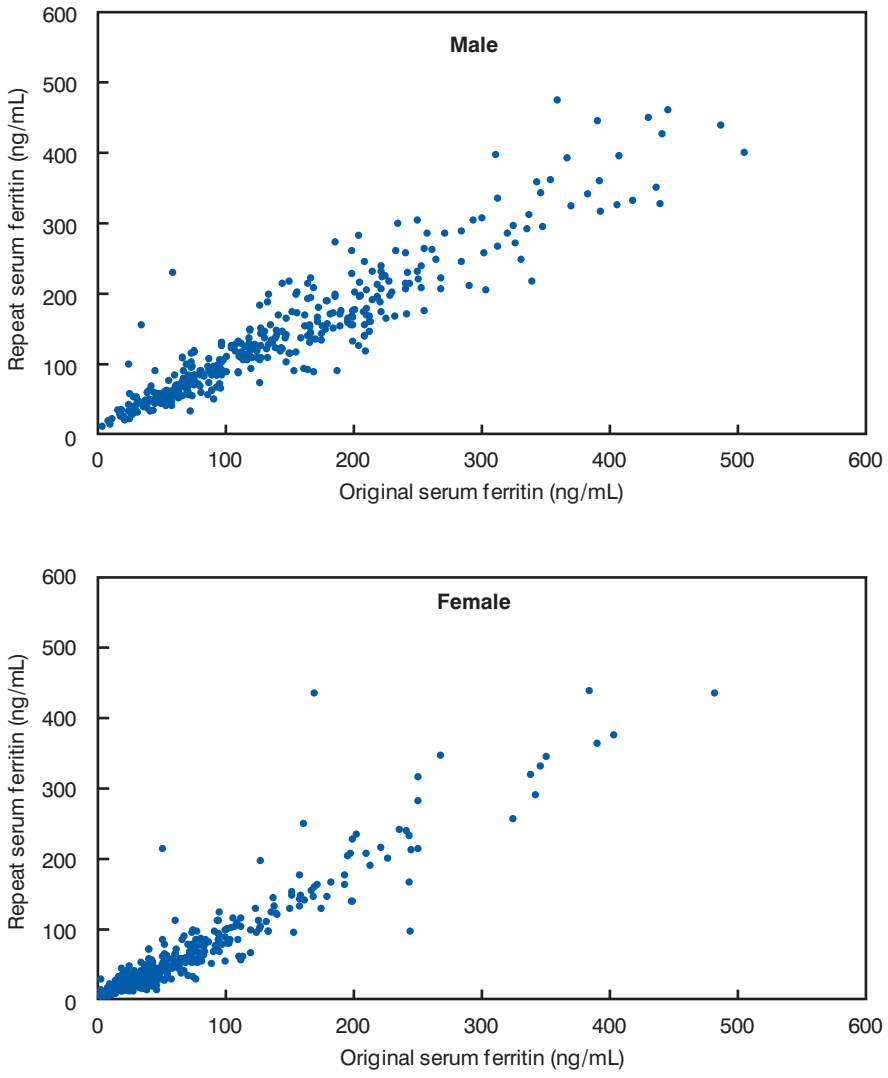

Figure 3. Original seum ferritin compared with repeat serum ferritin for males and females

Increased WP variance makes the BP distribution flatter and wider. This results in more people being above or below a cutoff value than distributions based on only single measurements from subjects.

In this study, BP and WP estimates of CVs were obtained for general biochemical, nutritional, and environmental analytes. NHANES 1999–2002 provides a better estimate of BP variation than other locally representative studies because the NHANES sample was nationally representative (1,17,18). The WP variation estimate was limited by the nonrandom, self-selected design and reflected a mean of 19 days between two measurements. In addition, the WP and BP CVs in NHANES were based on a relatively healthy sample of the population. The CV_w and CV_g would be increased in a sample of unhealthy individuals, as seen in a hospital population. The BP sample contained participants aged 1 year and over, whereas the WP sample was restricted to those aged 16–69. The estimate of CV_w could be improved by use of a stratified, multistage probability design over different time periods. Differences for CV_w and CV_g among subpopulations (sex, age, and race and ethnicity) can be further investigated using NHANES data. Additional WP and BP variation data for other laboratory analytes based on NHANES 1999–2002 will be available in the future.

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Table 1. Between-person (CV_g), within-person (CV_w), and method (CV_a) coefficients of variation and index of individuality (CV_w/CV_g)

Analyte (units)	Between-person				Within-person				Method[1]	Index[2]
	n[3]	Mean	SD	CV_g (%)	n	Mean	SD	CV_w (%)	CV_a (%)	CV_w/CV_g
Albumin (g/dL)	13,082	4.39	0.33	7.5	831	4.27	0.16	3.5	1.3	0.46
Alkaline phosphatase (U/L)	12,287	77.6	30.0	38.7	828	77.4	6.5	8.1	2.1	0.21
Alanine aminotransferase (U/L)	12,728	22.4	9.7	43.4	796	22.4	4.6	20.3	4.0	0.47
Aspartate aminotransferase (U/L)	12,757	22.7	6.2	27.1	795	22.3	3.5	15.5	3.1	0.57
Bicarbonate (mmol/L)	13,116	23.7	2.3	9.7	835	23.5	1.5	5.1	3.9	0.53
Bilirubin, total (mg/dL)	12,974	0.65	0.26	39.1	798	0.63	0.13	19.6	6.0	0.50
Blood urea nitrogen (mg/dL)	12,968	13.4	4.3	32.4	822	12.7	2.3	17.9	2.7	0.55
Calcium, total (mg/dL)	13,109	9.47	0.40	4.2	835	9.45	0.24	2.3	1.1	0.55
Chloride (mmol/L)	13,088	102.6	2.8	2.8	832	102.6	1.8	1.6	0.8	0.57
Cholesterol, total (mg/dL)	13,108	193.6	40.8	21.1	835	192.1	13.5	6.9	1.5	0.33
Creatinine (mg/dL)	13,011	0.79	0.22	27.6	823	0.80	0.06	6.7	4.6	0.24
Ferritin (ng/mL)	15,992	83.9	75.3	89.8	796	94.1	20.8	21.8	3.2	0.24
Folate, red blood cell (ng/mL RBC)	15,907	292.8	104.7	35.8	835	286.3	28.5	9.1	3.9	0.26
Folate, serum (ng/mL)	15,750	14.85	7.23	48.7	827	13.16	2.92	21.5	5.4	0.44
Gamma tocopherol (µg/dL)	14,645	226.03	115.32	51.0	265	236.04	55.35	23.2	3.4	0.45
Gamma glutamyl transferase (U/L)	12,558	22.7	12.9	56.7	797	23.6	3.9	16.2	3.0	0.29
Glucose (mg/dL)	12,552	89.1	10.5	11.7	789	88.9	6.8	7.5	1.5	0.64
Homocysteine (µmol/L)	15,880	7.508	2.786	37.1	832	7.641	0.982	12.2	4.0	0.33
Iron (µg/dL)	16,663	88.1	36.9	41.9	299	86.4	27.7	31.9	3.8	0.76
Lactate dehydrogenase (U/L)	13,070	139.9	29.8	21.3	831	135.4	12.6	8.9	2.7	0.42
Lead, blood (µg/dL)	16,521	1.82	1.17	64.4	833	1.69	0.23	12.6	4.3	0.20
Methylmalonic acid (µmol/L)	15,675	0.137	0.056	41.0	822	0.125	0.025	18.7	7.4	0.46
Phosphorus (mg/dL)	13,115	3.68	0.60	16.4	833	3.72	0.36	9.5	1.7	0.58
Potassium (mmol/L)	13,109	4.09	0.33	8.1	834	4.06	0.23	5.5	1.5	0.68
Protein, total (g/dL)	13,108	7.42	0.46	6.2	833	7.37	0.26	3.3	1.3	0.53
Protoporphyrin (µg/dL RBC)	16,592	49.6	16.3	32.9	300	51.0	5.4	9.8	4.1	0.30
Sodium (mmol/L)	13,105	139.1	2.5	1.8	834	138.6	1.7	1.0	0.8	0.55
Total iron binding capacity (µg/dL)	16,588	370.6	59.7	16.1	294	373.1	37.0	9.0	4.2	0.56
Triglycerides (mg/dL)	12,849	125.1	71.0	56.8	814	126.3	35.2	27.8	1.9	0.49
Uric acid (mg/dL)	13,115	5.33	1.46	27.4	835	5.35	0.50	9.3	1.2	0.34
Vitamin A (µg/dL)	15,784	56.05	17.37	31.0	297	55.38	6.03	10.4	3.3	0.33
Vitamin B_{12} (pg/mL)	15,736	527.4	229.8	43.6	831	497.9	74.3	14.6	2.9	0.34
Vitamin D, 25-hydroxy (ng/mL)	7,802	23.8	9.0	37.9	460	21.2	3.0	11.3	8.2	0.30
Vitamin E (µg/dL)	15,454	1,132.79	451.14	39.8	285	1,162.99	163.94	13.9	2.5	0.35

[1]Method analytical CV is the laboratory method precision assuming no method bias exists.
[2]Index of individuality.
[3]Between-person sample size for each laboratory test varied by age of participant and response rate for the test.
NOTE: CV is coefficient of variation, n is the size of the subsample, and SD is standard deviation.

Table 2. Between-person (CV_g), within-person (CV_w), and method (CV_a) coefficients of variation for males

Analyte (units)	Between-person				Within-person				Method[1]
	n[2]	Mean	SD	CV_g (%)	n	Mean	SD	CV_w (%)	CV_a (%)
Albumin (g/dL)	6,313	4.50	0.31	6.9	406	4.41	0.15	†3.22	1.3
Alkaline phosphatase (U/L)	5,651	80.6	31.0	38.4	406	79.9	6.7	8.1	2.1
Alanine aminotransferase (U/L)	6,035	25.8	10.2	39.6	380	26.1	4.9	††18.2	4.0
Aspartate aminotransferase (U/L)	6,083	24.5	6.3	25.6	376	24.4	4.0	16.0	3.1
Bicarbonate (mmol/L)	6,321	24.1	2.2	9.3	408	24.0	1.6	5.3	3.9
Bilirubin, total (mg/dL)	6,206	0.73	0.27	36.7	381	0.71	0.15	20.0	6.0
Blood urea nitrogen (mg/dL)	6,245	14.3	4.3	29.8	399	13.8	2.5	18.2	2.7
Calcium, total (mg/dL)	6,315	9.52	0.38	4.0	408	9.52	0.23	2.2	1.1
Chloride (mmol/L)	6,308	102.4	2.8	2.8	406	102.4	1.8	1.6	0.8
Cholesterol, total (mg/dL)	6,314	192.0	41.2	21.5	408	187.3	13.0	6.8	1.5
Creatinine (mg/dL)	6,246	0.89	0.20	22.4	399	0.93	0.07	††5.6	4.6
Ferritin (ng/mL)	7,624	112.3	82.8	73.7	373	130.9	23.8	††17.9	3.2
Folate, red blood cell (ng/mL RBC)	7,748	283.7	98.3	34.6	404	268.6	24.1	††8.1	3.9
Folate, serum (ng/mL)	7,686	14.13	6.74	47.7	405	12.42	2.61	20.3	5.4
Gamma tocopherol (µg/dL)	7,118	226.60	114.39	50.5	119	239.92	60.55	25.0	3.4
Gamma glutamyl transferase (U/L)	5,944	26.3	13.5	51.2	382	28.0	4.3	†15.0	3.0
Glucose (mg/dL)	6,017	90.7	10.2	11.3	380	91.0	6.6	7.1	1.5
Homocysteine (µmol/L)	7,698	8.035	2.805	34.9	400	8.440	0.971	††10.8	4.0
Iron (µg/dL)	8,144	93.9	37.0	39.4	136	94.5	30.0	31.5	3.8
Lactate dehydrogenase (U/L)	6,286	141.3	29.9	21.1	405	136.6	13.5	†9.5	2.7
Lead, blood (µg/dL)	7,970	2.13	1.25	58.7	396	1.96	0.23	††11.00	4.3
Methylmalonic acid (µmol/L)	7,598	0.140	0.056	39.7	396	0.129	0.024	†17.3	7.4
Phosphorus (mg/dL)	6,319	3.65	0.64	17.7	408	3.68	0.38	†10.3	1.7
Potassium (mmol/L)	6,315	4.15	0.33	7.9	408	4.12	0.22	†5.1	1.5
Protein, total (g/dL)	6,313	7.48	0.44	5.9	408	7.46	0.25	3.1	1.3
Protoporphyrin (µg/dL RBC)	8,182	45.2	14.0	30.8	137	45.2	5.2	10.7	4.1
Sodium (mmol/L)	6,315	139.4	2.4	1.7	407	139.1	1.7	1.0	0.8
Total iron binding capacity (µg/dL)	8,117	361.6	54.3	15.0	133	358.2	35.9	9.1	4.2
Triglycerides (mg/dL)	6,140	131.4	74.8	56.9	395	133.0	38.6	28.9	1.9
Uric acid (mg/dL)	6,318	6.04	1.30	21.5	408	6.20	0.55	8.7	1.2
Vitamin A (µg/dL)	7,679	58.85	17.39	29.5	135	59.11	6.55	10.6	3.3
Vitamin B_{12} (pg/mL)	7,676	525.1	217.8	41.5	404	507.0	73.3	14.2	2.9
Vitamin D, 25-hydroxy (ng/mL)	3,781	24.2	8.5	34.9	212	21.7	3.1	11.6	8.2
Vitamin E (µg/dL)	7,548	1,111.43	442.23	39.8	128	1,128.07	145.51	12.7	2.5

† $p < 0.01$ for likelihood ratio of CV_w for males equivalent to CV_w for females.
†† $p < 0.001$ for likelihood ratio of CV_w for males equivalent to CV_w for females.
[1]Method analytical CV is the laboratory method precision assuming no method bias exists.
[2]Between-person sample size for each laboratory test varied by age of participant and response rate for the test.

NOTE: CV is coefficient of variation, n is the size of the subsample, and SD is standard deviation.

Table 3. Between-person (CV_g), within-person (CV_w), and method (CV_a) coefficients of variation for females

Analyte (units)	Between-person				Within-person				Method[1]
	n[2]	Mean	SD	CV_g (%)	n	Mean	SD	CV_w (%)	CV_a (%)
Albumin (g/dL)	6,769	4.29	0.32	7.4	425	4.14	0.16	3.7	1.3
Alkaline phosphatase (U/L)	6,636	74.8	28.8	38.5	422	75.0	6.3	8.1	2.1
Alanine aminotransferase (U/L)	6,693	19.2	8.0	41.8	416	19.0	4.4	22.9	4.0
Aspartate aminotransferase (U/L)	6,674	21.1	5.6	26.5	419	20.4	3.1	14.8	3.1
Bicarbonate (mmol/L)	6,795	23.2	2.3	9.7	427	22.9	1.4	4.9	3.9
Bilirubin, total (mg/dL)	6,768	0.59	0.22	38.1	417	0.56	0.11	18.5	6.0
Blood urea nitrogen (mg/dL)	6,723	12.5	4.2	33.8	423	11.58	2.04	17.4	2.7
Calcium, total (mg/dL)	6,794	9.41	0.40	4.3	427	9.39	0.25	2.4	1.1
Chloride (mmol/L)	6,780	102.8	2.8	2.7	426	102.73	1.81	1.6	0.8
Cholesterol, total (mg/dL)	6,794	195.2	40.3	20.6	427	196.58	13.91	6.9	1.5
Creatinine (mg/dL)	6,765	0.69	0.19	26.8	424	0.68	0.06	8.1	4.6
Ferritin (ng/mL)	8,368	58.4	56.9	97.5	423	61.1	17.7	28.8	3.2
Folate, red blood cell (ng/mL RBC)	8,159	301.5	109.9	36.4	431	302.9	32.1	9.8	3.9
Folate, serum (ng/mL)	8,064	15.54	7.60	48.9	422	13.86	3.20	22.4	5.4
Gamma tocopherol (µg/dL)	7,527	225.49	116.20	51.5	146	232.60	50.72	21.5	3.4
Gamma glutamyl transferase (U/L)	6,614	19.5	11.4	58.4	415	19.5	3.5	17.5	3.0
Glucose (mg/dL)	6,535	87.6	10.4	11.9	409	87.1	6.9	7.8	1.5
Homocysteine (µmol/L)	8,182	7.009	2.675	38.2	432	6.897	0.993	13.8	4.0
Iron (µg/dL)	8,519	82.6	36.0	43.6	163	79.3	25.7	32.1	3.8
Lactate dehydrogenase (U/L)	6,784	138.5	29.7	21.4	426	134.2	11.6	8.2	2.7
Lead, blood (µg/dL)	8,551	1.53	1.01	66.1	437	1.45	0.22	14.5	4.3
Methylmalonic acid (µmol/L)	8,077	0.133	0.056	42.1	426	0.122	0.026	20.0	7.4
Phosphorus (mg/dL)	6,796	3.71	0.56	15.2	425	3.75	0.34	8.8	1.7
Potassium (mmol/L)	6,794	4.04	0.33	8.1	426	4.00	0.24	5.9	1.5
Protein, total (g/dL)	6,795	7.37	0.47	6.4	425	7.29	0.27	3.4	1.3
Protoporphyrin (µg/dL RBC)	8,410	53.8	17.3	32.1	163	56.2	5.6	9.1	4.1
Sodium (mmol/L)	6,790	138.8	2.5	1.8	427	138.2	1.7	1.0	0.8
Total iron binding capacity (µg/dL)	8,471	379.2	63.2	16.7	161	386.3	37.9	8.9	4.2
Triglycerides (mg/dL)	6,709	119.3	66.9	56.1	419	119.9	31.7	26.4	1.9
Uric acid (mg/dL)	6,797	4.66	1.28	27.5	427	4.55	0.45	9.9	1.2
Vitamin A (µg/dL)	8,105	53.38	16.93	31.7	162	52.05	5.56	10.2	3.3
Vitamin B_{12} (pg/mL)	8,060	529.6	240.7	45.5	427	489.4	75.2	15.1	2.9
Vitamin D, 25-hydroxy (ng/mL)	4,021	23.4	9.5	40.6	248	20.7	2.8	11.0	8.2
Vitamin E (µg/dL)	7,906	1,153.34	458.66	39.8	157	1,194.11	177.55	14.7	2.5

[1]Method analytical CV is the laboratory method precision assuming no method bias exists.
[2]Between-person sample size for each laboratory test varied by age of participant and response rate for the test.

NOTE: CV is coefficient of variation, n is the size of the subsample, and SD is standard deviation.

Suggested citation

Lacher DA, Hughes JP, Carroll MD. Biological variation of laboratory analytes based on the 1999–2002 National Health and Nutrition Examination Survey. National health statistics reports; no 21. Hyattsville, MD: National Center for Health Statistics. 2010.

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DHHS Publication No. (PHS) 2010–1250
CS209277
T35896 (03/2010)

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