RJL
S Y S T E M S

BC4 Body Composition Analysis

RJL
S Y S T E M S
Quantum Body Composition

Body Composition 4.0
User Guide

Table of Contents

Indications for Use Statement

Calculation and Historical Tracking of:

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

- Estimated Lean Soft Tissue (LST)
- Estimated Lean Dry Mass (LDM)
- Estimated Intra-Cellular Water (ICW)
- Estimated Bone Mineral Content (BMC)
- Estimated Skeletal Muscle Mass (SMM)
- Actual Body Mass Index (BMI)
- Estimated Fat Mass Index (FMI)
- Estimated Fat-Free Mass Index (FFMI)

Intended Population:
BC is intended only for use on normally healthy adults and adolescents age 3-94. It is not intended to be used to diagnose, prevent, 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). BIA technology introduces an alternating current (AC) signal into the body, and then measures how that signal is affected by the body. In keeping with FDA statements about the lack of studies done by **electronic medical device implant** manufacturers (i.e. pacemaker, defibrillator) regarding the safety of BIA with their devices, RJL Systems warns against the use of BIA on an individual with an implanted electronic device.

- BIA should not be utilized on individuals with **abnormal heart rhythms**, **during electrocardiograms**, or on individuals **connected to life-support electrical systems**.

- 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.

- Prediction equations used by the BC software assume there has not been an arm or leg **amputation**. In the case of active **prostheses** on the right side of the body, affecting standard electrode placement, the Practitioner may choose to test the left side of the body. In this case, individual tests can only be compared to subsequent tests on that individual, noting the average population ranges and prediction equations would likely not be relevant.

Precautions:
Using the BC software to evaluate individuals outside of the above intended population, or failing to follow the individual preparation and testing procedures detailed in the documentation for your Bio-electrical Impedance Analyzer could adversely affect the body composition assessment provided by this application.

RJL Systems BC software is intended for "Over-the-Counter" distribution.

Software License Agreement
(revised 2014-10-29)

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By using this software you accept the following terms of this License Agreement. If you do not agree with these terms, you should not use the software and promptly return it for a refund.

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- The United States of America
- Canada

The Indications for Use and Intended Use statement can be found in the software's User's Guide, and describes:

- what the software does,
- on what populations or groups of people it should (or should not) be used,
- and for what purposes the software and any information it produces should (or should not) be used.

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BIA Test Protocol

For best results, RJL Systems recommends that the following preparation and administration conditions be met:

- No alcohol within 12 hours of the test.
- No caffeine (i.e. coffee, tea, 'energy' drinks, soda pop) within 8 hours of the test.
- Height, weight, age, and gender are accurately recorded.
- All electrode sites will be cleaned with alcohol and allowed to dry, prior to electrode placement.
- Specified red and black leads need to be attached in the correct and standardized manner ('top or bottom placement'), as illustrated (see below).
- The right shoe and sock or nylon stocking, as well as any other objects in the way of proper electrode placement must be removed from the body.

- During the test, the individual will lie supine, quietly without moving, with arms 30 degrees from the body, and legs not touching each other. Consider a fabric pillow between the legs if necessary.
- No exercise or sauna within 8 hours of the test.
- Metal and/or magnetic jewelry, therapeutic magnets, communication devices, cellphones should be removed from the body.
- The attached in a precise and standardized manner, as illustrated (see below).
- To prevent damage, do not press too heavily on the electrode sites. Exert only enough pressure to ensure proper adhesion.
- Electrodes are to be discarded after one use.

Right Hand Electrode Placement

Signal injection electrode

HAND label on lead set

Red Clip

Black Clip

Detecting electrode edge is placed on an imaginary line bisecting the ulnar head (bone on the little finger side of the wrist).

Right Foot Electrode Placement

Detecting electrode edge is placed on an imaginary line bisecting the medial malleolus (bone on the big toe side of ankle).

Signal injection electrode

Black Clip

Red Clip

FOOT label on lead set

Form 48 (22 June 2012)

Practitioners must demonstrate the following level of proficiency before administering a BIA test:
Make two consecutive sets of Resistance and Reactance measurements on a single stable individual, using new electrodes for each measurement. There must be less than one percent (1%) variance. If multiple practitioners will be administering BIA tests, they must also demonstrate less than 1% variance between practitioners.

Software Installation

Your RJL BC4.0 Software will run on both a Windows PC and a Macintosh computer. The system requirements are as follows:

PC	•Windows XP or newer
	•32 MB of RAM
	•32 MB of disk space (plus space for the databases)
	•Standard USB Port (for installation)
Macintosh	•Snow Leopard (OS X 10.6) or newer
	•32 MB of RAM
	•32 MB of disk space (plus space for the databases)
	•Standard USB Port (for installation)

(RJL iPad BC software is an option available for purchase, through the Apple Store™)

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

Once the RJL Systems thumb drive has been inserted, 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 drive. 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 agreement before you can continue. Click **Enter.**

3) **Component Selection** – This screen 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) **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.

6) **Warranty Product Information** – Tell us about your RJL products, where you purchased them, and when.

7) **Ready** – Just click **Next.**

8) **Installing** – This is where setup does 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.

9) **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 explains how to get started.
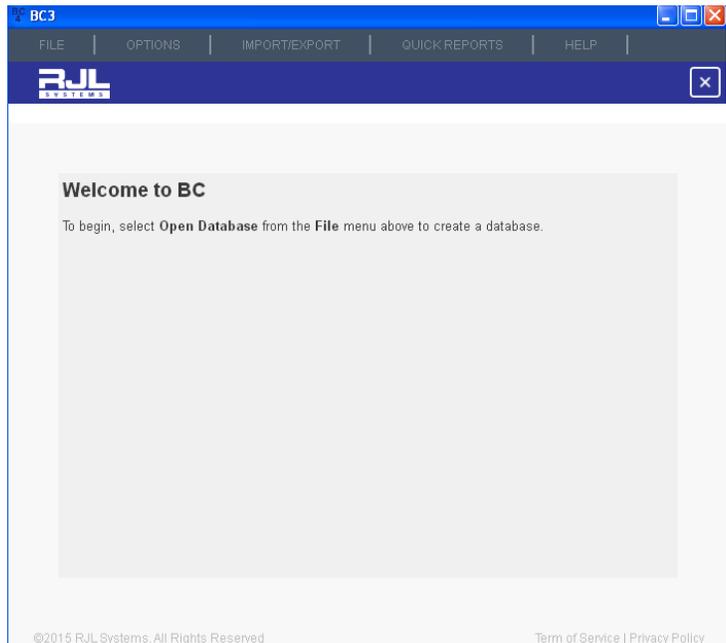
Opening a Database

To open or create a database in BC3, select "Open or Create 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 practitioner'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 previous RJL Software**.
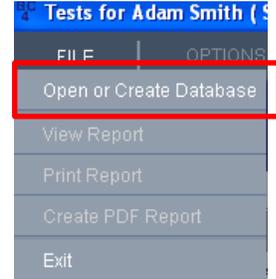
To create a new database, start by choosing a place to store it. If more than one person will be logging into the computer to use BC or if you have a file server on the network that is backed-up on a regular basis, you might want to change this location. Otherwise, the documents folder is probably a 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 "Body Composition Data". For the most part, it is a good idea to only create one database to hold all of your individual data, unless you have a very good reason to keep one group of people separate from another. If you 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 – this prevents having an individual's test history from being 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 BC 4.0 database, find it, select it, and then 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 individual 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 feature 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.
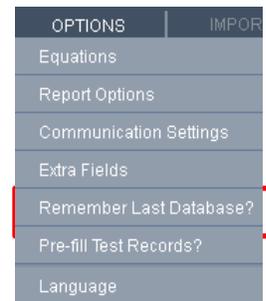
Creating a New Person

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 individual 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 individual ID. Some practices choose to use first and last name, or an assigned medical record number, or other specified HIPAA compliant method. This information is entered into the Individual ID field.

Make sure that you are consistent. If you have a test for John Doe with an individual ID of 1234 and a test for John Doe with no individual ID, BC will treat the two tests as two separate individuals.

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 Identification 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 body composition. Note: If at some point in the future, John Doe were to have had a gender reassignment procedure 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 Expanded Topics 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 individual, 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.

The Basal Metabolic Rate (BMR) is also calculated for the individual. BMR is the number of calories that the person would utilize in a completely sedentary 24-hour day.

The selection of Activity Level does not affect body composition estimates, but it does affect Daily Energy Expenditure (DEE) – the estimate of how many calories the individual actually burns in an average day.

Most Americans are going to be considered either "light" or "very light", especially if they spend the bulk of an average day sitting in a chair. For further clarification, please see the following descriptions:

Very Light (No Exercise)
A sedentary lifestyle with little to no exercise. Inactive in both work and leisure. **Example activities:** Seated and standing activities, painting, driving, laboratory work, typing, sewing, ironing, cooking, playing cards, playing a musical instrument.

Light (Some Exercise)
Intense exercise for at least 20 minutes once or twice per week or the daily routine includes some walking, such as a student. Generally reflects a person who does not exercise regularly, but who maintains a busy life style that requires walking frequently for long periods. **Examples of light intensity activities:** 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)
Intense exercise for at least 20 to 45 minutes 3 to 4 times per week or an occupation that involves a lot of walking or other a moderate intensity activities. **Examples of moderate intensity activities:** Walking 3.5 to 4 mph (5.6-6.5 kph), weeding and hoeing, carrying a load, cycling, skiing, tennis, dancing

Heavy (Athletic)
Intense exercise for 60 minutes or greater 5 to 7 days per week. Labor-intensive occupations also qualify for this level, such as construction work (brick laying, carpentry, general labor, etc.), farming, landscaping or similar occupations. **Examples of heavy activities:** Walking with a load uphill, tree felling, heavy manual digging, climbing, competitive basketball, football, or soccer

Exceptional (Elite Athlete)
Exceedingly active and/or very demanding activities. Generally, this level of activity is very difficult to achieve. **Examples:** athlete with an almost unstoppable training schedule with multiple training sessions throughout the day or a very physically demanding job, such as shoveling coal or working long hours on an assembly line.

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 the X button next to the person's name 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 stack-up 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 X button next to the person's name 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. The Food and Fitness button leads to a screen that offers food choices, lifestyle activities, and exercises that you could also choose to use in your discussions or consultations.

Food & Fitness

The **Food & Fitness** button on the results screen leads to the Food & Fitness page. You can choose to utilize these sections in your discussions or consultations. Instructions for this screen are in the box in the upper-left corner. A brief discussion on exercise and a list of activities and their respective caloric burn rates is on the right. In the lower left quarter, you can see the person's current weight, their target weight, and the current estimate of their DEE, which is how many calories we estimate the individual is currently burning per day as a result of their average daily routine's activity level.

The first thing you can choose to do is to adjust the rate of change sliding bar. The maximum rate of change that has been generally accepted safe without being under the close supervision of a practitioner, 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.

Food and Fitness

FILE   OPTIONS   IMPORT/EXPORT   QUICK REPORTS   HELP

December 10, 2012 Monday
3:29:33 PM

John Doe

Introduction

This section of the program calculates a suggested diet and an amount of additional calories for the person to burn in added exercise, in addition to what he or she is currently doing.

PLEASE NOTE: The suggestions made by this section of the program are not intended to replace the advice of a physician.

To begin, find the sliding bar labeled "Pounds / Kilograms per week to gain or lose." Slide this bar to indicate the rate at which the patient should change his or her weight. The maximum allowable rate of weight change is two(2) pounds (0.9 kg) per week, as this is the

Include in Report...

☑ Activity List   ☐ Sample Meal Plan   ☑ Food Groups

Current Weight	Target Weight
234.0 lbs	185.0 lbs

Current DEE	Rate of Change
2874 cal	1.0 lbs / week

Time to reach Goal	Daily Caloric Intake
51 weeks	2600 cal

Activity Calories per Day to Add

205 cal

Activities

Listed below are a relatively short number of activities, and the number of calories you could expect to burn in one half hour (30 minutes) engaged in each activity.

This list is provided as a reference. Performing an activity for half the amount of time (15 minutes) will only burn half of the calories listed. Likewise, exercising twice as long (1 hour) will yield twice as many calories burned.

If you need to burn 250 calories per day, and aerobics, for example, is listed as burning about 500 calories for every 30 minutes, then you would only have to do aerobics for about 15 minutes each day.

When a weight change program is created with this software, it involves an AVERAGE daily number of calories that will need to be burned through additional exercise. If you work twice as hard one day, you can take the next day off.

ACTIVITY	30min.
bicycling, BMX	546
bicycling, mountain, general	546
bicycling, leisure, 9.4 mph	372
bicycling, 14-15.9 mph, racing or leisure, fast, vigorous effort	642
Elliptical trainer, moderate effort	321
health club exercise, conditioning classes	501
stretching, mild	148
yoga, Hatha	161
yoga, Power	257
ballet, modern, or jazz, general, rehearsal or class	321
aerobic, low impact	321

Save to History Record

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 adjust the quantity and/or quality of the caloric intake, while ensuring an activity level sufficient to achieve the goals you have set. Only Practitioners trained in this area should make specific recommendations, and it is prudent to remind Individuals to seek the advice of their physician prior to making changes to his or her current lifestyle.

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. For example,, if the individual refuses to increase activity, but desires the same overall weight change, the practitioner may choose to discuss the option of more significant calorie reduction or calorie quality modification strategies. As you will see, the Health Enhanced Option foods are typically higher in fiber and nutritional benefit, while being lower in fat and cholesterol than the Standard Options. These choices may help practitioners in their discussions or consultations about weight management strategies.

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

At the top are three check-boxes – one to add the activity list to the printed report, one to add discussions of the various food groups and suggestions of foods and portion sizes in those groups, and one to add a sample meal plan of the selected daily number of calories – in this case, 2600. 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 is a tool you can choose to use to help individuals see that their caloric burn rates are affected by what they choose to do, and how long they choose to do it.

The sample daily menu and five food categories included in the RJL BC Food section has received significant and flexible updates. Each area contains several options, including foods that are gluten-free, cholesterol-free, dairy-free, wheat-free, egg-free, and appropriate for individuals choosing a vegan or vegetarian diet. The standard menu options are also listed, as a discussion point of familiarity. For example, the calcium-rich options include both animal-milk and plant-milks, encouraging the discussion of available options, and helping navigate allergies, intolerances, and dietary preferences.

The fitness section has also received significant updates. It now includes lifestyle activities like vacuuming, playing a musical instrument, dog-walking, and house-cleaning, along with athletic activities, like skiing, running and weightlifting. This expanded variety allows for a richer discussion of the many ways to increase activity levels in a customized, safe, and enjoyable manner.

When you are done with the Food & Fitness section, click the X button next to the person's name to go back.

Average Ranges

From the test results, click the Average Ranges button to see the averages, collected via NHANES-III research data. 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. Note: Average population ranges are NOT Reference, Clinical, or Optimal ranges.

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 the X button next to the person's name.

The Test List

Closing 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 Adam Smith'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 X button next to the person's name to close their history and return to the list of people.

Pre-filling Follow-Up Tests

Every time you create a new test for someone, you will need to fill in height, weight, age, resistance, and Reactance.   Any change in these parameters will need to be noted accurately in order for the composition assessment results to be accurate.

When you start a follow-up test for someone, if you activate "**pre-fill test records**" from the options menu, the height, weight, and age will be automatically loaded from the individual's last test date. This way, instead of asking "how tall are you? how old are you? etc", you can ask "Are you still.…"
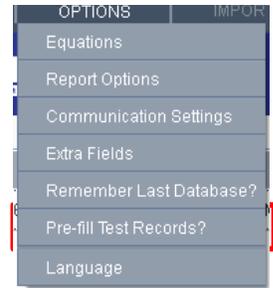
Creating Reports

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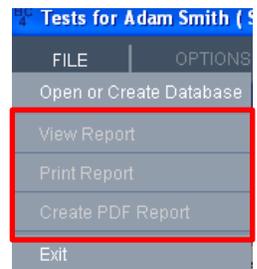
Any item on these three screens that is checked will be added to the report. Any item that is not checked will not appear in the report. If you want a report with no charts or graphs, make sure that all of the charts and graphs are turned off on the results page.

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 create Report so 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" equation set for the majority of their individuals. 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 Expanded Topics section of this manual.

Until recently, the only way to estimate Basal Metabolic Rate (BMR) without doing calorimetry was to use a formula, such as Harris-Benedict, which 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 an individual's BMR, based on the amount of Fat-free mass. After installing, this FFM-based formula to derive BMR will be 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 individual. Instructions on how to determine frame size can be found in the Expanded Topics section.

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 generate and report 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 sedentary and over-fat, 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. Again, the total simple scale weight portion of BMI becomes compartmentalized into the various measures reported by BIA.

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.
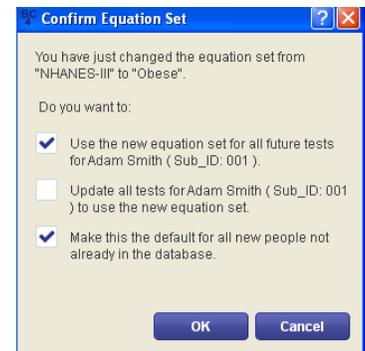
If you changed the equation set, you can choose to apply that change to the currently open test. You can also choose to make it the default for that person going forward, or the default for everybody. BC can also go back and change the equation set for all of the previous tests in the database for that particular individual. Since this last option involves changing already completed test records, it will no longer 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 any information you choose.

Below that is the report template to use. To browse for available templates, click the drop-down under "Report Template". "report" and "report_bigtable" are the standard layouts. You can see samples of both layouts in the back of this 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 averages.

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.

Clicking on **Charts and Graphs** will allow 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 you have entered comments for an individual, turning on Comments History will add a section for them to appear on all subsequent reports, as well.

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.
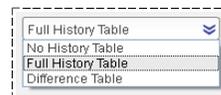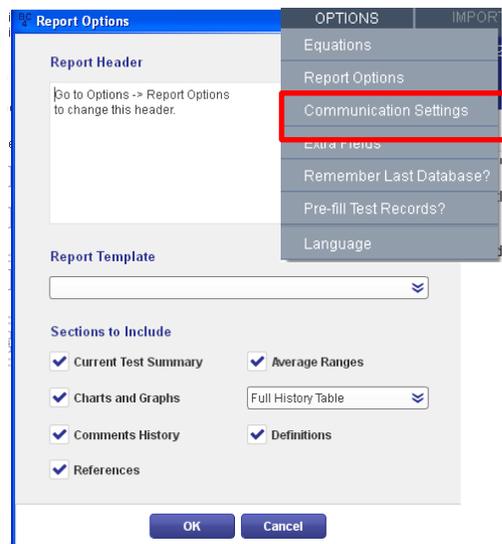
If you have an individual with an extraordinarily lengthy BIA test series, you can also click on **Difference Table,** to simplify the report. This feature will not print every single test; instead, it will list out all of the values in the current test, and show you how much of a difference there is between that test and the previous one, and between that test and the individual's very first baseline 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 have been selected 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 Food & Fitness screen, and then finally going to the file menu and selecting either print report or create PDF report.
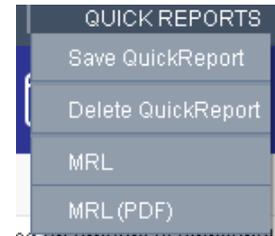
If you find you are frequently making the same selections every time you create a report, you can streamline the process by using the **Quick Reports** feature. To create a Quick Report template, make your selections to build your desired report format for a test in the database, as usual. But instead 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 would print a report using your new template, and one creates its corresponding PDF format.

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

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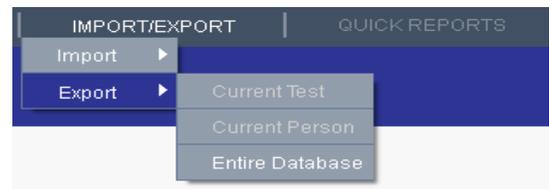
Go to the Import/Export menu and select Export. If you have a saved test open, you can choose to just export that one test to the spreadsheet. Or you can export all tests for the currently open person. Or the entire database.

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 Prior 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.
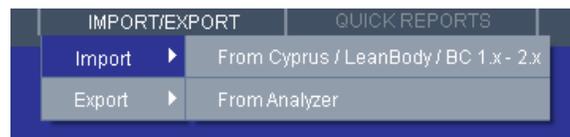
Configuring Communications

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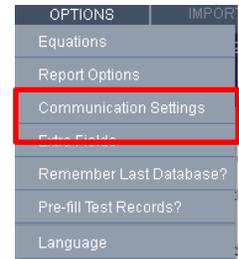
The first thing to do is to make sure that the "Communicate with Analyzer" box is checked. Turning this box off disables or hides certain controls to simplify the practitioner experience and to keep you from trying to do things that are certain to not work.

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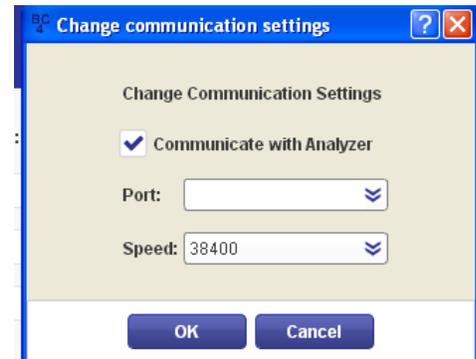
Click on the Ports drop-down menu and make note of which ports are listed. Because the analyzer cable is not connected, the one you want would not yet be listed.

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. Typically, the speed to choose would be 38400. However, some devices like the Quantum-III might need a slower speed, like 9600. To verify which one you should need, please refer to the manual that came with your BIA body composition analyzer device.. Once you have set both the port and speed , 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 individual 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, it means that there is still a problem to be corrected. 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 individual cables are connected to either an individual or the test resistor, numbers will appear in the resistance and Reactance fields. Otherwise, if the individual cables are disconnected, BC will tell you so. This still counts as a successful test of communication, as the BC Software is reporting what your analyzer sees.

Expanded Topics

Activity Level

The "Daily Activity Level" describes the amount of physical work associated with the individual's typical daily routine. The activity level does not affect the body composition estimates, but it is still important to select an activity level that is appropriate to the amount of activity that the person sees on *an average day.* 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.

Remember to choose the level that most closely reflects their typical routine. Lists of example activities are also provided for each level. If the listed activities are descriptive of what the person does for most of the day or the description fits, choose that activity level.

BC uses updated names for the activity levels, compared to those found in earlier software versions from RJL Systems. The older names are listed as well, for your reference.

Very Light (No Exercise)
A sedentary lifestyle with little to no exercise. Inactive in both work and leisure. **Example activities:** Seated and standing activities, painting, driving, laboratory work, typing, sewing, ironing, cooking, playing cards, playing a musical instrument.

Light (Some Exercise)
Intense exercise for at least 20 minutes once or twice per week or the daily routine includes some walking, such as a student. Generally reflects a person who does not exercise regularly, but who maintains a busy life style that requires walking frequently for long periods. **Examples of light intensity activities:** 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)
Intense exercise for at least 20 to 45 minutes 3 to 4 times per week or an occupation that involves a lot of walking or other a moderate intensity activities. **Examples of moderate intensity activities:** Walking 3.5 to 4 mph (5.6-6.5 kph), weeding and hoeing, carrying a load, cycling, skiing, tennis, dancing

Heavy (Athletic)
Intense exercise for 60 minutes or greater 5 to 7 days per week. Labor-intensive occupations also qualify for this level, such as construction work (brick laying, carpentry, general labor, etc.), farming, landscaping or similar occupations. **Examples of heavy activities:** Walking with a load uphill, tree felling, heavy manual digging, climbing, competitive basketball, football, or soccer

Exceptional (Elite Athlete)
Exceedingly active and/or very demanding activities. Generally, this level of activity is very difficult to achieve. **Examples:** athlete with an almost unstoppable training schedule with multiple training sessions throughout the day or a very physically demanding job, such as shoveling coal or working long hours on an assembly line.

Basal Metabolic Rate

By default, BC will currently 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.

Body Mass Index (BMI)

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)

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

in metric   in Imperial units

In the 1960s, an insurance company decided upon a general rule-of-thumb originally called the "Quetelet Index"[1], to say "This person weighs more than he ought to," and used that as justification to charge more for their life insurance policy. Later studies revealed problems with the use of BMI as a gauge of fatness. The formula does not take into account body frame size, fluid component variations, muscularity, gender, age, or ethnicity – BMI is strictly a ratio involving height and weight, without regard to the composition of the body. . 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 sedentary and over fat, or a champion bodybuilder.

For these reasons, the BIA accurately reflect how much fat is in the individual, rather than adding all of the other components of the body to the total weight only used in BMI.

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

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[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

Electrodes

Sometimes practitioners will consider utilizing electrodes from other medical devices in their office, or purchasing replacement electrodes from non-RJL vendors.

 The electrodes recommended by RJL meet the specifications represented in the published medical research utilizing BIA technology. RJL is committed to optimal performance, and we caution our customers against any practice that may compromise accuracy. While a variety of different electrodes may look the same, the conductive gel varies significantly, i.e. based in tin, silver, silver oxide, or some other medium.

RJL electrodes are regularly tested to deliver the quality and accuracy that you and your patients deserve, guaranteed.

Electronic Medical Implants

Since the manufacturers of implantable electronic medical devices (i.e. pacemakers) do not generally test their products to ensure that they will continue to operate correctly during and after a BIA test, the FDA has requested that RJL caution against the use of a BIA on individuals with those types of devices.

This issue was addressed and summarized in the international ESPEN 2004 statement on BIA in clinical practice, stating while there was a possibility of altered pacemaker or defibrillator activity, and that cardiac activity should be monitored, no interference with pacemakers or defibrillators is anticipated.[2]

A 2012 article published in *Pacing and Clinical Electrophysiology* reported no evidence of BIA interference in 20 subjects with implantable cardioverter defibrillators.[3]

Medical devices vary in specification and function. For your reference, RJL Systems Quantum BIA devices utilize a fixed 50 kHz signal, and conform to the requirements in ANSI/AAMI ES1 and IEC 60601-1:2005, for maximum allowable current applied to the patient.

RJL Sciences continues to advise individuals to consult with their physician regarding their particular electronic medical implant device.

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[2]Kyle U, et al., Bio-electrical impedance analysis—part II: utilization in clinical practice. *Clinical Nutrition,* 2004; 23, 1430-1453.

[3]Buch E, Bradfield J, Larson T, Horwich T, Effect of bioimpedance body composition analysis on function of implanted cardiac devices, *Pacing Clinical Electrophys,* 2012 Jun; 35(6):681-4.

Equation Selection

Many researchers have developed equations for estimating 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 a certain ethnicity or those 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**
To address the former 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**
This equation set is included for users whom have historically used the set, for example in an existing research project, and choose to continue. The updated equations are found in the 'New Pediatric' set, as described below. 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 original FFM and fat equations identified for males and females, were then 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.

• **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. Please note there is a growing body of equation research for 'power athletes' vs. 'endurance athletes'.

• **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 or obese. 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 should consider using a different equation set.

• **RJL Systems**

The equations for estimating Lean Soft Tissue, Skeletal Muscle Mass, and Bone Mineral Content were developed by analyzing DEXA data collected at the same time as the BIA values. That combined data-set also allowed us to develop new equations for Fat and Fat-Free Mass, which are used in this equation set.

Food & Fitness Section

Your BC 4.0 software includes food and fitness options consistent with the integrated Lifestyle Factors approach that many practitioners now choose to utilize.

The Food section emphasizes whole and unrefined foods, and lists product examples that include wheat-free, gluten-free, dairy-free and cholesterol-free choices. Every section also offers higher fiber, higher nutrient content, lower fat and lower cholesterol food choices as "Health Enhanced", next to the currently more familiar standard American fare. The new options often suggested by preventive nutrition specialists are also suitable for those eating a vegetarian or vegan diet.

The Fitness section has been fully redesigned to help illustrate that 'moving' is already a part of life – we typically just need to move *more* for better health outcomes. By allowing for individual starting points, goals, and abilities, practitioners can help keep patients motivated for change, and develop more effective treatment planning options with better patient compliance. Typical exercise examples remain intact (like weightlifting, swimming, and aerobics), but BC 4.0 also offers the caloric burn associated with lifestyle activities such as vacuuming, playing a musical instrument, various yoga forms, and even playing with the dog. The inclusion of daily activities helps illustrate the spectrum of fitness level starting points, making changes easier to envision.

Frame Size

There are two generally accepted methods for measuring frame size:

• **The Precise Method -**First, measure the individual's height. Next, use a measuring tape to measure the circumference of the individual's wrist. Be certain 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 individual has a small frame. If it is less than 9.6, the individual has a large frame. Otherwise, the individual has a medium frame.

• **The Easy Method –** A simpler, yet less precise, method is to have the individual wrap his or her thumb and forefinger of one hand around the wrist of the other hand. If the thumb and forefinger overlap, the person is said to have 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.

iPad™App

The RJL BC App for iPad™ provides another professional management tool for practitioners and researchers who also using an iPad. This RJL software app option is available online, directly from the Apple Store™.

Pounds vs. Percentages

Review the screen images shown 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 illustrate, imagine two different individuals, each with exactly 20 pounds of body fat. Person A weighs 100 pounds, but person B weighs 120 pounds. Keeping in mind they each have exactly the same amount of body fat, it equals 1/5 of Person A, but 1/6 of person B.

So, when you are comparing a person against someone else, or a reference range, it is probably best to look at the percentages. But when you are comparing that individual's historical changes over time, it is better to compare the weights of the compartments instead of the percentages.

For example, someone who weighs 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, but still has 20 pounds of fat. He hasn't changed the amount of fat in his body, but he now weighs only 190 pounds instead of 200, so his body fat percentage has gone up slightly.

Previous RJL Systems Software

This section is designed to assist you with the transition from previous RJL Systems software versions.

. 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 an individual's test record, 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 practitioner's guide for that program.

If you previously utilized Cyprus software, you will note that Body Cell Mass (BCM) and Extra Cellular Mass (ECM) are not reported by BC 3.0 or BC 4.0. These values were removed because the FDA has not yet been satisfied regarding the clinical utility of these values, therefore it is currently not legal to distribute a medical device that reports BCM or ECM in the United States.

Re-installation

If you have lost or misplaced the USB thumb drive for the software that came in your kit, you can purchase a new one by contacting RJL Systems through our website, or by calling 1-800-528-4513.

Statistical Analysis

BC 4.0 allows you to export 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**.

Calculating a Target Weight

On the individual 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. If the software calculates it, it will use one of two formulas:

Hamwi Ideal Weight Equation

By default, the formulas that the software uses to calculate target weight are called the "Hamwi Ideal Weight Equations" which are as follows:

> • **For Males**
> Target weight = 106 + [6 x ((height in inches) - 60)]

> • **For Females**
> Target weight = 100 + [5 x ((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 individual. Instructions on how to determine frame size can be found in the Expanded Topics section.

Target Weight Based on Target 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?" In this way, you can specify your own "desired BMI". The program will normally use a BMI of 23, which is the border between "normal" and "overweight" using BMI.

The way BMI is typically used – as an indicator of "fatness" - it is pretty universally considered to be a poor tool. 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?" In this way, we can use it to generate a ballpark target for that person's weight loss goals.

Glossary of Terms

The terms below, as well as the graphical representation at the right, will help describe the general breakdown of the composition of the body.

Total Body Weight				
Fat	Fat Free Mass			
	Lean Dry Mass	Total Body Water		
	Bone Mineral Content	Non-BMC LDM	Intra-Cellular Water	Extra-Cellular Water
		Lean Soft Tissue		
		Skeletal Muscle Mass	Non- SMM LST	

Height – in inches (in) or centimeters (cm)

Weight – in pounds (lbs) or kilograms (kg).

Resistance – the opposition to the flow of an electrical current. Higher TBW and LDM yield a lower Resistance, and higher Fat and dehydration yield a higher Resistance.

Reactance – measures the body's opposition to changes in the flow of an electrical current. Reactance is related to the capacitance of the cell membranes, and reflects integrity, function, and composition.

Phase Angle (PA) – PA reflects the relative contributions of fluid (resistance), and cellular membranes (capacitive reactive). It is calculated as the arc-tangent of Reactance over resistance, measured in degrees. Typical Phase Angles (NHANES human data) range between 4-9.

Fat – provides insulation, warmth, and energy storage, and is necessary for the absorption of many vitamins.

Fat Free Mass (FFM) – is also called Lean Body Mass, and is everything in your body, except Fat.

Lean Dry Mass (LDM) – is what is left after subtracting all of the water from your Fat Free Mass.

Total Body Water (TBW) – is all of the water throughout your body, both inside and outside of your cells.

Intra-Cellular Water (ICW) – represents the amount of water inside your cells.

Extra-Cellular Water (ECW) – represents the amount of water outside of your cells.

Bone Mineral Content (BMC) – Bones are dynamic organs that include cells, blood vessels, collagen and mineral deposits. BMC is only an estimate of the minerals in the bones and does not represent the total weight of the skeleton. It is part of Fat-Free Mass.

Lean Soft Tissue (LST) – In the same way that LDM is the result of removing all water from Fat-Free Mass, Lean Soft Tissue is the result of subtracting Bone Mineral Content from Fat-Free mass. This includes your organs, muscles, connective and supportive tissues, as well as all of Total Body Water.

Skeletal Muscle Mass (SMM) – SMM are the muscles responsible for posture and movement.

Basal Metabolic Rate (BMR) – The caloric energy required to sustain life in a sedentary state for 24 hours.

Daily Energy Expenditure (DEE) – DEE adjusts the BMR valued based on the selected activity level. The caloric energy required to sustain life, plus daily activities.

Body Mass Index (BMI) – BMI is derived by diving total weight (kg) by height (m), squared. BMI is a general measure typically used to determine if someone is overweight, but knowing actual body composition is much more accurate.

Fat Mass Index (FMI) – FMI relates fat mass to height in the same way that BMI relates total weight to height. Because it takes into account only the fat mass, it is a superior indicator of obesity compared to BMI.

Fat Free Mass Index (FFMI) – FFMI relates fat-free mass to height in the same way that FMI does to fat. Fat+ FFM – Weight, FMI +FFMI = BMI.

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 multi-component 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 stature(2)/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 individuals 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 individuals. The purpose of this paper is to verify the reliability of bioelectrical measurements in extracellular water (ECW) prediction in healthy individuals and in fluid retention states. We studied 40 individuals (19 males and 21 females) aged 21-81 years; 22 were healthy individuals, 12 were affected by chronic heart failure, and 6 by chronic renal failure. In all individuals 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 individuals. ECW was best predicted by resistance at 1 kHz corrected for height, group (considered as dummy variable), weight and gender (R2 = 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 (R2 = 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 individuals 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 individuals' 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 x (height2/impedance) + 0.68 x age + 0.15 (R2 = 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-drived 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 individual data sets representing 62 adults, 37 prepubertal children, 44 preschool children, and 32 premature low-birth-weight neonates were combined. Individuals 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 ht2/R + 0.065 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 individuals 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 (kg) = 0.7374 * (Ht2 /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 (kg) = 6.86 + 0.81 x (ht2/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 (ht2/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 individuals, 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.

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

Differences in resting metabolic rate between paraplegic and able-bodied individuals 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 individuals. 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 individuals and 28 paraplegics (mean age: 29.1 +/- 7.6 and 33.9 +/- 9.2 y, respectively) with body mass indexes (in kg/m(2)) 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 individuals 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 individuals and 0.70 for paraplegics, P < 0.0001 for both). RMR adjusted for FFM did not differ significantly between control individuals and paraplegics (6670 +/- 504 and 6588 +/- 501 kJ/d, respectively). TEF also did not differ significantly between control individuals 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 individuals. RMR does not differ between control and paraplegic individuals 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 individuals' 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 individuals greater than 42% body fat. This effect was greatest in individuals greater than 48% body fat and a regression equation was derived for determination of FFM for these individuals. 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 individuals.

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.height2/resistance + 0.1996.weight gave best predictions of FFM in female runners. Further research is necessary to validate BIA prediction formulas in other athletes.

Validity of bioelectrical impedence 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, Creighon University, Omaha, NE 68178, USA.

The present study examined the validity of bioelectrical impedence (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 +/- SD = 15.7 +/- 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 +/- SD = 43.8 +/- 4.5 kg) and the age-specific constants of Lohman (mean FFW +/- SD = 44.8 +/- 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.

References for the FAT & FFM prediction equations used in the RJL Systems equation set, and for the LST, SMM, and BMC equations used by all equation sets:

Bioelectrical Impedance Analysis (BIA) New Indications of Use for RJL Systems BC 4.0 Body Composition Software
27 May 2014
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Recently RJL Systems completed a comparative segmental BIA (Σ BIA) study where whole body (WB) and segmental BIA (Σ BIA) resistance and reactance values were collected along with the values from a Lunar iDXA dual X-ray scanner. Control measurements were made on 20 males and 25 females that were used to develop the equation sets and validated with an additional 21 males and 26 females. Two of the values that the iDXA scanner reports are whole body lean soft tissue and bone mineral content. These values were compared to BIA and have significant comparative accuracy to be included as new indications for use (see statistical summary).

Peer review literature[1] reports the relationship of total body skeletal muscle mass (SMM) to iDXA derived appendicular lean soft tissue (right, left, leg and arm). The comparative relationship between SMM and whole body BIA is highly predictive and will also be included as a new indication of use. In addition, the new iDXA data refines the prediction equation for fat free mass and total body fat. Therefore, these new updated equations also are included. This document introduces five body composition values that are based on Dual-energy X-ray absorptiometry (DXA) and Bioelectrical Impedance Analysis (BIA). All measurements are of the whole body.

Further References for the LST, SMM, and BMC equations used by all equation sets:

Total-body skeletal muscle mass: estimation by a new dual-energy X-ray absorptiometry method.
Kim J1, Wang Z, Heymsfield SB, Baumgartner RN, Gallagher D.
Am J Clin Nutr. 2002 Aug;76(2):378-83.

BACKGROUND: Skeletal muscle (SM) is an important body-composition component that remains difficult and impractical to quantify by most investigators outside of specialized research centers. A large proportion of total-body SM is found in the extremities, and a large proportion of extremity lean soft tissue is SM. A strong link should thus exist between appendicular lean soft tissue (ALST) mass and total-body SM mass.
OBJECTIVE: The objective was to develop prediction models linking ALST estimated by dual-energy X-ray absorptiometry (DXA) with total-body SM quantified by multislice magnetic resonance imaging in healthy adults.
DESIGN: ALST and total-body SM were evaluated with a cross-sectional design in adults [body mass index (in kg/m$^{(2)}$) < 35] with an SM-prediction model developed and validated in model-development and model-validation groups, respectively. The model-development and model-validation groups included 321 and 93 ethnically diverse adults, respectively.
RESULTS: ALST alone was highly correlated with total-body SM (model 1: R$^{(2)}$ = 0.96, SEE = 1.63 kg, P < 0.001), although multiple regression analyses showed 2 additional predictor variables: age (model 2: 2-variable combined R$^{(2)}$ = 0.96, SEE = 1.58 kg, P < 0.001) and sex (model 3: 3-variable combined R$^{(2)}$ = 0.96, SEE = 1.58 kg, P < 0.001). All 3 models performed well in the validation group. An SM-prediction model based on the SM-ALST ratio was also developed, although this model had limitations when it was applied across all subjects.
CONCLUSION: Total-body SM can be accurately predicted from DXA-estimated ALST, thus affording a practical means of quantifying the large and clinically important SM compartment.