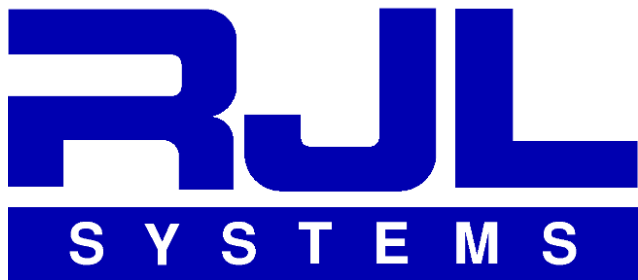


BC3

BC3
Body Composition
3.0
User's Guide



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Indications for Use

Calculation and Historical Tracking of:

- Actual Impedance
- Actual Phase Angle (PA)
- Estimated Body Fat (FAT)
- Estimated Fat Free Mass (FFM)
- Lean Dry Mass (LDM)
- Estimated Total Body Water (TBW)
- Estimated Intra-Cellular Water (ICW)
- Estimated Extra-Cellular Water (ECW)
- Estimated Basal Metabolic Rate (BMR)
- Estimated Daily Energy Expenditure (DEE)
- Actual Body Mass Index (BMI)

Intended Population:

BC is intended only for use on normally healthy adults and adolescents age 3-94. The prediction equations used by the BC software assume that the person being tested has not had either arm or leg amputated.

It is not intended to be used to diagnose, treat, or cure any disease or medical condition.

Contraindications:

No known contraindications exist.

Warnings:

The BC software provides body composition estimates based on the electrical characteristics measured by a Bioelectrical Impedance Analyzer (BIA). BIAs work by introducing an alternating current (AC) signal into the body and then measuring how that signal is affected by the body. This device should not be used on subjects with any implanted electronic devices such as pacemakers or implantable cardioverter-defibrillators (ICD)'s.

Women who use this device should not be pregnant or suspected of being pregnant. Besides increased inaccuracy of readings in this condition, the effects of measurement on the fetus are unknown.

Precautions:

Using the BC software to evaluate individuals outside of the above intended population or failing to follow the subject preparation and testing procedures detailed in the documentation for your Bioelectrical Impedance Analyzer could adversely effect the body composition estimates provided by this application.

The BC software is intended for “Over-the-Counter” distribution.

Installing BC

BC3 will run on both a Windows PC and a Macintosh computer. The system requirements are as follows:

- | | |
|-----------|---|
| PC | <ul style="list-style-type: none">• Windows XP or newer• 32 MB of RAM• 32 MB of disk space (plus space for the databases)• CD/DVD ROM Drive (for installation) |
| Macintosh | <ul style="list-style-type: none">• Snow Leopard (OS X 10.6) or newer• 32 MB of RAM• 32 MB of disk space (plus space for the databases)• CD/DVD ROM Drive (for installation) |

To install BC, you must be logged into the computer using an administrator-privileged account.

Once the disk has been inserted into the drive, your computer should either automatically start the setup program (or ask for permission to start the setup) or it should show you the contents of the disk. If you are shown the disk contents, double-click the icon for the appropriate setup wizard. (either setup-windows or setup-osx)

Your computer may ask you for permission or a password to start the setup wizard. Once it is running, you will see the following screens in the wizard:

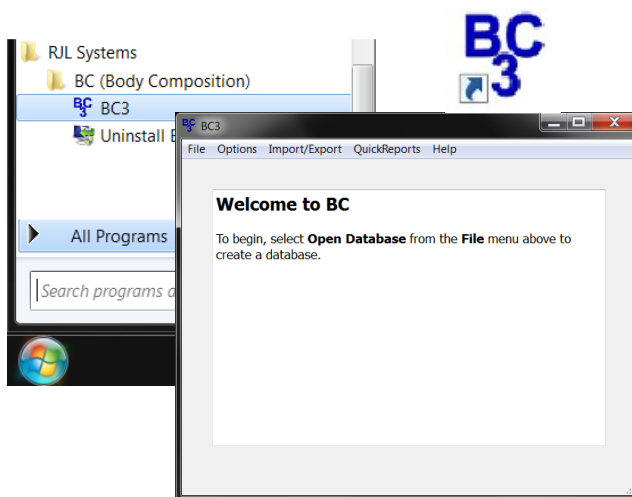
- 1) Welcome
Just click Next
- 2) License
You must accept the license before you can continue.
- 3) Component Selection
This screen basically asks, “What do you want to do?” and provides the following options:
 1. Install BC3
 2. Communication Device Drivers – Some RJL analyzers have either a USB or a 9-pin serial port which allows them to communicate with software on your computer. If your analyzer has a communication port, in order to use it, your computer must have certain device drivers installed. Installing the drivers is safe even if your analyzer does not have a communication port, so you can safely leave this selected regardless.
 3. Register Warranty – Leave this selected to submit warranty registration electronically.
- 4) Installation Directory
Tell setup where to install the program. Most people will simply accept the default.
- 5) Extra Subject Input Fields
BC will always ask for the information required to estimate body composition, but it can also be used to store and track other data not directly related to body composition analysis. If you want BC to track any of the extra information, check the box labeled “Do you want to collect extra information about each test?” and select the boxes for the information you want BC to track.
- 6) Warranty Contact Information
If you told setup to register the warranty, this screen will ask for the contact information for the person using and/or managing the RJL products. While all of the information is important, please be sure to at least provide an email address and leave the “Send me news of updates” box checked. This will ensure that if an update to BC is released, or if there is important news about any of your RJL products, you will stay informed.

- 7) Warranty Product Information
Tell us about your RJL products, where you purchased them, and when.
- 8) Ready
Just click Next.
- 9) Installing
This is where setup does all of its work. If you told setup to install the communication drivers, you may see extra windows appear briefly, or a new installer wizard may ask for permission to install them.
- 10) Finished
When you get to this screen, setup is done.

Launching BC

The icon to launch BC3 will be listed under “RJL Systems” in the Applications list on OSX, or “All Programs” in the Start Menu in Windows. The Windows setup wizard will also put a shortcut on your desktop.

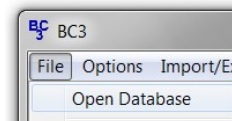
If this is your first time working with BC or you instructed BC to not automatically reopen the last database that was used, you will see the Welcome screen, which helpfully tells you how to get started.



Opening a Database

To open or create a database in BC3, select "Open Database" from the File menu.

If you have previously opened a database in BC3, the folder containing that database will be opened in the file-chooser by default. If not, the current user's documents folder is likely to be the one shown.



If you are migrating to BC3 from an older Windows-based RJL software package and want to continue working with your existing data in BC3, you must first create a database in BC3 and then import your existing legacy database. For guidance on the import process, see the section of this manual titled **Importing Data from Legacy RJL Software**.

To create a new database, start by choosing a place to store it. If more than one person will be logging into the computer to use BC or if you have a file server on the network that is backed-up on a regular basis, you might want to change this location. Otherwise, the documents folder is probably a good choice.

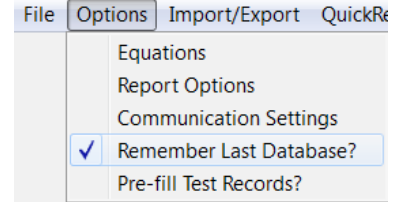
Once you are satisfied with where your database is going to be saved, you have to decide what to call it. RJL Systems recommends that you choose something generic, like "Patients". For the most part, it is a good idea to only create one database to hold all of your patient data, unless you have a very good reason to keep one group of people separate from another. If you *do* choose to create more than one database, you will need to be careful that you always make sure that you have the correct one open before you start entering data. Otherwise, you may end up with patients whose test history is spread across multiple databases.

After giving your new database a name, click Save. BC will ask to confirm that you really want to create a new database. If you want to reopen an existing BC3 database, find it, select it, and click the Save button. If you already have a database open, BC will ask to confirm that you really want to change to a different one.

Remembering the Last Database

By default, when you close and reopen BC, it will automatically reopen the last database that was used. If you only have one database with patient data, this feature allows you to begin working without requiring you to find and open your database every time you start the program.

If you do not find this behavior useful and would rather manually select your database every time, go to the options menu and uncheck "Remember last database". Now, when you start BC, you will be presented with the welcome screen.

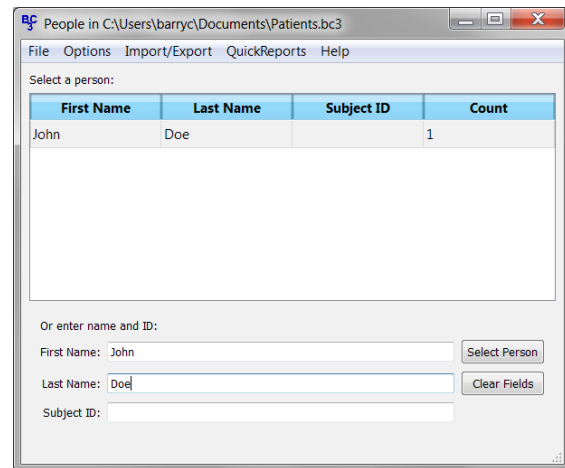


Creating a New Person

Once a database is open, you can begin entering data. If you have no people in your database, you will need to enter a new person.

BC uses a combination of first name, last name, and subject ID to identify an individual. To create a new person, fill in at least one of these three fields. If you are collecting data for a research study where the data needs to be stored anonymously, you can choose to use just the subject ID. Many practices will use just first and last name, unless they have an existing system that assigns each person a medical record number. If that is the case, you might consider using that number in the subject ID field.

Make sure that you are consistent. If you have a test for John Doe with a subject ID of 1234 and a test for John Doe with no subject ID, BC will treat those as two separate people.



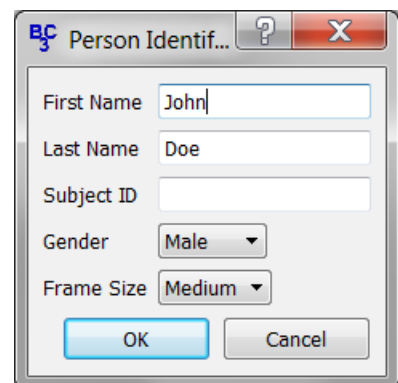
If you select a person who does not already exist in the database, you will be asked if you are sure the ID information was entered correctly, and if you want to create a new person.

The Person ID Window

If you tell BC to create a new person, you will be brought to the Person ID window. You can also get there from the test list.

Here, you can verify that the ID information is correct, and select the person's gender and frame size. These two values are here instead of with the rest of the test data because they cannot change from test to test.

Since fat and other tissues are distributed throughout the body differently for men versus women, that affects how the BIA signal interacts with the person's body. As a result, different formulas for males versus females are used to estimate the body composition. If at some point in the future, John Doe were to have a sex-change operation to become a woman, he would need to remain "male" in BC, since genetically, he's still male.



Guidance on selecting frame size can be found in the FAQ section of this manual.

Entering Test Data

On this screen, you can enter the bulk of the information about the test. At the top is the date and time that the test was performed. If you need to change that, click the change date button, make your changes, and click OK.

The BIA values, Resistance and Reactance are entered in the upper-right area of the form, and the height, weight, age, activity level, and target weight are in the list on the left. If, when BC was installed, some or all of the "extra" input fields were selected, they will appear here, below target weight. If there are more fields than will fit in the window as it is currently sized, you can scroll the list or re-size the window.

Height can be entered in centimeters, inches, or feet and inches. If you change the height units, the units on the circumference fields are automatically updated to match. The same is true for weight units and target weight.

On the right, below the BIA fields, is a box for comments. This is purely optional, but if you have any messages to give the patient, or if there are things about this test that are noteworthy, you can type them in here. If you do fill this in, you can have your comments appear on the printed report.

If you leave the target weight blank, BC will calculate one for you when you save the test.

For activity level, most people are going to be either "light" or "very light", especially if they spend the bulk of an average day sitting in a chair. Don't worry too much about getting exactly the right activity level, as it does not affect the body composition estimates. One of the additional values that BC calculates is called Basal Metabolic Rate (BMR). BMR is the number of calories that the person would burn in 24 hours spent completely at rest – basically, if they were in a coma. An estimate of how many calories the person **actually** burns in a day would be more likely to be useful, especially if you intended to assemble a diet plan. This is called a Daily Energy Expenditure, or DEE.

To get to DEE from BMR, BC needs an idea of what the person spends the bulk of their day doing. This is where the activity level comes in, and that is all that it does. For guidance on selecting activity levels, refer to the FAQ section of this manual.

If the test has not yet been saved to the database, the Delete Test button will be disabled. If you change your mind about saving a new test to the database, you can just click Close Test to go back. Otherwise, after asking you to confirm your intent, BC will remove the test from the database and take you to the Test List when you click Delete Test.

To save this test to the database, click the Save Test button. If the Target Weight field was left blank, BC will automatically fill it in using the selected method. If, after saving it, you realize that you need to make a change – say you thought 185 was a more reasonable target weight instead of the 178 that BC came up with – make the necessary change and click Save Test again. BC will warn you that the change cannot be undone.

If the test has been saved to the database, you can see the calculated results by clicking the "Go to Results" button in the lower right.

Test Results

The results screen shows all of the calculated values for the test.

In the Current Test Data table which is shown on the results tab, you see the person's current weight, body fat, fat-free mass, lean-dry mass, total body water, intracellular water, and extra-cellular water, all in pounds. (or kilograms, if appropriate)

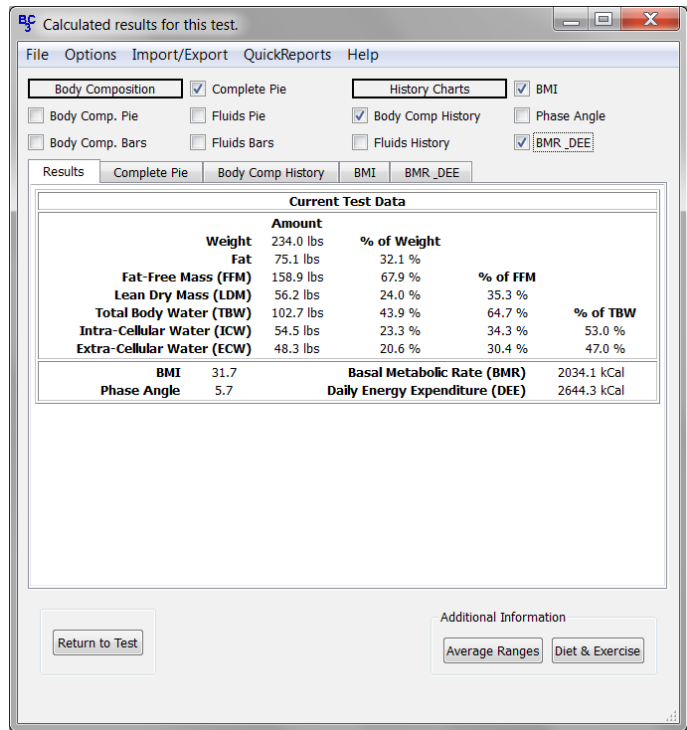
There are check-boxes at the top for all of the various charts and graphs that BC can generate. Bar charts for the body composition and fluids compartments, showing pounds, pie charts showing the breakdown of fat and fat-free mass and ICW and ECW as percentages, and a complete pie chart showing how all of the compartments relate to each other and the whole body.

There are also historical graphs for Body composition, fluids, Body Mass Index, Phase Angle, and BMR and DEE.

Each graph that gets selected is opened as a new tab in the results area. The Current Test Data table is always shown under the **Results** tab. If you end up with more tabs than will fit across the window, arrow-buttons will appear to allow you to scroll back and forth. You can also stretch the window to make more of the tabs visible.

The fact that the graphs have check-boxes is significant – it shows you which charts and graphs will appear in the report if you printed it. If all of the charts and graphs are selected when you create a report now, they would all go in it. If you change your mind about printing a graph, just uncheck it. It will disappear from the list of tabs, and will not go into the report when you print.

The Return to Test button at the bottom of the window will take you back to the test input form. The Average Ranges button leads to a screen that shows how this person compares to an average American of the same gender and 10-year age range, and the Diet and Exercise button leads to a screen that talks, predictably, about diet and exercise.

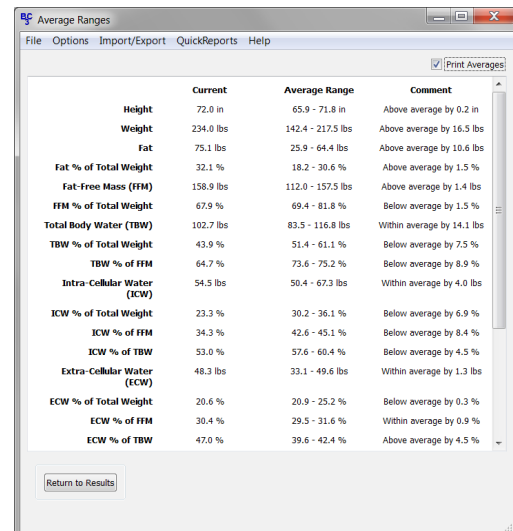


Average Ranges

From the test results, click the Average Ranges button to see the averages. The Average Ranges screen shows the person's height, weight, and all of the calculated values and their percentages where appropriate, and how they compare against the typical American of the same gender and 10-year age range. If the person is 34 year old man, the average ranges shown will be for American men aged 30-39.

All of the values and percentages that were on the test results tab are shown with their averages, so for example, you can see intracellular water represented as percentages of weight, fat-free-mass, and total body water.

To exit from the average ranges, click "Return to Results".



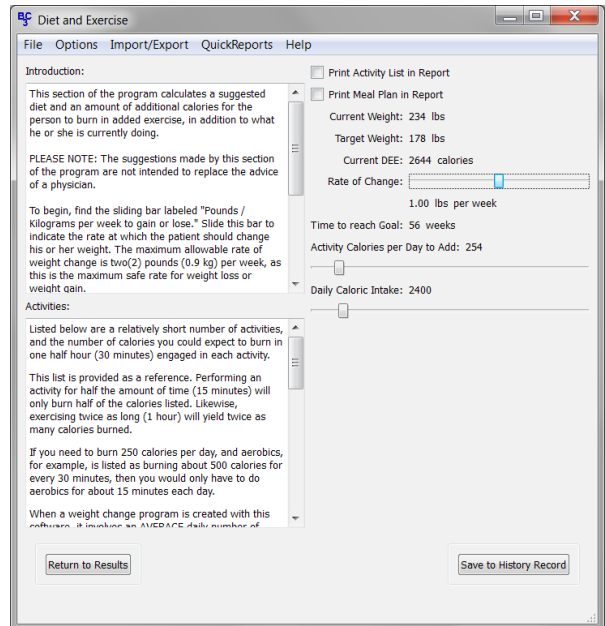
Diet & Exercise

The Diet & Exercise button on the results screen leads to the Diet and Exercise page. This page can be a helpful motivational tool to assist a person in changing their weight, and is very simple to use. Instructions for this screen are in the box in the upper-left corner.

The box in the lower left contains a brief discussion on exercise and a short list of activities and an estimate of how many calories this person would burn if he spent 30 minutes in each of the activities.

On the right, you can see the person's current weight, his target weight, and the current estimate of his DEE, which is how many calories we estimate that he is currently burning per day as a result of his average daily routine.

The first thing to do is to adjust the rate of change sliding bar. The maximum rate of change that is generally to be considered safe without being under the close supervision of a doctor is 2 pounds per week, or 0.9 kilograms, so that is the maximum rate that you can select by default. As you move the sliding bar notice the changes below. The time to reach the goal changes, as do the activity and intake sliding bars.



This tool works using the rule of thumb that one pound of body weight (0.45 kg) is roughly equivalent to 3500 calories. To lose weight, you have to maintain a caloric deficiency – that is, you have to burn more calories, on average, than you consume. So, to lose a pound a week, you need to burn 3500 calories per week or 500 calories per day more than you eat.

To lose a pound a week, you could tell your patient that you want him to do 500 extra calories worth of exercise every day on top of what he's currently doing. Or you could say "Keep doing what you're doing, but we're going to take 500 calories out of your daily diet." By default, however, BC will suggest the happy medium – it will take half of the total deficit, in this case 250 calories, and subtract it from DEE to get a recommended caloric intake, and suggest adding the other 250 in added daily exercise.

If you adjust either the intake or the activity sliding bar, the other one will automatically update at the same time to enforce whatever rate of change was selected above. This way, if the patient were to say that he has no time to do extra exercise every day, you can respond "Okay, but if you really want to lose a pound a week, we're going to have to cut the entire 500 calories out of your diet", and so on.

The button in the lower-right corner allows you to save these recommendations to the patient's record so you can check at future visits whether or not he is progressing as expected.

At the top are two check-boxes – one to add the activity list to the printed report, and one to add a sample meal plan of the selected daily number of calories – in this case, 2400. If you add the activities, they will be the ones listed here, but instead of just showing the calories per half hour, it will show multiple columns so you can see how many calories would be burned in 10, 20, 30, 60, and 120 minutes of each activity. This can really help drive home the message that if you do an exercise for twice as long, you'll burn twice the calories, etc.

Turning on the meal plan check box will add a sample diet to the report. The diet plans used by BC are based on the old food pyramid but many people still find them useful. If you want both the activity list and the meal plan to appear in the report, make sure both check-boxes are active.

When you are done, click Return to Results to go back.

The Test List

Clicking on "Close Test" from the test data form will bring you to the test list. You can also get there from the Person List by selecting somebody who already exists in the database.

All of the information that was on the Person ID form is in the upper-left corner. If any of this needs to be changed, click the Edit Identification button and return to the Person ID form.

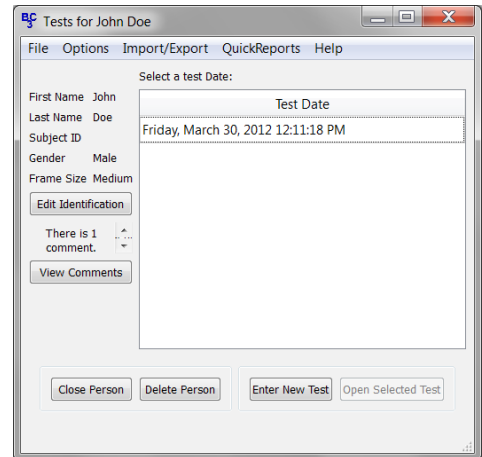
Below that is a count of how many tests for this person have comments. If comments have been made on any of the person's tests, clicking View Comments will open a new window displaying them.

The list of John Doe's saved tests is on the right. If he had more than one test in the database, they would be sorted in reverse-chronological order, or newest first.

To view an existing test, select it from the list and click Open Selected Test. To enter a new test, click "Enter New Test".

Great caution must be used with the Delete Person button, as it will completely remove the person from the database and erase all of their test records. If you do click this button, BC will ask you for confirmation before proceeding.

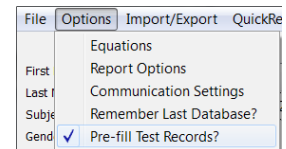
Click the Close Person button to return to the list of people.



Pre-Filling Follow-Up Tests

Every time you create a new test for someone, you have to fill in height, weight, age, resistance, and reactance. When someone comes in for a follow-up, especially if you are testing them multiple times over the course of the year, it is likely that height and age will be the same as the previous test and the weight will be only slightly different.

When you start a follow-up test for someone, if you activate "pre-fill test records" from the options menu, height, weight, and age will start out with the last test's values. This way, instead of asking "how tall are you? how old are you? etc", you can ask "Are you still...."



Creating Reports

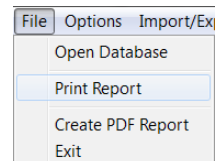
If you have a test record open, you can create a report by going to the file menu and selecting either Print Report or Create PDF Report. Print Report will bring up the standard window asking which printer to send the report to. PDF report will open a window asking what to name the report and where to save it.

In either case, the generated report will contain:

- all of the selected charts and graphs,
- the average ranges if they were selected and,
- if they were selected, the Diet and Exercise information.

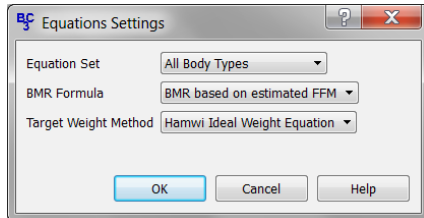
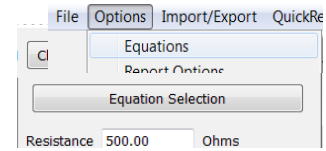
Any item on these three screens that is checked will be added to the report. Any item that is not checked will not appear in the report. If you want a report with no charts or graphs, make sure that all of the charts and graphs are turned off on the results page.

Additional settings for controlling the appearance of the reports can be found in the Report Options window, which is accessed from the Options menu.



Changing Equations

BC allows you to change which equations are being used to estimate the body composition information from the BIA results. To change the equations, either go to the options menu and select "Equations" or, from the test data form, click the Equation Selection button.



The equations used by BC to estimate body composition have been collected into groups called "Equation Sets". The top drop-down menu in this form allows you to choose which set to use. In general, most people usually choose either the "NHANES-III" or the "All Body Types" equation set for the majority of their patients. If you need guidance in selecting an equation set, the Help button will display a brief description of each one. These descriptions can also be found in the FAQ section of this manual.

Until recently, the only way to estimate Basal Metabolic Rate (BMR) without doing calorimetry was to use a formula like Harris-Benedict that relied strictly on anthropometric values like height, weight, age, and gender. In 2003, a paper was published in the American Journal of Clinical Nutrition where the researchers had developed a formula to estimate a person's BMR based on the amount of Fat-free mass. After installing, this FFM-based formula is selected by default. If you prefer, you can choose to use the Harris-Benedict formula instead.

There are also two different options for calculating a default target weight. Regardless of which option is chosen here, the value that is calculated only gets used if you leave the target weight field blank when you save a person's test.

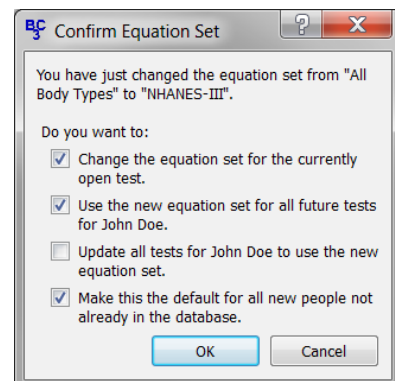
The Hamwi Ideal Weight Equation is based on height and gender. Most agencies that use the Hamwi formula will adjust the calculated value for body frame size. If a person has a "large frame", they add 10% to the result of the Hamwi formula. For a "small frame", they subtract 10%. BC automatically applies this adjustment for you. To see the unadjusted result from the Hamwi formula, select a "medium frame" for the patient. Instructions on how to determine frame size can be found in the FAQ.

The other option for calculating a default target weight is to essentially use the formula for body mass index, backwards. The BMI formula uses a relationship between height and weight to spit out a number. The higher the number, the more "overweight" a person is assumed to be, but it does not actually address how fat they are. If somebody is 5-foot 6 inches tall and 235 pounds (167.6cm and 106.6kg) then they have a BMI of 37.9, regardless of whether they are a "couch potato" or a champion bodybuilder. But if we **start** from the assumption that somebody is **already** over-fat and needs to lose weight, we can ask the question, "Assuming this person does not get any taller or shorter, how much would they weigh if their BMI was a more generally-accepted value?" By default, if you select this method, a "target BMI" of 23 is used, which is near the top of what is generally accepted as the "normal range", but you can use any value for BMI.

Regardless of which method is used, if you do not like the value that was calculated, you can change it to a value you feel is more reasonable and save the updated test.

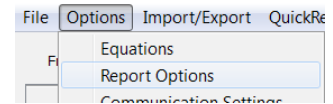
Changes made to the BMR and target weight methods will always affect every test performed and every report generated going forward.

If you changed the equation set, you can choose to apply that change to the currently open test, if you have one open. You can also choose to make it the default for that person going forward, or the default for everybody. BC can also go back and change the equation set for all of the previous tests in the database for the person. Since this last option involves changing already completed test records, it will never be active by default. You must manually select it. To commit the equation set change, click OK.



Report Options

The report options window allows you to change various aspects of the generated reports. You can get to it from the Options menu.



The report header will appear at the top of the first page of the report. Most people put the name, address, and contact information for their facility in the header, but it can be anything you want.

Below that is the report template to use. To browse for available templates, click the "..." button. "report" and "report_bigtable" are the standard layouts. You can see samples of both layouts in the back of this user manual.

The rest of the options control sections within the report layout.

Current test summary will add all the calculated values to a table in the report. Using the plain report template, this table will look exactly like the Current Test Data table on the Test Results screen.

Average Ranges controls whether the averages appear in the report. In the plain template, the averages table will look exactly like the results table, but instead of showing the calculated values, it will have the average ranges.

In the "Big Table" report, the calculated values and averages are added to one large table, which looks very much like the table shown on the Averages screen.

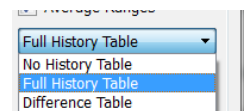
Charts and Graphs allows you to override the selection of graphs. If it is turned off, no charts or graphs will ever appear in the report, regardless of how many are selected on the Test Results screen.

If any of the person's tests have comments, turning on Comments History will add a section for them to the printed report.

The majority of equations used by BC are published in scientific journals. If you want the bibliographic citations for the equations used to appear at the end of the report, turn on References. For reference, the complete list of citations with full abstracts, or summaries, for all equation sets, is in the back of this user guide.

Activating Definitions will add a brief, 1-2 line description of each value near the end of the report.

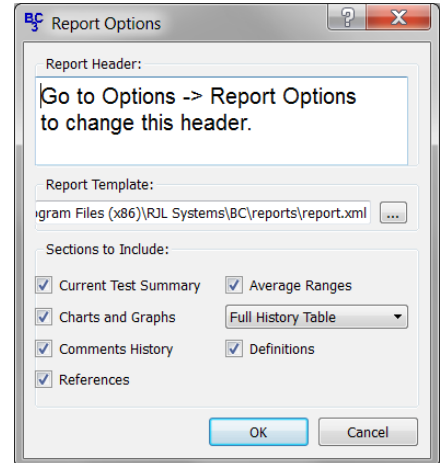
In addition to the historical graphs on the results screen, you can also add a table which shows, strictly numerically, how the person has changed over time. If you choose to add a history table, you have two choices.



The **Full History Table** will list the values for every test in the person's history in columns for easy comparison. If there are more tests than will fit across the page, BC will start a new row. This sounds fine unless you have a person with dozens of tests in the database.

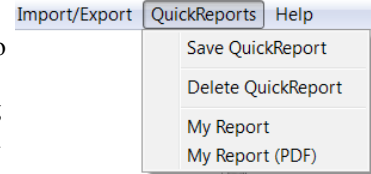
In this situation, the **Difference Table** can really simplify things. Instead of printing EVERY test, it will list out all of the values in the current test, and show you how much of a difference there is between that test and the previous one, and between that test and the person's very first test.

To make any changes to the report settings permanent, click OK.



"Quick Report" Templates

The normal process for printing a report for a test is to check the report options window to make sure that all of the settings there are as desired, then going to test results and checking all of the desired charts and graphs, verifying the average ranges option, making the appropriate selections on the diet & exercise screen, and finally going to the file menu and selecting either print report or create PDF report.



If you find you are frequently making the same selections every time you create a report, you can greatly streamline the process by using the Quick Reports feature. To create a Quick Report template, go through the process of making selections to build a report for a test in the database, like normal. But instead of going to the File menu and generating the report, go to the QuickReports menu and click Save QuickReport. Give it a descriptive name, and click OK.

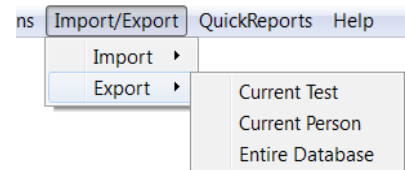
Now if you go back to the QuickReports menu, you will see two new entries. One for printing a report using your new template, and one for creating a PDF.

Now, if you select a different test, instead of building the report the way you normally would, you can go to QuickReports, select which layout you want, and the report will be built automatically.

To delete a QuickReport template, select Delete QuickReport from the menu and select the template to delete from the drop-down menu, and click OK.

Exporting Data to a Spreadsheet

BC allows you to export all or part of the currently open database as a spreadsheet. While most people will probably never have a use for this functionality, some, including researchers, will find it invaluable.

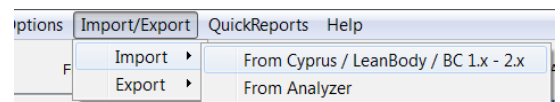


Go to the Import/Export menu and select Export. If you have a saved test open, you can choose to just export that one test to the spreadsheet. Or you can export all tests for the currently open person. Or the entire database.

Choose the appropriate amount of data to export, select a location and name for the spreadsheet, and click save. BC will save the spreadsheet in a Comma-Separated Values (CSV) format which is compatible with every spreadsheet program and most statistical analysis software packages currently available.

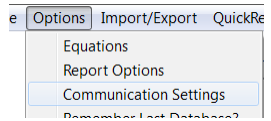
Importing Data from Legacy RJL Software

The process to import a database from Cyprus, LeanBody, or BC 1.0 – 2.1 is very simple. Start by making sure that you have a database open to import the data into. Go to the Import/Export menu and select Import and From Cyprus / LeanBody / BC 1.x – 2.x. Find the database you wish to import in the file-chooser window and click the Open button. When the import is finished, the Person List screen will be updated to reflect all of the imported records.

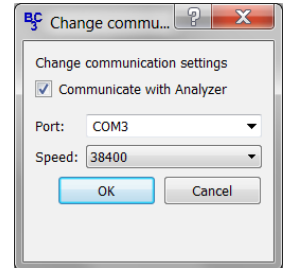


Configuring Communications

If you have an analyzer with a communications port, before it will work with BC, you will have to tell BC how to talk to it. To do this, go to the Options menu and select Communication Settings.



The first thing to do is to make sure that the "Communicate with Analyzer" box is checked. Turning this box off disables or hides certain controls to simplify the user experience and to keep you from trying to do things that are certain to not work.



The next thing to do is select which port to use. Here are some guidelines to help you choose the right port: If, when you connect your analyzer to your computer, the end of the cable that plugs into the computer has 9 pins, the port you want will probably be listed either as COM1 or COM2, on Windows.

If the analyzer plugs into a USB port on your computer, there is an easy way to find the right one. If the analyzer is currently connected to your computer's USB port, click OK to close the Communication Settings, disconnect the cable from the USB port on the computer (do not just disconnect it from the analyzer) and reopen the Communication Settings.

Click on the Ports drop-down menu and make note of which ports are listed. Because the analyzer cable is not connected, the one you want should not be listed.

Now, close the window, connect the cable to both the analyzer and your computer's USB port, and reopen Communication settings. There should be a new entry here – that is the one you want to select.

You also need to set the speed to use. Normally, the right speed to choose should be 38400, but some devices like the Quantum-III might need a slower speed, like 9600. To verify which one you should need, please refer to your analyzer's user manual. Once you have both the port and speed set, click OK.

To easily test the settings, you need to be on the test data screen, so you will need to select or create a random person and tell BC you want to enter a new test. If you have a test open that has already been saved to the database, close it and start a new one so you don't accidentally change it.

For this test to work, the subject cables do not need to be connected to the analyzer, but it does need to be turned on and connected to your computer. Once you think everything is ready, click the Get BIA Data from Analyzer button.

If you get a message about a timeout, that means that something is still not right. Double-check that your analyzer is turned on and still connected to your computer. If it is, change the speed and try again.

If it works and the subject cables are connected to either a patient or the test resistor, numbers will appear in the resistance and reactance fields. Otherwise, if the subject cables are disconnected, BC will tell you so. This still counts as a successful test of communication since BC is telling you what the analyzer sees.

Frequently Asked Questions (FAQs)

How Do I measure Frame Size?

There are two methods for measuring frame size:

- **The Precise Method**

First, measure the patient's height. Next, use a measuring tape to measure the circumference of the patient's wrist. (make sure to use the same units for both measurements. Do not mix inches and centimeters.) Divide the height by the wrist circumference. If the result is greater than 10.4, the patient has a small frame. If it is less than 9.6, the patient has a large frame. Otherwise, the patient has a medium frame.

- **The Easy Method**

A simpler, albeit less precise, method is to have the patient wrap the thumb and forefinger of one hand around the wrist of the other hand. If the thumb and forefinger overlap, the person has a small frame. If the tips of the thumb and forefinger touch, the person has a medium frame. If there is a gap, the person has a large frame.

How is Target Weight calculated?

On the subject input form, you can choose to either enter in your own value for target weight, or you can allow the software to calculate one for you. By default, the formulas that the software uses to calculate target weight are called the "Hamwi Ideal Weight Equations" which are as follows:

Hamwi Ideal Weight Equation

- **For Males**

Target weight = $106 + 6 \times ((\text{height in inches}) - 60)$

- **For Females**

Target weight = $100 + 5 \times ((\text{height in inches}) - 60)$

As you can see, the Hamwi Ideal Weight Equation is strictly based on height and gender. Most agencies that use the Hamwi formula will adjust the calculated value for body frame size. If a person has a "large frame", they add 10% to the result of the Hamwi formula. For a "small frame", they subtract 10%. BC automatically applies this adjustment for you. To see the unadjusted result from the Hamwi formula, select a "medium frame" for the patient. Instructions on how to determine frame size can be found in the FAQ.

Using a Target BMI

The other option for calculating a default target weight is to essentially use the formula for body mass index, backwards. The BMI formula uses a relationship between height and weight to spit out a number. The higher the number, the more "overweight" a person is assumed to be, but it does not actually address how fat they are. If somebody is 5-foot 6 inches tall and 235 pounds (167.6cm and 106.6kg) then they have a BMI of 37.9, regardless of whether they are a "couch potato" or a champion bodybuilder. But if we **start** from the assumption that somebody is **already** over-fat and needs to lose weight, we can ask the question, "Assuming this person does not get any taller or shorter, how much would they weigh if their BMI was a more generally-accepted value?" By default, if you select this method, a "target BMI" of 23 is used, which is near the top of what is generally accepted as the "normal range", but you can use any value for BMI.

BC also has the ability to calculate target weight based on a "desired" BMI. Using this method, the program answers the question, "How much would this person weigh if they changed their weight so their BMI was XX?" (You can specify your own "desired BMI".)

How is Basal Metabolic Rate calculated?

By default, BC will estimate BMR based on the person's current estimated FFM. In the past, BMR was calculated using the Harris-Benedict formula by default. To return to using Harris-Benedict, see the **Changing Equations** section in this manual.

What do the Activity Levels mean?

The “Daily Activity Level” describes the amount of physical work associated with the individual’s typical daily routine. It is important to select an activity level that is appropriate to the amount of activity that the person sees on ***an average daily basis***. This is used to help estimate the person’s Daily Energy Expenditure (DEE), or the number of calories the person needs to consume to keep their weight stable. Right-clicking on the Activity Level drop-down will open a new window containing the following descriptions to help choose the most appropriate activity level.

BC uses different names for the activity levels than earlier software from RJL Systems. The older names are listed as well.

- Very Light (No Exercise)
Seated and standing activities, painting, driving, laboratory work, typing, sewing, ironing, cooking, playing cards, playing a musical instrument
- Light (Some Exercise)
Walking on a level surface at 2.5 to 3 mph (4-4.8 kph), garage work, carpentry, restaurant trades, house-cleaning, child care, golf, sailing, table tennis
- Moderate (Moderate Exercise)
Walking 3.5 to 4 mph (5.6-6.5 kph), weeding and hoeing, carrying a load, cycling, skiing, tennis, dancing
- Heavy (Athletic)
Walking with a load uphill, tree felling, heavy manual digging, basketball, climbing, football, soccer
- Exceptional (Elite Athlete)
Extremely strenuous physical activity.

Again, to get a reasonable estimate of the person's DEE, it is important to choose the level that most closely reflects what the person spends the majority of the day doing – that is, 12 or more hours per day.

How do I choose which Equation Set to use?

Many researchers have developed equations for estimating people’s body composition using bioelectrical impedance analysis. Some of these equations were developed from a general population of average people. Other equations were developed from studies which only evaluated people of a certain ethnicity or people with a specific medical condition. In other studies, researchers have taken equations which were developed for one population and evaluated them for accuracy in a different group of people. In some cases, the equations worked well in the new group. In other cases, they did not.

For your convenience, we have collected some of these published equations into “sets” which BC can use to estimate body composition. Abstracts for the published papers describing the development and/or validation of the prediction equations can be found in the “References” section near the back of this manual. Here is a brief description of each of the equation sets:

- **NHANES-III**
This is a general-population equation set, and is the default upon installation. The equations for fat, FFM, and TBW were first published in 2002. A large population was used to develop these equations. (1829 people) Further, the equations were validated against records contained within the NHANES-III published data-set. People involved in either the development or validation of the equations were in the 12 - 94 year age range.

- **Obese**
A common complaint about using Bioelectrical Impedance Analysis in obese populations is that equations developed for the general population tend to under-estimate body fat in people who are obese. (BMI > 30) The equations for fat and FFM in this equation set were developed strictly from an obese population.
- **Pediatric**
Most studies that develop body composition equations strictly study adult (and/or teenage) populations. The equation for estimating FFM (and fat) in this equation set was developed from a population of children aged 9-14.
- **BIA-103**
This equation set is preserved for historical purposes. Its inclusion allows users of some of our older body composition software to upgrade to BC and continue to use the same prediction equations.
- **New Pediatric**
The study which produced the equations for FFM and fat which were selected for this equation set is somewhat more recent than the Pediatric equation set above, and it had a much larger range of ages. The children studied to develop these equations were aged 3.9-19.3.

Further, a second study was done which validated these equations in a population of overweight and obese children.
- **Native American**
These equations were developed from a study of Pima Indians.
- **Obese African American**
The FFM and fat equations in this set were validated in a study which looked at obese African American women.
- **Mexican Adults**
These equations were developed from a study of Mexican men and women.
- **HIV**
The fat and FFM equations in this set were among those examined in a study which evaluated the performance of using BIA to estimate body composition in patients with AIDS wasting. These equations were found to be among the best performers.
- **Athletic**
Just as people complain about BIA underestimating body fat in obese individuals, people tend to complain that BIA overestimates body fat in highly athletic individuals. While the equations for fat and fat-free mass in this set were originally developed for use in general populations, they were validated for use in athletic populations in at least two separate studies.
- **All Body Types**
This equation set automatically changes the equations for fat and fat-free mass to account for body type. Therefore, you should achieve decent results whether the individual being tested is athletic, obese, or run-of-the-mill average. There is one caveat with using this equation set. Because it switches which equations are used based on the input data, there can be a “disconnect” – a sudden change in the estimated fat value that does not make sense. A key point where this would occur is when somebody loses (or gains) weight to go from having a BMI of just over 30 to being just under 30. If you have a person that you expect to make this transition, you might consider using a different equation set.

I have a test that I printed using BC3 and an older RJL Systems program. The results are completely different. Why is that?

RJL Systems software uses equation sets to estimate all of the body composition values. If the two programs are set to use the same equation sets, you should get the same results. If they are using different equation sets, you are going to get different answers. To check which equation set is being used for a person's test record in BC3, look at the printed report or see the **Changing Equations** section in this manual. For help identifying the equations used in the older software package, see the user's guide for that program.

My old software used the Cyprus/FNA equations, but those aren't in the list of available options. What do I do?

The Cyprus/FNA equations were developed in a study run by St. Luke's Roosevelt University, which then filed and was granted a patent on the equations. RJL Systems had used those equations in our software under a licensing agreement with the University. That agreement expired and was not renewed. As a result, those equations are no longer available in our software. We suggest using either the "NHANES-III" or "All Body Types" equation sets, instead. If, for some reason, you feel you must continue using the Cyprus/FNA equations, you must continue using the old software.

I am looking for Body Cell Mass (BCM) and Extra-Cellular Mass (ECM) but I can not find them anywhere in the software or on the printed report. What am I doing wrong?

Nothing. BCM and ECM are not reported by BC3. In the United States, to be able to legally distribute a product, you have to first get permission from the FDA. If your product is used to measure something, part of getting permission involves listing out all of the things you are going to measure, explaining why someone would want to measure them, and prove to the FDA that you can actually measure them reliably and with a reasonable amount of accuracy. If the value you want to report is "new" to the FDA, (nobody has gotten permission to measure and report it before you) the burden of proof is much higher. At present, since the FDA has not explicitly granted permission to anybody to distribute a product that reports BCM or ECM, it is not legal for any product that reports them to be distributed in the United States.

Once a company has received permission to distribute a product from the FDA, there are rules on what kind of changes are allowed to be made before you have to go back and ask for permission again. When RJL Systems added BCM and ECM to our software in the 1990s, we thought we were obeying those rules. We discovered that we were wrong.

We have resubmitted to the FDA to ask for permission to report BCM and ECM, but it is a long process, and one which RJL Systems has little control over. We are already several years in, and there is still no end in sight.

I need to reinstall the software for my BIA but I can not find my disk. Can you send me a replacement for free or allow me to download the complete program from your website?

Sorry, but no. You must order (and pay for) a replacement disk. You can either order online from our website, or you can call and order over the phone.

Can I use BC to do statistical analysis of the tests in my database?

Statistical analysis is outside the scope of what BC was intended to do. That said, BC allows you to export data in your database to a Comma-Separated (CSV) file. Any spreadsheet or statistical analysis package should be able to read files in this format without any problems. For more information, see **Exporting data to a Spreadsheet**.

I have a report that says a patient is within the average range for pounds of FFM but BELOW the average range for FFM as a percentage. How can that be?

Go back and look at the screen images in the **Entering Test Data**, **Test Results**, and **Average Ranges** sections in this manual. The data shown for John Doe is a good example of this situation.

Since John is 234 pounds, he is above the average range for weight of 142-217.

Look at Fat-free mass, in terms of weight. at 150.4 pounds, he is within the average range of 112-157. But if you look at it as a percentage of his total body weight, 64 percent is **below** the average range of 69-81 %.

The key is that John is heavier than the average man in his 30s. So, while he may have a typical amount of fat-free mass in his body, since he is heavier, that typical amount actually represents a smaller portion of his body.

To make this a little clearer, let us try an example with numbers that are easier to visualize. Picture two people. Each person has exactly 20 pounds of body fat. But person A weighs 100 pounds, and person B weighs 120 pounds. They both have exactly the same amount of fat in their bodies, but fat makes up 1/5 of Person A's body and only 1/6 of person B. So, despite the fact that they have the same amount of fat, Person A is fatter.

So, when you are comparing a person against someone else, or a reference, it is probably best to look at the percentages. But when you are comparing that person against themselves – looking at historical changes over time, it is better to compare the weights of the compartments instead of the percentages. Say someone who is 200 pounds comes in to get a body composition test done. We find that he's got 20 pounds of fat, but he's also bloated and retaining excess water. A couple weeks later, he comes back to retest, and we find that he has lost 10 pounds of water weight and still has 20 pounds of fat. Although he hasn't changed the amount of fat in his body, because he now weighs only 190 pounds instead of 200, his body fat percentage has gone up slightly.

Why is the BMI reported by BC the same as the BMI I calculated by hand before doing the BIA test? I thought the BIA was supposed to be more accurate!

The formula for calculating Body Mass Index was published in 1832 by a man named Adolphe Quetelet. He had done numerous cross-sectional studies of how humans grow, and observed that aside from the growth spurts after birth and during puberty, “the weight increases as the square of the height.”¹ He noted that, with some variability for people getting fatter or leaner, or more or less muscular, this ratio tends to stay more or less constant for a person as they grow.

The formula for Body Mass Index (BMI)

$$BMI = \frac{\text{weight (kg)}}{(\text{height (meters)})^2} \qquad BMI = \frac{\text{weight (pounds)}}{(\text{height (inches)})^2} \times 703$$

in metric in Imperial units

It was not until the 1960s, that somebody who worked for an insurance company got the idea that, as a general rule-of-thumb, they could look at this ratio (which was originally called the “Quetelet Index”) and say “This person weighs more than he ought to,” and use that as justification to charge them more for a life insurance policy. But, like all rules-of-thumb, it only works to a point. Later studies revealed problems with the use of BMI as a gauge of fatness. The formula does not take into account body frame size, muscularity, gender, age, or ethnicity – BMI is strictly a ratio involving height and weight, and that is all it will ever be. If somebody is 5-foot 6 inches tall and 235 pounds (167.6cm and 106.6kg) then they have a BMI of 37.9 which means they are morbidly obese, regardless of whether they are a “couch potato” or a champion bodybuilder.

If want to know how fat somebody is, look at the fat estimate on their report. You should only rely on BMI if you have no other method for estimating the person's body composition. A BIA test will much more accurately reflect how much fat is in somebody's body than their BMI will.



*Dexter Jackson, Mr. Olympia 2008
Height: 5'6" Weight: 235 lbs. BMI: 37.9
Photo by: LocalFitness.com.au*

¹ Adolphe Quetelet (1796–1874)—the average man and indices of obesity. *Nephrology Dialysis Transplantation* (2008) 23(1):47-51. <http://ndt.oxfordjournals.org/content/23/1/47.full>

References

References for FAT & FFM in the NHANES-III equation set and TBW in the NHANES-III, Pediatric, and Obese equation sets:

Development of bioelectrical impedance analysis prediction equations for body composition with the use of a multicomponent model for use in epidemiologic surveys.

Sun SS, Chumlea WC, Heymsfield SB, Lukaski HC, Schoeller D, Friedl K, Kuczmarski RJ, Flegal KM, Johnson CL, Hubbard VS.
American Journal of Clinical Nutrition. (2003) 77, 331-40

Lifespan Research Center, Department of Community Health, Wright State University School of Medicine, Dayton, OH 45420, USA.
shumei.sun@wright.edu

BACKGROUND: Previous studies to develop and validate bioelectrical impedance analysis (BIA) equations to predict body composition were limited by small sample sizes, sex specificity, and reliance on reference methods that use a 2-component model. **OBJECTIVE:** This study was designed to develop sex-specific BIA equations to predict total body water (TBW) and fat-free mass (FFM) with the use of a multicomponent model for children and adults. **DESIGN:** Data from 5 centers were pooled to create a sample of 1474 whites and 355 blacks aged 12-94 y. TBW was measured by dilution, and FFM was estimated with a multicomponent model based on densitometry, isotope dilution, and dual-energy X-ray absorptiometry. **RESULTS:** The final race-combined TBW prediction equations included stature²/resistance and body weight ($R(2) = 0.84$ and 0.79 and root mean square errors of 3.8 and 2.6 L for males and females, respectively; CV: 8%) and tended to underpredict TBW in black males (2.0 L) and females (1.4 L) and to overpredict TBW in white males (0.5 L) and females (0.3 L). The race-combined FFM prediction equations contained the same independent variables ($R(2) = 0.90$ and 0.83 and root mean square errors of 3.9 and 2.9 kg for males and females, respectively; CV: approximately 6%) and tended to underpredict FFM in black males (2.1 kg) and females (1.6 kg) and to overpredict FFM in white males (0.4 kg) and females (0.3 kg). **CONCLUSION:** These equations have excellent precision and are recommended for use in epidemiologic studies to describe normal levels of body composition.

Body composition estimates from NHANES III bioelectrical impedance data.

Chumlea WC, Guo SS, Kuczmarski RJ, Flegal KM, Johnson CL, Heymsfield SB, Lukaski HC, Friedl K, Hubbard VS.
International Journal of Obesity. (2002) Dec;26(12):1596-609.

Department of Community Health, Wright State University School of Medicine, Dayton, Ohio, USA.

BACKGROUND: Body composition estimates for the US population are important in order to analyze trends in obesity, sarcopenia and other weight-related health conditions. National body composition estimates have not previously been available. **OBJECTIVE:** To use transformed bioelectrical impedance analysis (BIA) data in sex-specific, multicomponent model-derived prediction formulae, to estimate total body water (TBW), fat-free mass (FFM), total body fat (TBF), and percentage body fat (%BF) using a nationally representative sample of the US population. **DESIGN:** Anthropometric and BIA data were from the third National Health and Nutrition Examination Survey (NHANES III; 1988-1994). Sex-specific BIA prediction equations developed for this study were applied to the NHANES data, and mean values for TBW, FFM, TBF and %BF were estimated for selected age, sex and racial-ethnic groups. **RESULTS:** Among the non-Hispanic white, non-Hispanic black, and Mexican-American participants aged 12-80 y examined in NHANES III, 15 912 had data available for weight, stature and BIA resistance measures. Males had higher mean TBW and FFM than did females, regardless of age or racial-ethnic status. Mean TBW and FFM increased from the adolescent years to mid-adulthood and declined in older adult age groups. Females had higher mean TBF and %BF estimates than males at each age group. Mean TBF also increased with older age groups to approximately 60 y of age after which it decreased. **CONCLUSIONS:** These mean body composition estimates for TBW, FFM, TBF and %BF based upon NHANES III BIA data provide a descriptive reference for non-Hispanic whites, non-Hispanic blacks and Mexican Americans in the US population.

Reference for the ICW & ECW prediction equations used in all equation sets:

Accuracy of bioelectrical impedance analysis in estimation of extracellular space in healthy subjects and in fluid retention states.

Sergi G, Bussolotto M, Perini P, Calliari I, Giantin V, Ceccon A, Scanferla F, Bressan M, Moschini G, Enzi G.
Annals of Nutrition and Metabolism (1994) 38, 158-65

Department of Internal Medicine, University of Padova, Italy.

Bioelectrical impedance analysis (BIA) is a noninvasive method recently introduced for body fluid evaluation in healthy subjects. The purpose of this paper is to verify the reliability of bioelectrical measurements in extracellular water (ECW) prediction in healthy subjects and in fluid retention states. We studied 40 subjects (19 males and 21 females) aged 21-81 years; 22 were healthy subjects, 12 were affected by chronic heart failure, and 6 by chronic renal failure. In all subjects resistance (R) and reactance (Xc) at 1 and 50 kHz corrected for height were compared with ECW measured by the bromide dilution method. Our results suggested a different behavior of the current in fluid-retention states with respect to healthy subjects. ECW was best predicted by resistance at 1 kHz corrected for height, group (considered as dummy variable), weight and gender ($R^2 = 0.89$, $p < 0.001$, $SEE = 1.7$ liters). The bioelectrical impedance analysis at 50 kHz explained the 89% of ECW variability when resistance and reactance corrected for height are considered with gender group and weight ($R^2 = 0.89$, $p < 0.001$, $SEE = 1.7$ liters). In conclusion, the bioelectrical method at 1 kHz can be considered sufficiently accurate in ECW prediction in healthy subjects and in fluid retention states. Also, the bioelectrical impedance analysis at 50 kHz is useful for predicting ECW, but this role must be further investigated.

Reference for the FAT & FFM prediction equations used in the Obese equation set:

Lean body mass estimation by bioelectrical impedance analysis: a four-site cross-validation study.

Segal KR, Van Loan M, Fitzgerald PI, Hodgdon JA, Van Itallie TB.
American Journal of Clinical Nutrition (1988) 47, 7-14

Division of Pediatric Cardiology, Mount Sinai School of Medicine, New York, NY 10029.

This study validated further the bioelectrical impedance analysis (BIA) method for body composition estimation. At four laboratories densitometrically-determined lean body mass (LBMD) was compared with BIA in 1567 adults (1069 men, 498 women) aged 17-62 y and with 3-56% body fat. Equations for predicting LBMD from resistance measured by BIA, height, weight, and age were obtained for the men and women. Application of each equation to the data from the other labs yielded small reductions in R values and small increases in SEEs. Some regression coefficients differed among labs but these differences were eliminated after adjustment for differences among labs in the subjects' body fatness. All data were pooled to derive fatness-specific equations for predicting LBMD: the resulting R values ranged from 0.907 to 0.952 with SEEs of 1.97-3.03 kg. These results confirm the validity of BIA and indicate that the precision of predicting LBM from impedance can be enhanced by sex- and fatness-specific equations.

Reference for the FAT & FFM equations used in the Native American equation set:

Body composition in Pima Indians: validation of bioelectrical resistance.

Rising R, Swinburn B, Larson K, Ravussin E.
Am J Clin Nutr. 1991 Mar;53(3):594-8.

Clinical Diabetes and Nutrition Section, National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Phoenix, AZ 85016.

To assess the validity of bioelectrical resistance (BR) in an obese population, body composition was determined by both hydrostatic weighing and by BR in 156 Pima Indian volunteers representing a wide range of body weight (46.1-202.6 kg) and body composition (11-52% fat). A predictive equation was derived by use of data on height, BR, weight, age, and sex from 130 randomly selected volunteers and was applied to the remaining 26 volunteers. When compared with the manufacturer's software, the new equation increased correlations with hydrostatic weighing for predicting percent body fat and fat-free mass (FFM) from 0.70 to 0.92 and 0.79 to 0.97, respectively. The manufacturer's software underestimated FFM by 5.3 +/- 8.6 kg (P less than 0.05) when compared with FFM derived from hydrostatic weighing whereas the new equation improved the accuracy to -0.1 +/- 3.3 kg (NS). There were no significant effects of fluid intake (700 mL) or breakfast consumption on body composition as determined by BR. BR represents a simple and accurate way to assess body composition in Pima Indians with our newly derived equation.

Reference for the “Activity Factor” multiplier to calculate DEE from BMR in all equation sets:

Recommended Dietary Allowances, 10th Edition.
National Academy Press 1989-1999.
ISBN: 0-309-04633-5

This book is also available online via the National Academy Press website at:
<http://books.nap.edu/catalog/1349.html>

The relevant section on activity factors to calculate Daily Energy Expenditure from Basal Metabolic Rate is contained in pages 27-29.

References for the FAT & FFM equations used in the New Pediatric equation set:

Usefulness of bioelectric impedance and skinfold measurements in predicting fat-free mass derived from total body potassium in children.
Schaefer F, Georgi M, Zieger A, Schärer K.
Pediatr Res. 1994 May;35(5):617-24.

University Children's Hospital, Heidelberg, Germany.

Despite the increasing use of tetrapolar whole-body bioelectric impedance (BI) analysis in the assessment of body composition, its usefulness in estimating fat-free mass (FFM) has not been evaluated in comparison with conventional skinfold anthropometry in children. We therefore compared 1) the intraobserver and interobserver reproducibility of BI and skinfold measurements and the derived FFM estimates, and 2) the predictability of FFM as calculated from measurements of total body potassium (TBK) using 40K spectrometry by equations based on either BI or skinfold measurements in 112 healthy children, adolescents, and young adults aged 3.9 to 19.3 y. A best-fitting equation to predict TBK-derived FFM from BI and other potential independent predictors was developed and cross validated in two randomly selected subgroups of the study population by stepwise multiple regression analysis. Although the technical error associated with BI measurements was much smaller than that of skinfold measurements, the reproducibility of BI-derived FFM estimates (intraobserver coefficient of variation [CV], 0.39%; interobserver CV, 1.23%) was only slightly better than that of FFM estimates obtained by use of weight and two skinfold measurements (0.62% and 1.39%, respectively). The cross validation procedure yielded the following best-fitting prediction equation: $FFM = 0.65 \times (\text{height}^2/\text{impedance}) + 0.68 \times \text{age} + 0.15$ ($R^2 = 0.975$, root mean square error = 1.98 kg, CV = 5.8%, 95% limits of agreement = -11.1% to +12.4%). Conventional anthropometry, using published equations to estimate FFM from skinfolds, slightly over-estimated TBK-derived FFM, but predicted FFM with precision similar to the best-fitting equation involving BI. Previously published FFM equations incorporating BI predicted TBK-derived FFM with variable predictive precision and accuracy.

Predictive validity of four bioelectrical impedance equations in determining percent fat mass in overweight and obese children.
Cleary J, Daniells S, Okely AD, Batterham M, Nicholls J.
J Am Diet Assoc. 2008 Jan;108(1):136-9.

Department of Clinical Nutrition, Wollongong Hospital, Wollongong, NSW, Australia.

Bioelectrical impedance equations are frequently used by food and nutrition professionals to estimate percent fat mass in overweight and obese children. However, it is not known whether they are accurate for such children, as they have been primarily developed for children of varying body weights. The aim of this cross-sectional study was to evaluate the predictive validity of four previously published prediction equations developed for the pediatric population, among a sample of overweight and obese children. Thirty overweight or obese children (mean age=7.57±1.28 years) underwent measurement of fat mass, percent fat mass, and fat-free mass using dual-energy x-ray absorptiometry (DEXA) and bioelectrical impedance analysis (BIA). Impedance values from the BIA were entered into the four prediction equations and Pearson correlations used to determine the significance of associations between each of the BIA prediction equations and DEXA for percent fat mass, fat mass, and fat-free mass. For percent fat mass, paired t tests were used to assess differences between the methods and the technique of Bland and Altman was used to determine bias and error. Results showed that the mean percent fat mass as determined by DEXA for this age group was 40.79%. In comparison with other BIA prediction equations, the Schaefer equation had the closest mean value of 41.98%, and was the only equation not to significantly differ from the DEXA (P=0.121). This study suggests that the Schaefer equation is the only accurate BIA prediction equation for assessing percent fat mass in this sample of overweight and obese children from primarily white backgrounds.

Reference for the TBW equation used in the New Pediatric, Native American, Obese African American, Mexican Adult, HIV, Athletic, and All Body Types equation sets:

Is the impedance index (ht²/R) significant in predicting total body water?

Kushner RF, Schoeller DA, Fjeld CR, Danford L.

Am J Clin Nutr. 1992 Nov;56(5):835-9.

Clinical Nutrition Research Unit, University of Chicago, IL.

We investigated the general utility of bioelectrical impedance analysis (BIA) and the implications of BIA theory in populations of various ages from infancy to adulthood by developing a single impedance equation. Four subject data sets representing 62 adults, 37 prepubertal children, 44 preschool children, and 32 premature low-birth-weight neonates were combined. Subjects were randomly divided into a development group (n = 116) and a cross-validation group (n = 59). The single best predictor of total body water (TBW) was height²/resistance (ht²/R), which explained 99% of the variation in TBW (SEE = 1.67 kg). The addition of weight reduced the SEE to 1.41 kg. A significant bias was only seen in the preschool children. These results were confirmed in the cross-validation group and the best prediction formula was $TBW = 0.59 \text{ ht}^2/R + 0.065 \text{ wt} + 0.04$. We conclude that the impedance index (ht²/R) is a significant predictor of TBW and that there is some improvement in prediction of TBW by inclusion of a weight term.

References for the FFM equation used in the Mexican Adult equation set:

Body fat measurement by bioelectrical impedance and air displacement plethysmography: a cross-validation study to design bioelectrical impedance equations in Mexican adults.

Macias N, Alemán-Mateo H, Esparza-Romero J, Valencia ME.

Nutr J. 2007 Aug 15;6:18.

Centro de Investigación en Nutrición y Salud, Instituto Nacional de Salud Pública. Universidad 655, Santa Maria Ahuacatitlan, CP 62508, Cuernavaca, México. nmacias@insp.mx

BACKGROUND: The study of body composition in specific populations by techniques such as bio-impedance analysis (BIA) requires validation based on standard reference methods. The aim of this study was to develop and cross-validate a predictive equation for bioelectrical impedance using air displacement plethysmography (ADP) as standard method to measure body composition in Mexican adult men and women. **METHODS:** This study included 155 male and female subjects from northern Mexico, 20-50 years of age, from low, middle, and upper income levels. Body composition was measured by ADP. Body weight (BW, kg) and height (Ht, cm) were obtained by standard anthropometric techniques. Resistance, R (ohms) and reactance, Xc (ohms) were also measured. A random-split method was used to obtain two samples: one was used to derive the equation by the "all possible regressions" procedure and was cross-validated in the other sample to test predicted versus measured values of fat-free mass (FFM). **RESULTS AND DISCUSSION:** The final model was: $FFM \text{ (kg)} = 0.7374 * (Ht^2 / R) + 0.1763 * (BW) - 0.1773 * (Age) + 0.1198 * (Xc) - 2.4658$. R² was 0.97; the square root of the mean square error (SRMSE) was 1.99 kg, and the pure error (PE) was 2.96. There was no difference between FFM predicted by the new equation (48.57 +/- 10.9 kg) and that measured by ADP (48.43 +/- 11.3 kg). The new equation did not differ from the line of identity, had a high R² and a low SRMSE, and showed no significant bias (0.87 +/- 2.84 kg). **CONCLUSION:** The new bioelectrical impedance equation based on the two-compartment model (2C) was accurate, precise, and free of bias. This equation can be used to assess body composition and nutritional status in populations similar in anthropometric and physical characteristics to this sample.

Reference for the FAT & FFM equations used in the Pediatric equation set:

Body composition determination in children using bioelectrical impedance.

Cordain L, Whicker RE, Johnson JE.

Growth, Development, & Aging (1988) 52, 37-40

Department of Exercise and Sport Science, Colorado State University, Fort Collins 80523.

Estimation of body composition by measurement of tetrapolar bioelectrical resistive impedance (R) is a technique only recently validated in adults. To evaluate this technique in children, 16 girls aged 11.6 +/- 0.9 yr (mean +/- SD) and 14 boys aged 12.5 +/- 1.0 yr were assessed for fat free mass (FFM) by hydrostatic weighing, total body potassium (TBK) by whole body counting of ⁴⁰K, and R by an electrical impedance plethysmograph. Significant relationships (P less than 0.001) were demonstrated between TBK and ht²/R (r = 0.92), and FFM and ht²/R (r = 0.83). The reliability coefficient for the impedance measurements was r = 0.97. The following equation describes FFM in the present group of children: $FFM \text{ (kg)} = 6.86 + 0.81 * x \text{ (ht}^2/R)$, r = 0.83, P less than 0.001, SEE = 4.08. These data suggest that impedance measurements are valid and reliable predictors of FFM in pediatric populations.

References for the FFM equations used in the Obese African American equation set:

Validation of tetrapolar bioelectrical impedance method to assess human body composition.
Lukaski HC, Bolonchuk WW, Hall CB, Siders WA.
J Appl Physiol. 1986 Apr;60(4):1327-32.

This study was conducted to validate the relationship between bioelectrical conductance (ht^2/R) and densitometrically determined fat-free mass, and to compare the prediction errors of body fatness derived from the tetrapolar impedance method and skinfold thicknesses, relative to hydrodensitometry. One-hundred and fourteen male and female subjects, aged 18-50 yr, with a wide range of fat-free mass (34-96 kg) and percent body fat (4-41%), participated. For males, densitometrically determined fat-free mass was correlated highly ($r = 0.979$), with fat-free mass predicted from tetrapolar conductance measures using an equation developed for males in a previous study. For females, the correlation between measured fat-free mass and values predicted from the combined (previous and present male data) equation for men also was strong ($r = 0.954$). The regression coefficients in the male and female regression equations were not significantly different. Relative to hydrodensitometry, the impedance method had a lower predictive error or standard error of the estimates of estimating body fatness than did a standard anthropometric technique (2.7 vs. 3.9%). Therefore this study establishes the validity and reliability of the tetrapolar impedance method for use in assessment of body composition in healthy humans.

Comparison of body composition methods in obese African-American women.
Newton RL Jr, Alfonso A, York-Crowe E, Walden H, White MA, Ryan D, Williamson DA.
Obesity (Silver Spring). 2006 Mar;14(3):415-22.

Pennington Biomedical Research Center, Louisiana State University, 6400 Perkins Road, Baton Rouge, LA 70808, USA.
NewtonRL@pbrc.edu

OBJECTIVE: To compare the accuracy of percentage body fat (%BF) estimates between bioelectrical impedance analysis (BIA) and DXA in obese African-American women. **RESEARCH METHODS AND PROCEDURES:** Fifty-five obese African-American women (mean age, 45 years; mean BMI, 38; mean %BF, 48%) were studied. BF was assessed by both BIA (RJL Systems BIA 101Q; RJL Systems, Clinton Township, MI) and DXA (Hologic QDR-2000 Bone Densitometer; Hologic Inc., Bedford, MA). Generalized and ethnicity- and obese-specific equations were used to calculate %BF from the BIA. Bland-Altman analyses were used to compare the agreement between the BIA and the DXA, with the DXA serving as the criterion measure. **RESULTS:** Two of the generalized equations provided consistent estimates across the weight range in comparison with the DXA estimates, whereas most of the other equations increasingly underestimated %BF as BF increased. One of the generalized and one of the ethnicity-specific equations had mean differences that were not significantly different from the DXA value. **DISCUSSION:** The findings show that the Lukaski equation provided the most precise and accurate estimates of %BF in comparison with the QDR 2000 and provide preliminary support for the use of this equation for obese African-American women.

References for the FFM equations used in the HIV equation set:

Theory and Validation of the Tetrapolar Bioelectrical Impedance Method to Assess Human Body Composition.
HC Lukaski and WW Bolonchuk
In Vivo Body Composition Studies, London: The Institute of Physical Sciences in Medicine, 1986, pp 410-414.

Comparison of total body potassium with other techniques for measuring lean body mass in men and women with AIDS wasting.
Corcoran C, Anderson EJ, Burrows B, Stanley T, Walsh M, Poulos AM, Grinspoon S.
Am J Clin Nutr. 2000 Oct;72(4):1053-8.

Neuroendocrine Unit and the General Clinical Research Center, Massachusetts General Hospital, Harvard Medical School, Boston, MA 02114, USA.

BACKGROUND: Lean body mass is an important predictor of survival and functional status in patients with AIDS wasting. The bias between different techniques for assessing body composition in AIDS wasting is not known. **DESIGN:** We compared total body potassium (TBK) with fat-free mass (FFM) determined by dual-energy X-ray absorptiometry (DXA), bioelectrical impedance analysis (BIA), and skinfold-thickness measurement (SKF) in 132 patients (63 men, 69 women) with AIDS wasting (weight < 90% of ideal body weight, or weight loss > 10% of original, or both). None of the subjects exhibited clinical lipodystrophy. Comparisons were made by using different BIA equations. **RESULTS:** Lean body mass determined by DXA was highly correlated with TBK in men ($r = 0.79$, $P < 0.0001$) and women ($r = 0.84$, $P < 0.0001$). FFM(BIA) and FFM(DXA) were significantly different ($P < 0.01$ in men and $P < 0.0001$ in women). The difference between FFM(DXA) and FFM(BIA) was significantly greater with greater weight and body fat, particularly in HIV-infected women ($r = -0.39$, $P = 0.001$ for weight; $r = -0.60$, $P < 0.0001$ for fat). The comparability of FFM and fat mass determined by DXA and BIA was dependent on the specific BIA equation used. Among men, no single BIA equation was more highly predictive of fat mass and FFM in comparison with DXA. **CONCLUSIONS:** The differences between DXA, BIA, and SKF in the determination of fat mass and FFM are significant in patients with AIDS wasting. BIA overestimates FFM compared with DXA in those with greater body fat. Standard BIA equations may not accurately estimate FFM and fat mass in men and women with AIDS wasting.

Reference for the optional FFM-based BMR equation available to all equation sets:

Differences in resting metabolic rate between paraplegic and able-bodied subjects are explained by differences in body composition.
Buchholz AC, McGillivray CF, Pencharz PB.
Am J Clin Nutr. 2003 Feb;77(2):371-8.

Department of Nutritional Sciences, University of Toronto, Ontario.

BACKGROUND: Little is known about the relation between body composition and energy metabolism in paraplegia. **OBJECTIVE:** We investigated the relation between body composition and energy metabolism in healthy paraplegics as compared with able-bodied control subjects. We hypothesized that paraplegics would have lower fat-free mass (FFM), body cell mass (BCM), resting metabolic rate (RMR), and thermic effect of feeding (TEF). **DESIGN:** This cross-sectional study included 34 control subjects and 28 paraplegics (mean age: 29.1 +/- 7.6 and 33.9 +/- 9.2 y, respectively) with body mass indexes (in kg/m²) of 23.5 +/- 1.8 and 24.3 +/- 6.0, respectively. We measured RMR and TEF with indirect calorimetry, total body water with deuterium dilution, and extracellular water with corrected bromide space. We calculated FFM (total body water/0.732) and BCM [(total body water - extracellular water)/0.732]. **RESULTS:** FFM was higher in control subjects than in paraplegics (77.2 +/- 7.2% and 69.2 +/- 8.7%, respectively; $P = 0.0002$), as were BCM (47.4 +/- 6.7% and 35.9 +/- 8.1%, respectively; $P < 0.0001$) and RMR (7016 +/- 935 and 6159 +/- 954 kJ/d, respectively; $P = 0.0007$). FFM was the single best predictor of RMR in both groups ($r(2) = 0.83$ for control subjects and 0.70 for paraplegics, $P < 0.0001$ for both). RMR adjusted for FFM did not differ significantly between control subjects and paraplegics (6670 +/- 504 and 6588 +/- 501 kJ/d, respectively). TEF also did not differ significantly between control subjects and paraplegics (6.25 +/- 2.2% and 5.53 +/- 1.8% of energy intake, respectively). **CONCLUSIONS:** FFM, BCM, and RMR, but not obligatory TEF, are lower in paraplegics than in control subjects. RMR does not differ between control and paraplegic subjects after adjustment for FFM, indicating similar metabolic activity in the fat-free compartment of the body.

References for the FAT & FFM prediction equations used in the Athletic and All Body Types equation sets:

Lean body mass estimation by bioelectrical impedance analysis: a four-site cross-validation study.

Segal KR, Van Loan M, Fitzgerald PI, Hodgdon JA, Van Itallie TB.

American Journal of Clinical Nutrition (1988) 47, 7-14

Division of Pediatric Cardiology, Mount Sinai School of Medicine, New York, NY 10029.

This study validated further the bioelectrical impedance analysis (BIA) method for body composition estimation. At four laboratories densitometrically-determined lean body mass (LBMD) was compared with BIA in 1567 adults (1069 men, 498 women) aged 17-62 y and with 3-56% body fat. Equations for predicting LBMD from resistance measured by BIA, height, weight, and age were obtained for the men and women. Application of each equation to the data from the other labs yielded small reductions in R values and small increases in SEEs. Some regression coefficients differed among labs but these differences were eliminated after adjustment for differences among labs in the subjects' body fatness. All data were pooled to derive fatness-specific equations for predicting LBMD: the resulting R values ranged from 0.907 to 0.952 with SEEs of 1.97-3.03 kg. These results confirm the validity of BIA and indicate that the precision of predicting LBM from impedance can be enhanced by sex- and fatness-specific equations.

Effect of obesity on bioelectrical impedance.

Gray DS, Bray GA, Gemayel N, Kaplan K.

Am J Clin Nutr. 1989 Aug;50(2):255-60.

Department of Medicine, University of Southern California, Los Angeles.

The purpose of this study was to validate the use of bioelectrical impedance in assessing human body composition and to explore the use of this technique in obesity. Eighty-seven adults varying widely in body composition (range: 8.8-59.0% body fat) underwent measurement of bioelectrical impedance and underwater weighing (density). Fat-free mass determined from density (FFMd) was compared with FFM estimated from bioelectric impedance according to previously published regression equations. Correlation coefficients were high at all levels of body fat (0.94-0.99) but impedance equations overestimated FFM compared with FFMd in subjects greater than 42% body fat. This effect was greatest in subjects greater than 48% body fat and a regression equation was derived for determination of FFM for these subjects. These data confirm the excellent agreement between body composition determined from bioelectrical impedance and density but suggest that caution should be used in applying existing regression equations to very obese subjects.

**References for the FAT & FFM prediction equations used in the Athletic and All Body Types equation sets:
(Continued)**

Body composition by x-ray absorptiometry and bioelectrical impedance in female runners.
Pichard C, Kyle UG, Gremion G, Gerbase M, Slosman DO.
Med Sci Sports Exerc. 1997 Nov;29(11):1527-34.

Orthopedic Department, Geneva University Hospital, Switzerland. pichard@cmu.unige.ch

Body composition interests athletes since athletic performance is influenced by and dependent on the proportion and total amount of fat-free mass (FFM) and fat mass. The use of bioelectrical impedance (BIA) has increased recently since portable instruments make the measurements easy to execute and relatively inexpensive. The purpose of this study was to test the degree of relationship between FFM and fat mass calculated in elite female runners with 12 different BIA formulas reported in the literature and measured by dual-energy x-ray absorptiometry (DXA). The present study shows that body composition by BIA is valid in female runners. Prediction equations used to calculate FFM and fat mass must be appropriate for this population subgroup and validated against other methods, such as DXA and hydrodensitometry. Those formulas that performed well in the controls gave poor results in the female runner and vice versa. The below average fat mass noted in female runners suggests that prediction equations for untrained women with average fat mass are inappropriate. The formula by RJL Systems-2 for women: $FFM = 5.091 + 0.6483 \cdot \text{height}^2 / \text{resistance} + 0.1996 \cdot \text{weight}$ gave best predictions of FFM in female runners. Further research is necessary to validate BIA prediction formulas in other athletes.

Validity of bioelectrical impedance equations for estimating fat-free weight in high school female gymnasts.
Eckerson JM, Evetovich TK, Stout JR, Housh TJ, Johnson GO, Housh DJ, Ebersole KT, Smith DB.
Med Sci Sports Exerc. 1997 Jul;29(7):962-8.

Exercise Science Department, Creighton University, Omaha, NE 68178, USA.

The present study examined the validity of bioelectrical impedance (BIA) equations for estimating fat-free weight (FFW) in female gymnasts by comparing the values to those obtained from underwater weighing (UWW). Ninety-seven female Caucasian high school gymnasts (mean age \pm SD = 15.7 \pm 1.1 yr) participated in the study. FFW from UWW was calculated from percent fat using the revised formula of Brozek et al. (mean FFW \pm SD = 43.8 \pm 4.5 kg) and the age-specific constants of Lohman (mean FFW \pm SD = 44.8 \pm 4.6 kg). Cross-validation analyses included examination of the constant error (CE), SEE, r, and total error (TE). The results indicated similar trends between equations when based on either the Brozek or Lohman conversions; however, the CE, SEE, and TE values were consistently lower for the majority of the equations using the revised formula of Brozek et al. Based upon the results of the cross-validation analyses, the equation of Houtkooper et al. and the interlaboratory equations of Van Loan et al. and Lohman, which resulted in identical TE values of 2.4 kg are recommended for use with young high school gymnasts.