



## Laboratory Procedure Manual

*Analyte:* **Ferritin**

*Matrix:* **Serum**

*Method:* **Ferritin - Hitachi 912**

*Method No.:*

*Revised:*

*as performed by:* *Inorganic Toxicology and Nutrition Branch  
Division of Laboratory Sciences  
National Center for Environmental Health, CDC*

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### **Important Information for Users**

The Centers for Disease Control and Prevention (CDC) periodically refines these laboratory methods. It is the responsibility of the user to contact the person listed on the title page of

each write-up before using the analytical method to find out whether any changes have been made and what revisions, if any, have been incorporated.

## Public Release Data Set Information

This document details the Lab Protocol for NHANES 2003-2004 data. There are two methods associated with this file. Ferritin was measured with the Bio-Rad Laboratories assay in 2003 and with the Hitachi 912 in 2004. The Bio-Rad method is listed separately on the NHANES web page under Laboratory Methods Manual folder.

A tabular list of the released analytes follows:

<b>Lab Number</b>	<b>Analyte</b>	<b>SAS Label</b>
I06_c	LBDFER	Ferritin (ng/mL)
	LBDFERSI	Ferritin (µg/L)

## 1. Summary of Test Principle and Clinical Relevance

The method principle for measurement of Ferritin is immuno-turbidimetry using Roche kits on the Hitachi 912 clinical analyzer. Latex-bound Ferritin antibodies react with the antigen in the sample to form an antigen/antibody complex. Following agglutination, this is measured turbidimetrically. Turbidity formed is proportional to the Ferritin concentration, and is measured at 700 nm (primary wavelength).

Ferritin has a molecular weight of 440 kD, depending on the iron content, and consists of a protein shell (apoferritin) that is composed of 24 subunits and an iron core containing an average of 2500 Fe<sup>3+</sup> ions (in liver and spleen ferritin).

Ferritin tends to form oligomers, and when it is present in excess in the cells of the storage organs, there is a tendency to condense in the lysosomes to form semicrystalline hemosiderin.

At least 20 isoferritins can be distinguished with the aid of isoelectric focusing. This microheterogeneity is due to the differences in the contents of the acidic H and weakly basic L subunits. The basic isoferritins are responsible for the long-term iron storage function, and are found mainly in the liver, spleen, and bone marrow. Acidic isoferritins are found mainly in the myocardium, placenta, and tumor tissue. They have lower iron content, and presumably function as intermediaries for the transfer of iron in various syntheses.

Ferritin determinations are useful in evaluating iron metabolism, and determinations at the beginning of therapy provide a baseline measurement of the iron depot level. A storage deficiency in the reticulo-endothelial system (RES) can be detected at a very early stage. Clinically, ferritin values have proved useful in the detection of prelatent iron deficiency, and provide a reliable indication of the iron reserves available for hemoglobin synthesis. A value that falls below the threshold of 20 ng/mL indicates exhaustion of iron reserves. Latent iron deficiency is defined as a fall below the 12 ng/mL ferritin threshold. The two values are diagnostic even when the blood picture is still morphologically normal. A depressed ferritin level accompanied by hypochromic, microcytic anemia, indicates manifest iron deficiency.

When abnormal distribution can be ruled out, an elevated ferritin level indicates iron overloading in the body. Elevated ferritin values are also encountered with the following tumors: acute leukemia, Hodgkin's disease and carcinoma of the lung, colon, liver, and prostate. Ferritin determinations have also proved to be of value in liver metastasis. Reasons for the elevated values could be cell necrosis, blocked erythropoiesis or increased synthesis in tumor tissue.

## 2. Safety Precautions

Consider all plasma/serum specimens potentially positive for infectious agents including HIV and the hepatitis B virus. We recommend the hepatitis B vaccination series for all analysts working with whole blood and/or plasma. Observe universal precautions; wear protective gloves, laboratory coats, and safety glasses during all steps of this method. Discard any residual sample material by autoclaving after analysis is completed. Place disposable plastic, glass, and paper (pipet tips, autosampler vials, gloves, etc.) that contact plasma/serum in a biohazard autoclave bag and keep these bags in appropriate containers until sealed and autoclaved. Wipe down all work surfaces with 10% bleach solution when work is finished. Handle acids and bases with extreme care; they are caustic and toxic. Handle organic solvents only in a well-ventilated area or, as required, under a chemical fume hood.

Reagents and solvents used in this study include those listed in Section 6. Material safety data sheets (MSDSs) for these chemicals are readily accessible as hard copies in the lab. If needed, MSDS for other chemicals can be viewed at <http://www.ilpi.com/msds/index.html> or at <http://intranet.cdc.gov/ohs>.

## 3. Computerization; Data System Management

- A. Calculation of Ferritin values are accomplished with the software on the Hitachi 912 instrument. Ferritin results are manually entered into a Microsoft Excel result file spreadsheet. After a run is complete and any additional corrections by the analyst are made, the result file (containing the patient data as well as the QC data) is electronically transferred to the appropriate analyte-specific subfolder in Q: /ITN/Nutrition Lab/Import into Access on the NCEH/DLS Local Area Network (LAN). The analyst

also gives a hardcopy of the result file to the reviewing supervisor. After the reviewing supervisor approves the final values for release by checking off the bench and blind QC values and signing the hardcopy, he/she sends an email to the computer support staff that the data has been released to be imported into the NHANES 1999+ database that is located in Microsoft Access; the computer support staff imports the data into the NHANES 1999+ database by using a macro. Data entry is verified by the computer support staff and the supervisor. Data is transmitted electronically several times weekly to Westat's ISIS computer system, and transferred from there to NCHS. Abnormal values are confirmed, and codes for missing data are entered by the analyst and are transmitted as part of the data file to the Westat ISIS computer, and are eventually forwarded to NCHS. Westat also prepares the abnormal report notifications for the NCHS Survey Physician.

- B. Files stored on the network or CDC mainframe are automatically backed up nightly by DLS LAN support staff and CDC Data Center staff, respectively. Backup of the daily data containing all raw data files and result files for each run are the responsibility of the analyst. Typically these files are backed up once a week onto a floppy disk or a CD-ROM using a CD writer.
- C. Documentation for data system maintenance is contained in printed copies of data records, as well as in "system log" files on the local hard drives used for the archival of data.

#### 4. Specimen Collection, Storage, and Handling Procedures; Criteria for Specimen Rejection

- A. Use serum or plasma collected by standard venipuncture technique. Lithium and sodium heparin plasma may be used. Do not use venoject® II Autosep® containers for blood collection.
- B. All samples may be stored for 3 days at 20–25 °C, 7 days at 2–8 °C or 4 weeks at –20 °C (if only one freeze/thaw).
- C. Centrifuge samples containing precipitate before performing the assay.
- D. A 500–µL sample of serum/plasma is preferable to allow for repeat analyses; a volume of 150 µL is required for analysis.
- E. The appropriate amount of serum/plasma is dispensed into a Nalge cryovial or other plastic screw-capped vial labeled with the participant's ID.
- F. Specimens collected in the field are frozen, and then shipped on dry ice by overnight mail. Frozen samples are stored at –70°C. Samples are stable for at least 5 years if stored at –20°C [7] and can withstand 2 freeze/thaw cycles [6].
- G. Specimens generally arrive frozen. Refrigerated samples may be used provided they are kept cold and brought promptly (within 2 hours) from the site of collection.
- H. Specimens that have been through more than two freeze-thaw cycles, have been refrigerated for more than one week, undergone hemolysis, or contain particulate matter may give inaccurate results.
- I. Specimen handling conditions are outlined in the Policies and Procedures Manual of DLS (copies are available in the Nutritional Laboratory and the electronic copy of this file is located at Q: /ITN/Nutrition Laboratory/CLIA). The protocol discusses collection and transport of specimens and the special equipment required. In general, plasma should be transported and stored at no more than –20°C. Samples thawed and refrozen less than twice are not compromised. If there is more than one analyte of interest in the specimen and it needs to be divided, the appropriate amount of blood or plasma should be transferred into a sterile Nalge cryovial labelled with the participant's ID.

#### 5. Procedures for Microscopic Examinations; Criteria for Rejection of Inadequately Prepared Slides

Not applicable for this procedure

6. Preparation of Reagents, Calibration (Standards), Controls, and All Other Materials; Equipment and Instrumentation

A. Reagent Preparation

The assay is performed exactly as outlined by the manufacturer. All reagents are supplied by Roche Diagnostics in liquid form ready to be used. If the entire reagent kit is not used in one run, store the kit at 2–8°C on the analyzer until the expiration date of the reagent is reached or the reagent has been on the analyzer for 42 days, whichever comes first?

B. Standards Preparation

0.9% NaCl is used as the zero standard and C.F.A.S protein supplied by Roche Diagnostics in liquid form is used and automatic dilution for varying concentrations is used. Calibration factors vary between kit lot numbers. Store the standards at 2–8°C until the expiration date of the kit.

C. Preparation of Quality Control Materials

(1) Roche QC pools:

Commercially prepared quality control material is purchased from Roche Diagnostics in two levels (Precinorm protein and precipath protein with values varying with each lot number). Controls are in liquid form and ready to use. Unopened controls are stable at 2–8°C until expiration date. Once opened, controls are stable for 7 days at 2–8°C. Controls should be allowed to come to room temperature before analyzing. Control values are lot specific and values of each new lot should be entered into the Hitachi 912 before analyzing a new lot number of control.

(2) CDC QC pools:

Low, Medium and high serum based QC pools are prepared and characterized in-house. Means plus range limits for all pools are established by analyzing duplicates for at least 20 consecutive runs.

The low QC pool is prepared by selecting and pooling serum that contains low levels of Ferritin (~67–96ng/mL) to represent a sample with normal Ferritin concentration.

The medium QC pool is prepared by selecting and pooling serum that contains mid- levels of Ferritin (~150–200ng/mL). The high QC pool is prepared by selecting and pooling serum that contains high levels of Ferritin (~370–500 ng/mL).

(3) Other Materials

The following materials are all provided by the manufacturer (Roche Diagnostics):

- (a) Sample trays
- (b) Sample cups (standard and micro)
- (c) Probe / electrode
- (d) Cells
- (e) Wash solutions (probe wash, basic wash, cell wash)
- (f) Hitergent
- (g) Lamp
- (h) Diluent
- (i) System Cleaning Solution
- (j) Reagent Adapters
- (k) Calibrators (2–6) and Controls (I and II)

D. Instrumentation

- (1) Roche Diagnostics Hitachi 912 system (Roche Diagnostics, Indianapolis, IN)
- (2) Daigger Vortex Genie 2 (VWR, Suwanee, GA)
- (3) Multi-tube vortexer (VWR, Suwanee, GA)

(4) Eppendorf micropipet (Brinkmann Instruments Co., Westbury, NY)

## 7. Calibration and Calibration Verification Procedures

The reagent is stable for 42 days on the analyzer or until the expiration date on the bottle of reagent is reached, whichever comes first. The calibration is stable for 28 days or whenever the lot number of reagent is changed.

The Hitachi 912 system must be recalibrated if any of the following events occur:

One or more QCs are out of specification.

- A. A new lot of reagent is started.
- B. Any dispense system component is replaced or any major maintenance is performed on the instrument to include replacing the lamp.
- C. Cells are replaced.
- D. A CALIB error occurs indicating a difference in current values from previously stored values of >20%. Check QC and if in control no recalibration is necessary.
- E. A STD?, SENS? Or CALERR flag. Error codes let you know what aspect of calibration failed. Errors should be investigated and corrected and calibration repeated.
- F. Calibration is performed by placing calibrator (C.F.A.S. Protein) and controls in the pre-assigned calibration and control locations on the inner sample wheel compartment. The calibrators are loaded onto the wheel with the saline blank (diluent) in position S18. The remaining calibrator is loaded into positions S19 (check calibration installation screen for definite calibrator locations). Instrument is programmed to do a start-up calibration; the calibrators are automatically analyzed, and the controls will be run before any patient samples are analyzed. Patient samples may be run with the calibration.

CDC participates in the College of American Pathologists' Proficiency Testing Program 3 times per year.

## 8. Procedure Operating Instructions; Calculations; Interpretation of Results

### A. Preliminaries

Allow frozen serum/plasma (patient samples) to reach ambient temperature.

Perform the required maintenance of the Hitachi 912 system (monthly, weekly, and daily).

### B. Creating an Order List

Be sure to clear all previously programmed samples from the Work list menu screen.

In the "Work Place" menu, select the beginning sequence, disk and position numbers. Select appropriate sample type, sample cup and volume types. Select routine or STAT sample and then select test to be performed on the sample and enter or scan the patient bar-coded ID number. Once you have completed programming each sample select "Accept/Next" button to program the next sample. The instrument will assign each sample a position number in sequence to the beginning number.

### C. Preparing the Run

One run is defined as one carousel (max. 50 samples per carousel). Controls are run from the inner control wheel at the beginning of the first carousel (set 1) and the end of the first carousel (set 2). The controls run at the end of the first carousel (set 2 for run 1) are also the set 1 controls for run 2. Each run must contain three levels (low, medium and high) of CDC Ferritin QC pools at the beginning of the run before patient samples are run and at the end of the designate run.

When performing small runs or confirmation (repeat) runs, all levels of CDC Ferritin QC pools must be run in duplicate.

- (1) Place empty micro sample cups onto 16 × 100 tubes in a test tube rack and pipette 150 µL of the serum samples into the sample cup. Be sure to load the samples from left to right.
- (2) For a calibration run: Pipette 500 µL of calibrator into the sample cup, and place in designated calibrator positions on the inner wheel.
- (3) For runs other than calibration run: Pipette 150 µL of all levels of control into each sample cup, and place in designated control position on the inner wheel. Pipette 150 µL of patient sample into each sample cup and place on the instrument in the order of the work list starting with position 1 and ending with position 50 for the first run.
- (4) Ensure that no air bubbles are present in the sample cups. Break a wood applicator into pieces and use them to pop the bubbles.
- (5) Ensure that the amount of reagents, diluent, and wash solutions is adequate for the amount of samples to be run. You may place more than one bottle of reagent at a time on the analyzer, however, avoid using more than one lot number of reagent for a single run.

D. Initiating a Run

**NOTE:** Be sure to archive all previous test results before starting a new run and/or be sure to change the tray number. Be sure that all sequence and tray numbers match.

- (1) For all runs, go to the start conditions screen, enter the number of the sequence you wish to start with (should correspond to your order/work list).
- (2) Select “Start up Calibration” (this has to be done to get controls and QC to run from the inner wheel).
- (3) Once all necessary items are selected on this menu, press the “Start Button” on the screen.

E. End of Assay

Once results are complete, the instrument will automatically print the results. Review all results from the “Data Review” screen, then highlight all results and select archive. This will archive all results to the database for future retrieval.

**NOTE:** Be sure to check Data Review screen before starting a new run. Make sure that all results have been archived.

F. System Maintenance

The system maintenance consists of daily, weekly, and monthly maintenance.

- (1) Daily maintenance (Section 4-29 to 4-44 of the Hitachi 912 User’s Guide Manual) should be performed at the start of each 8-hour shift, or more frequently, if necessary. It consists of performing a probe wash and clean, photometer check, cleaning and adjusting stirrers and probes and checking the printer paper supply along with checking reagent, wash and diluent volumes and reagent compartment temperatures.
- (2) Weekly maintenance (Section 4-45 to 4-47 of the Hitachi 912 User’s Guide Manual) consists of performing cell wash, cell blank and cleaning cell rinse unit nozzles and probe and stirrer rinse baths.
- (3) Monthly maintenance (Section 4-48 to 4-63 of the Hitachi 912 User’s Guide Manual) consists of replacing reaction cells, cleaning the bath and filter, cleaning sample and reagent disk compartments, cleaning ISE drain Port, cleaning refrigerator condenser filter and replacing ISE measuring cartridge.

G. Special Method Notes

- (1) The Hitachi 912 system should always be “put to sleep” when not in use.
- (2) Turn the system completely off only if you will be taking the instrument apart or when indicated by maintenance procedure or error code.

#### H. Calculations

All calculations are performed by the Hitachi 912 Software system using a machine-stored calibration curve.

#### 9. Reportable Range of Results

Maximum reportable range is dependent on the concentration of the highest standard. For the purposes of CDC reporting, we will use a reportable range of 3–780 ng/mL.

Samples with values of <15.0 ng/mL repeated using an increased sample. Samples with values of >780 ng/mL are manually diluted with 0.9% NaCl (saline) and reanalyzed using routine (normal) sample volume. The result is multiplied by the appropriate dilution factor.

No instrument flag will be generated on results that fall below the reportable lower range of the assay. In the event that a sample result falls between the lower reportable range and –99999 with no data flag, this result will be used in a calculated or compensated test regardless of where the qualitative limit is set.

#### 10. Quality Control (QC) Procedures

##### A. Blind Quality Controls

Blind QC specimens are inserted prior to the arrival of the samples in the Inorganic Toxicology and Nutrition Branch. These specimens are prepared at two levels so as to emulate the patient samples; the labels used are identical to those used for patient samples. One blind QC specimen randomly selected for concentration is included at a randomly selected location in every 20 specimens analyzed.

##### B. Bench Quality Controls

Bench QC specimens are prepared from three serum pools, which represent low, med and high levels of Ferritin in serum. These pools are prepared in the same manner as patient samples and analyzed in duplicate as part of each run.

The results from the pools are checked after each run. The system is declared “in control” if all QC results are within 2s limits and the run is accepted. If one of the two QC results is outside the 2s limits then apply rules below and reject if any condition is met - the run is then declared “out of control”:

- (1) 13s Any of the two QC results is outside the 3s limit
- (2) 22s Both QC results in the run are outside the 2s limit (same side of mean)
- (3) R4s Sequential QC results (either within the run or across runs) are outside the 2s limit on the opposite sides of the mean
- (4) 10x ten sequential QC results (across pools and across runs) are on the same side of the mean

A QC program written in SAS is available from the DLS Quality Assurance Officer and should be used to apply these rules to QC data and generate Shewhart QC charts. No results for a given analyte are to be reported from an analytical run that has been declared “out of control” for that analyte as assessed by internal (bench) QC.

The initial limits are established by analyzing pool material in 20 consecutive runs and then reevaluated quarterly. When necessary, limits are updated to include more runs.

While a study is in progress, electronic copies of the QC results from each run are stored in the analyte-specific folder on Q:/ITN/Nutrition Lab/Data handling/Import into Access. Electronic copies of the tracking of the QC results over time are stored in the analyte-specific folder on Q:/ITN/Nutrition Lab/Data handling/QC Results in Excel. A hardcopy of the QC results from each run is also kept by the analyst.

11. Remedial Action if Calibration or QC Systems Fail to Meet Acceptable Criteria

- A. Check to make sure that the hardware is functioning properly.
- B. Recalibrate the instrument.
- C. If the steps outlined above do not result in correction of the "out of control" values for QC materials, consult the supervisor for other appropriate corrective actions. Do not report analytical results for runs not in statistical control.

12. Limitations of Method; Interfering Substances and Conditions

Only one freeze/thaw cycle is recommended. Samples containing particulate matter should be centrifuged and the material removed before analysis. Results are not known to be affected by icteric, hemolyzed, or lipemic specimens.

13. Reference Ranges (Normal Values)

Ferritin reference ranges are assay-specific. The Roche Diagnostics kit specifies expected values of 30–400 ng/mL for men and 15–150 ng/mL for women.

14. Critical Call Results (Panic Values)

The collaborating agency with access to patient identifiers or the responsible medical officer is notified by FAX by the supervisor of any Ferritin result that is <15 ng/mL, which possibly represents iron deficiency. Copies of Faxes sent concerning abnormal results are kept in a notebook by the supervisor for the duration of the study. For NHANES 1999+, since data are transmitted several times weekly to the Westat ISIS computer, Westat automatically notifies the NCHS survey physician.

15. Specimen Storage and Handling during Testing

Specimens are allowed to reach room temperature during preparation. The unused portion of the patient specimen is returned to the freezer, and kept for 3 months and then discarded.

16. Alternate Methods for Performing Test of Storing Specimens if Test System Fails

If the analytical system fails, we recommend that the specimens be stored at –20°C until the analytical system is restored to functionality.

17. Test Result Reporting System; Protocol for Reporting Critical Calls (If Applicable)

The collaborating agency with access to patient identifiers or the responsible medical officer is notified by FAX by the supervisor of any Ferritin result that is <15 ng/mL, which possibly represents iron deficiency. Copies of Faxes sent concerning abnormal results are kept in a notebook by the supervisor for the duration of the study.

Test results that are not abnormal are reported to the collaborating agency at a frequency and by a method determined by the study coordinator. Generally, data from this analysis are compiled with results from other analyses and sent to the responsible person at the collaborating agency as an ASCII text file, either through electronic mail or on a diskette.

For NHANES 1999+, all data are reported electronically several times weekly to the Westat ISIS computer and then are transferred to NCHS. For some smaller studies, hard copies of a data report are sent, as well as the results in electronic format.

18. Transfer or Referral of Specimens; Procedures for Specimen Accountability and Tracking

The Microsoft Access database is used to keep records and track specimens for NHANES 1999+. Records are kept in files on Q:\ITN\Nutrition Lab on the DLS LAN.

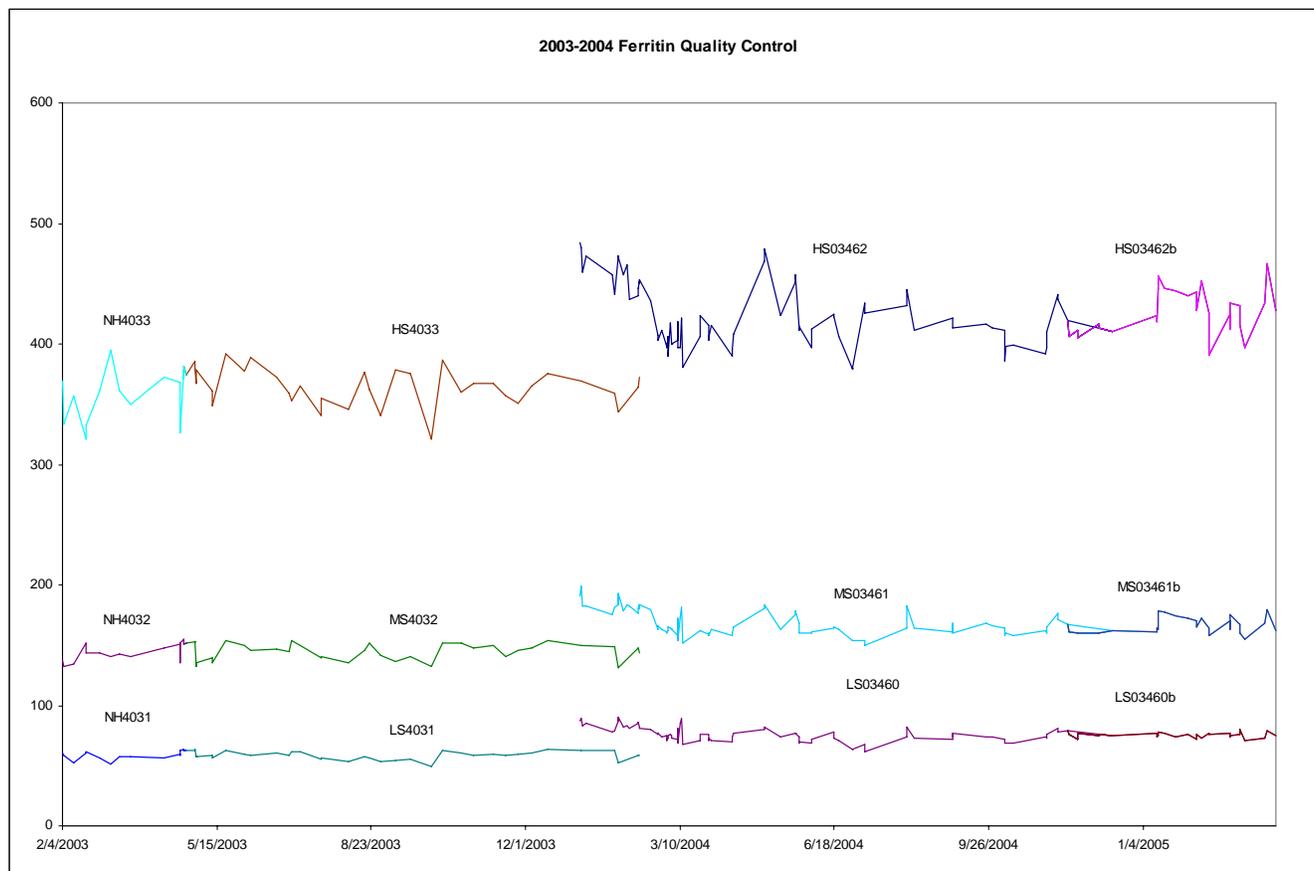
We recommend that records, including related QA/QC data, be maintained for 10 years after completion of the NHANES study. Only numerical identifiers should be used (e.g., case ID numbers). All personal identifiers should be available only to the medical supervisor or project coordinator. Residual serum from these analyses for non-NHANES studies may be discarded at the request of the principal investigator, or may be transferred to the CDC CASPIR facility for use by other investigators. Very little residual material will be available after NHANES analyses are completed, and these vials may be routinely autoclaved.

The exact procedure used to track specimens varies with each study and is specified in the study protocol or the interagency agreement for the study. Copies of these documents are kept by the supervisor. In general, when specimens are received, the specimen ID number is entered into a database and the specimens stored in a freezer at  $-70^{\circ}\text{C}$ . The specimen ID is read off of the vial by a barcode reader attached to the computer used to prepare the electronic specimen table for the analytical system. When the analyses are completed, the DIF file containing the electronic copy of the results is loaded into the database, and the analytical results are linked to the database by ID number. The analyst is responsible for keeping a notebook containing the ID numbers of specimens prepared incorrectly, those with labeling problems, and those with abnormal results, together with information about these discrepancies.

19. Summary Statistics and QC Graphs

Summary Statistics for Ferritin by Lot

Lot	N	Start Date	End Date	Mean	Standard Deviation	Coefficient of Variation
NH4031	17	2/4/2003	4/25/2003	59.1	3.7	6.3
NH4032	17	2/4/2003	4/25/2003	144.9	7.2	5.0
NH4033	17	2/4/2003	4/25/2003	357.6	22.1	6.2
LS4031	38	4/24/2003	2/13/2004	58.7	3.4	5.8
MS4032	38	4/24/2003	2/13/2004	145.3	6.8	4.7
HS4033	38	4/24/2003	2/13/2004	365.5	15.4	4.2
LS03460	91	1/5/2004	12/15/2004	76.1	6.1	8.0
MS03461	91	1/5/2004	12/15/2004	168.2	10.8	6.4
HS03462	91	1/5/2004	12/15/2004	423.1	26.6	6.3
LS03460b	28	11/16/2004	3/31/2005	75.3	2.2	3.0
MS03461b	28	11/16/2004	3/31/2005	166.1	6.7	4.0
HS03462b	28	11/16/2004	3/31/2005	426.4	18.4	4.3



## REFERENCES

1. Wick M, Pinggera W, Lehmann P, eds. *Iron Metabolism, Diagnosis and Therapy of Anemias*. 4th ed. Vienna/New York: Springer Verlag, 1999.
2. Ferguson BJ, Skikne BS, Simpson KM et al. Serum transferrin receptor distinguishes the anemia of chronic diseases from iron deficiency anemia. *J Lab Clin Med*. 1992;19:385–390.
3. Baynes RD, Skikne BS, Cook JD. Circulating transferrin receptors and assessment of iron status. *J Nutr Biochem*. 1994;5:322–330.
4. Kuiper-Kramer EPA, Huisman CMS, van Raan J, van Eijk HG. Analytical and clinical implications of soluble transferrin receptors. *Eur J Clin Chem Clin Biochem*. 1996;34:645–649.
5. Baynes RD. Assessment of iron status. *Clin Biochem*. 1996;29:209–215.
6. De Paoli Vitali E, Ricci G, Perini L, Malacarne F, Vedovato M, Guerra G, Dapporto M, Gilli P. The determination of plasma transferrin receptor as a good index of erythropoietic activity in renal anemia and after renal transplantation. *Nephron*. 1996;72:552–556.
7. Punnonen K, Irjala K, Rajamäki A. Serum transferrin receptor and its ratio to serum ferritin in the diagnosis of iron deficiency. *Blood*. 1997;89:1052–1057.
8. Suominen P, Punnonen K, Rajamäki A, Irjala K. Serum transferrin receptor and transferrin receptor-ferritin index identify healthy subjects with subclinical iron deficits. *Blood*. 1998;92:2934–2939.
9. Haecckel R, ed. *Evaluation methods in laboratory medicine*. VCH Verlagsgesellschaft, Weinheim 1993.
10. Data on file at Roche.
11. Tietz NW. *Clinical Guide to Laboratory Tests*. 3rd ed. Philadelphia, Pa: WB Saunders Co; 1995:604–607.
12. Glick M, Ryder K, Glick S. *Interferographs: User's Guide to Interferences In Clinical Chemistry Instruments*. 2nd ed. Indianapolis, IN. Science Enterprises, Inc.
13. Young DS. *Effects of Drugs on Clinical Laboratory Tests*. 4th ed. Washington, DC: AACC Press; 1995.
14. Friedman RB, et al. *Effects of Disease on Clinical Laboratory Tests*. 3rd ed. Washington, DC: AACC Press; 1997.
15. Passing H, Bablok W. A new biometrical procedure for testing the equality of measurements, from two different analytical methods. *J Clin Chem Clin Biochem*. 1983;21:709–720.
16. Bablok W et al. A General Regression Procedure for Method Transformation. *J Clin Chem Clin Biochem*. 1988;26:783–790.
17. Statland BE. *Clinical Decision Levels for Laboratory Tests*. 2nd ed. Oradell, NJ: Medical Economics Books. 1987.

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