

Eight Electrode Segmental BIA

Using the Quantum IV and an
eight lead 12 channel isolated switch
to measure each arm, leg and torso
of the human body

4 June 2010



Segmental BIA

Introduction

The RJL segmental BIA system is an electronic lead switching multiplexer that can resolve resistance and reactance values from each arm and leg including the torso from right and left whole body electrode placements. These segments better define the human body as individual electrical cylinders that allow the assessment of local muscle volume and improved whole body composition assessment[1].

Electrode placement is the same as with traditional methods except the right and left side of the body are included (8 electrodes vs 4 electrodes). In addition, the electrode protocol can be changed to a more proximal position by moving the detecting electrodes to simple anatomical locations opposite the elbow and knee. This will directly measure the upper arms and upper leg where muscle volume is the greatest.

The Quantum IV BIA instruments have an optional feature to accommodate the micro-controller driven eight lead 12 channel multiplexer that is the basis of segmental measurements. Therefore, the BIA instruments are the traditional RJL Systems phase sensitive design, portable and battery operated.

The repeatability and accuracy of the resistance and reactance measurement for each arm, leg and torso allow the smallest changes to be recorded to 0.1 ohms of resolution. In addition, detecting electrodes can be symmetrically (right and left side) re-positioned to compare local muscle groups.

The comparative characteristic from the measured resistance and reactance of right and left segments are highly significant. Segmental muscle atrophy (ALS - aging) and hypertrophy (exercise - sports) can clearly be illustrated by studying the individual arms and legs as a comparative percentage or a percent change over time. This does not require any prediction or regression equations and relies only on the measured values and their ratio (X_c/Res).

Akern Srl (Florence, Italy) pioneered a BIA system that incorporates an isolated lead switching multiplexer that can easily make segmental measurements using traditional "stick-on" electrodes. The Akern design was so successful that the company won the FIBO Innovation Award (The European Award of the Fitness and Wellness Industry - 2008). This design was based on RJL Systems OEM modules and BIA printed circuit boards (US Patent 6,631,292 B1).

Common segmental body composition analyzers (Tanita, Omron, BioSpace) incorporate foot and hand contact points that are a result of standing on four metal plates and holding two rods with the fingers and thumb of each hand. These devices have a significant disadvantage because the high resistance of the bony ankle and wrist are included in the measurement. The ankle, wrist, lower leg and forearm, have very little to do with whole body composition yet contribute more than 50 percent of the measurement[2]

1. LESLIE W. ORGAN, GILBERT B. BRADHAM, DWIGHT T. GORE, AND SUSAN L. LOZIER
Segmental bioelectrical impedance analysis: theory and application of a new technique. 0161 7567/94,
The American Physiological Society 1994

2. MARC R. SCHELTINGA, M.D., DANNYO.JACOBS, M.D., THOMAS D. KIMBROUGH, M.D.,
and DOUGLAS W. WILMORE, M.D. Alterations in Body Fluid Content Can Be Detected by Bioelec-
trical Impedance Analysis. JOURNAL OF SURGICAL RESEARCH 50,461-468 (1991)

The Quantum IV

The Quantum-IV with the multiplexed BIA cable allow multi-zone and segmental measurements to be taken quickly and easily. Software within the Quantum-IV automatically handles selecting leads and scanning multiple zones. The resistance and reactance data is saved on the Quantum-IV so it can be downloaded to a computer for analysis. With a standard BIA cable without the multiplexer, the investigator would have to physically move the leads to many sets of electrodes located on both arms and legs.

With the Quantum-IV Download Utility, retrieving the BIA data from the Quantum-IV is as easy as clicking a button. In its database, the program stores not just the BIA data, but height, weight, age, and gender - all the information one would need to develop a model for estimating body composition or any other parameter. The easy to use interface allows the investigator to view the history for an individual, and make and review comments on individual tests. When it is time to begin the data analysis, the data can easily be exported to a CSV-formatted spreadsheet for import into almost any analysis tool.

What is measured and saved for analysis (26 Data Points)

1	Right Body resistance	2	Right Body reactance
3	Left Body resistance	4	Left Body reactance
5	Lower Body resistance	6	Lower Body reactance
7	Upper Body resistance	8	Upper Body reactance
9	Right Arm resistance	10	Right Arm reactance
11	Left Arm resistance	12	Left Arm reactance
13	Right Leg resistance	14	Right Leg reactance
15	Left Leg resistance	16	Left Leg reactance
17	Right Torso resistance	18	Right Torso reactance
19	Left Torso resistance	20	Left Torso reactance
21	Transverse RA -> LL resistance	22	Transverse RA -> LL reactance
23	Transverse LA -> RL resistance	24	Transverse LA -> RL reactance
25	Whole Body resistance	26	Whole Body reactance

How Segmental BIA Works

Segmental BIA is the impedance (resistance and reactance) measurement of each arm, leg and torso using eight electrodes. The eight electrodes are positioned the same as a whole body measurement except both the right and left side are used. The selection or switching of the individual detecting and source electrodes allow the limbs (arms and legs) to be used as virtual electrodes that measure the opposite side of the body.

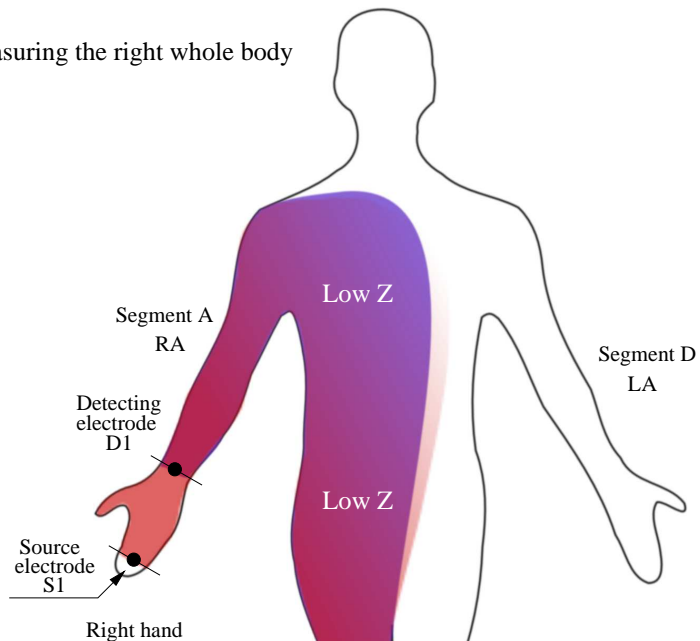
Principles of segmental BIA

measuring the right and left whole body
using eight electrode BIA

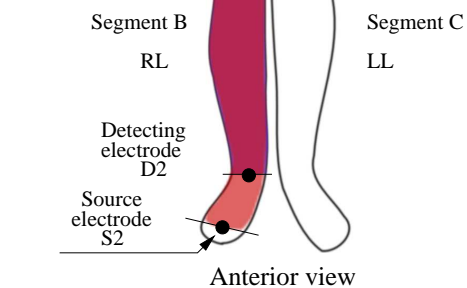
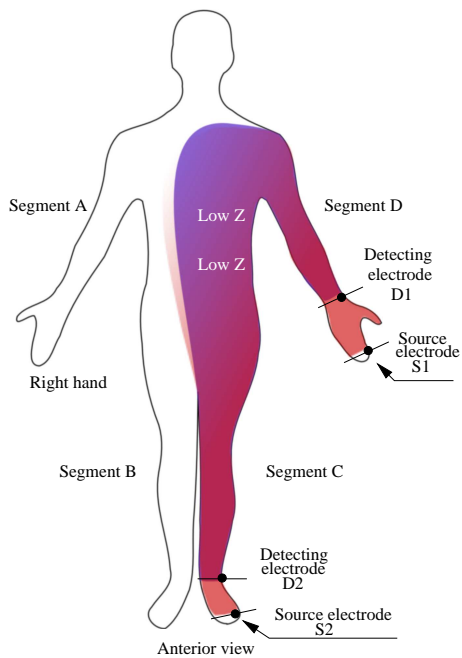
Measuring the right whole body

Blue detecting voltage sensing path
Red constant current source path

Note:
Current source and detecting voltage
paths are hypothetical and have not
been actually measured.

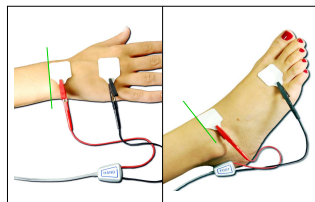


Measuring the left whole body



Active electrodes: source RA(A) RL(B), detector RA(A) RL(B)
Inactive electrodes : source LA(D) LL(C), detector LA(A) LL(C)

Active electrodes: source LA(D) LL(C), detector LA(D) LL(C)
Inactive electrodes : source RA(A) RL(B), detector RA(A) RL(B)



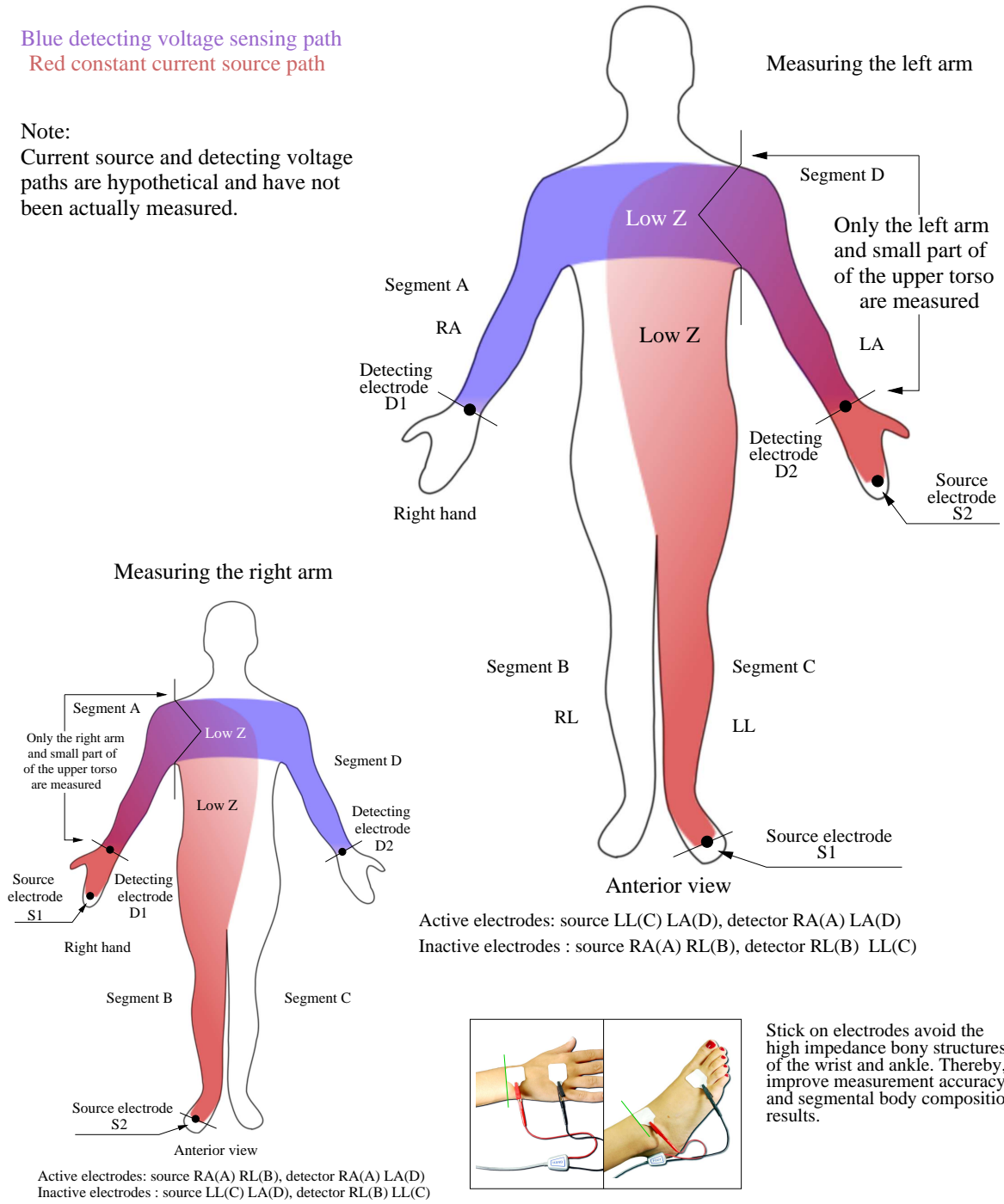
Stick on electrodes avoid the
high impedance bony structures
of the wrist and ankle. Thereby,
improve measurement accuracy
and segmental body composition
results.

Principles of segmental BIA

measuring the left and right arm
using eight electrode BIA

Blue detecting voltage sensing path
Red constant current source path

Note:
Current source and detecting voltage paths are hypothetical and have not been actually measured.

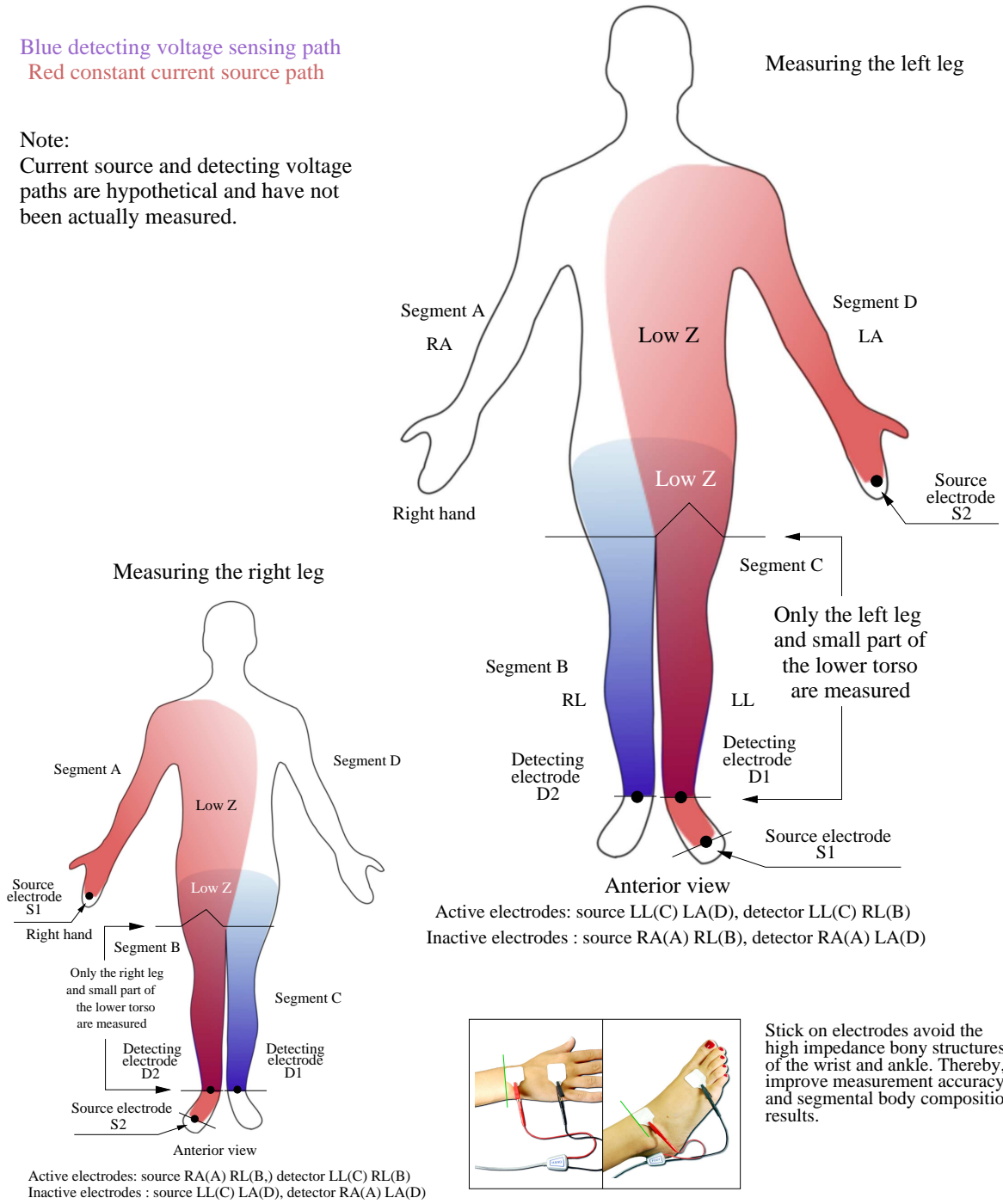


Principles of segmental BIA

measuring the left and right leg
using eight electrode BIA

Blue detecting voltage sensing path
Red constant current source path

Note:
Current source and detecting voltage paths are hypothetical and have not been actually measured.

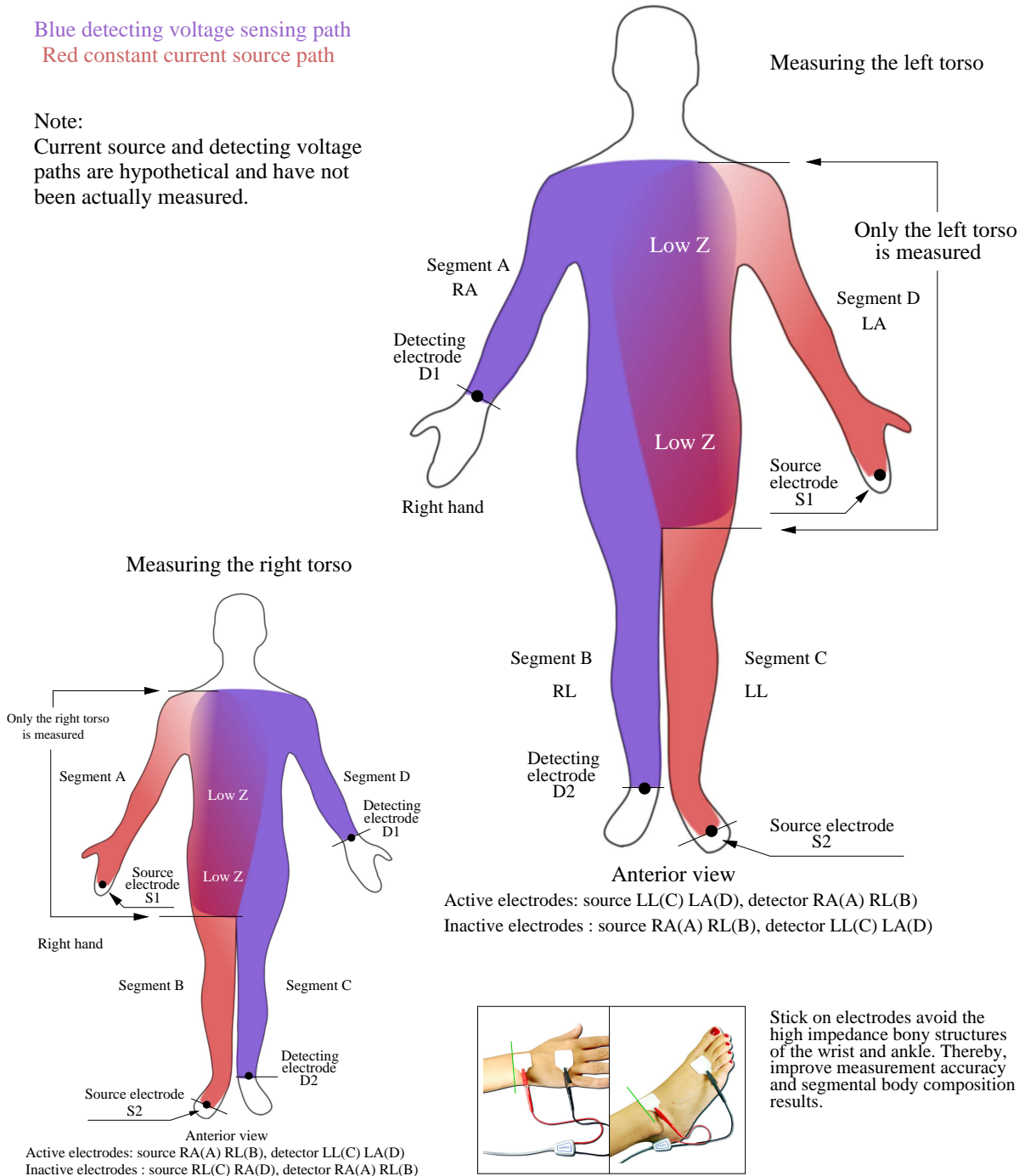


Principles of segmental BIA

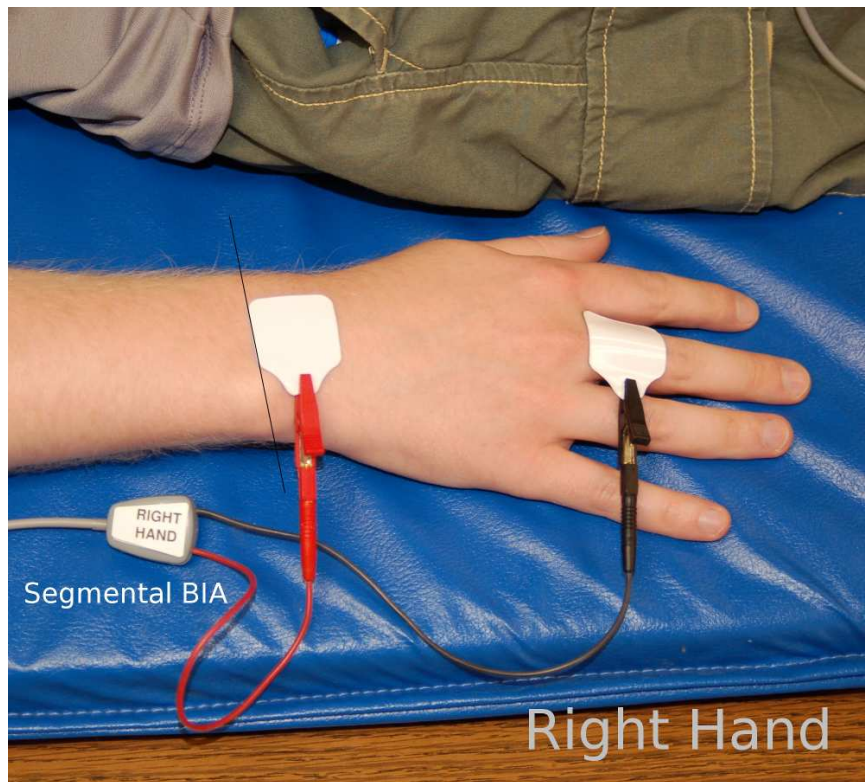
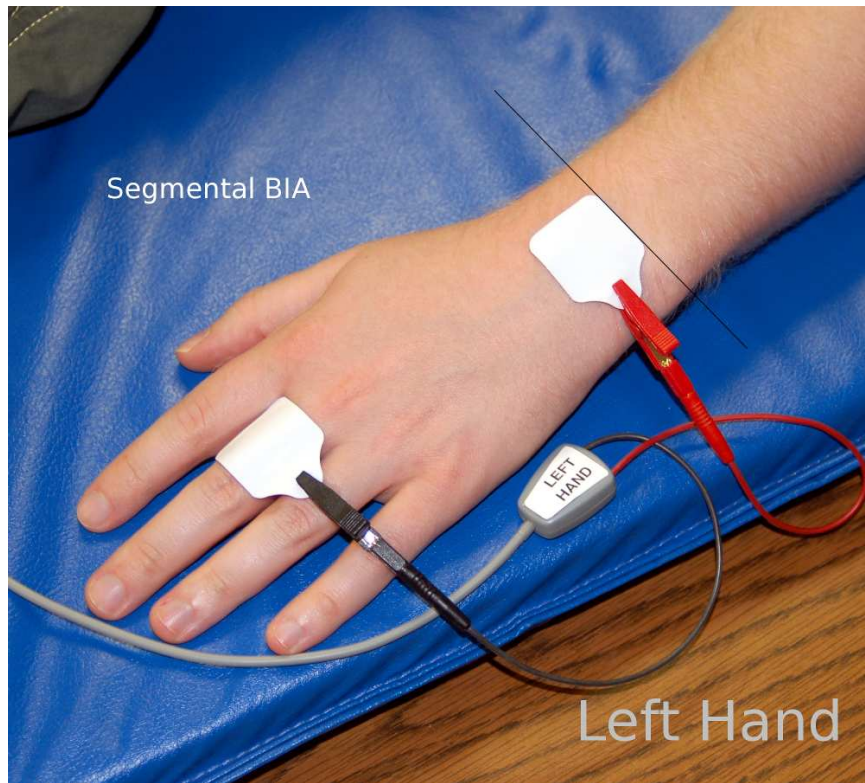
measuring the left and right torso
using eight electrode BIA

Blue detecting voltage sensing path
Red constant current source path

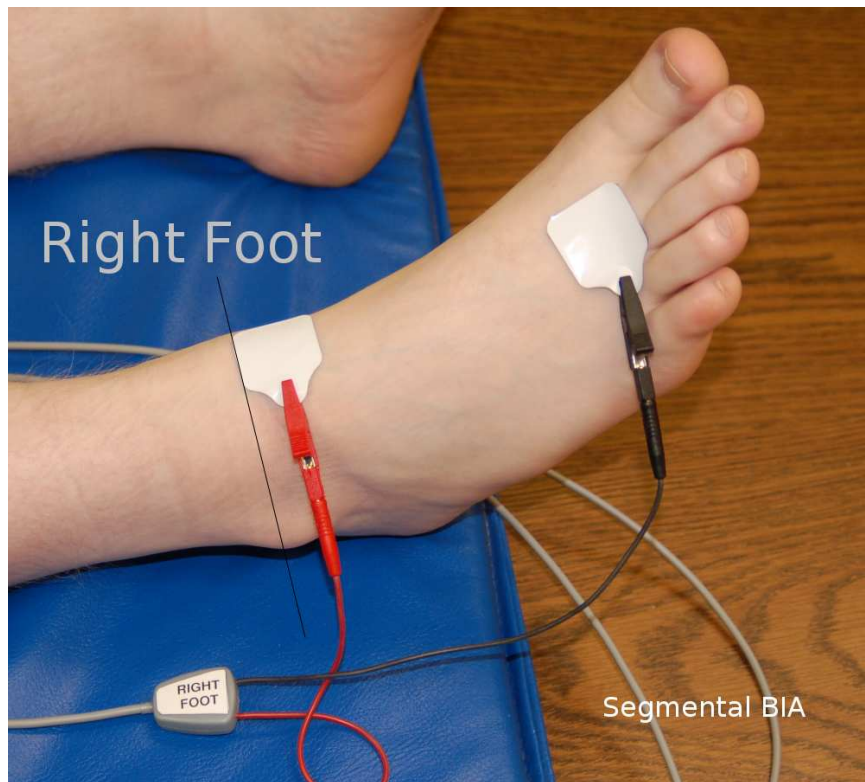
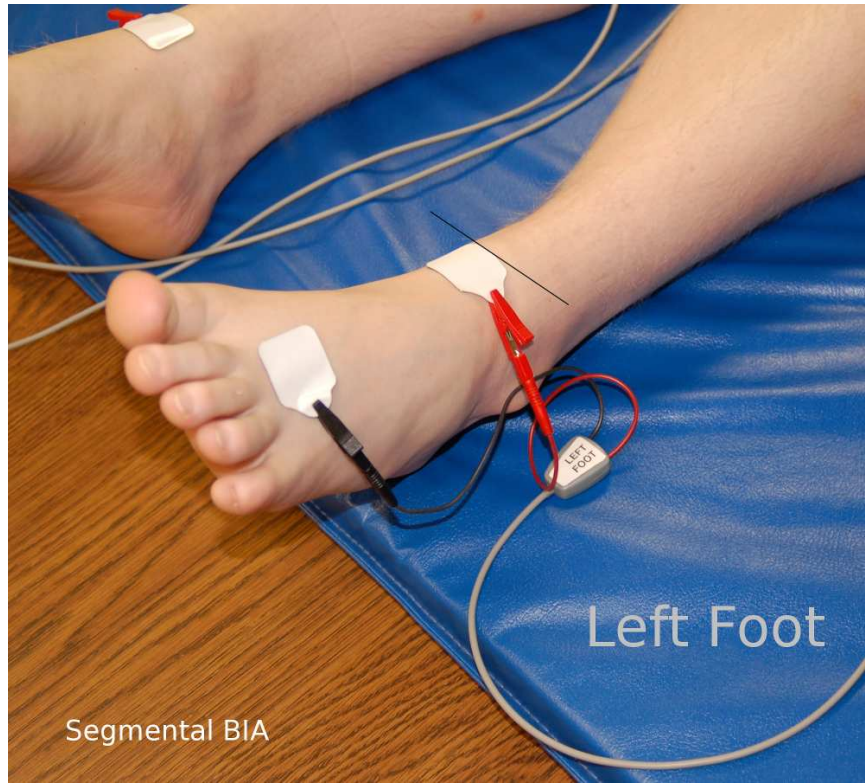
Note:
Current source and detecting voltage paths are hypothetical and have not been actually measured.



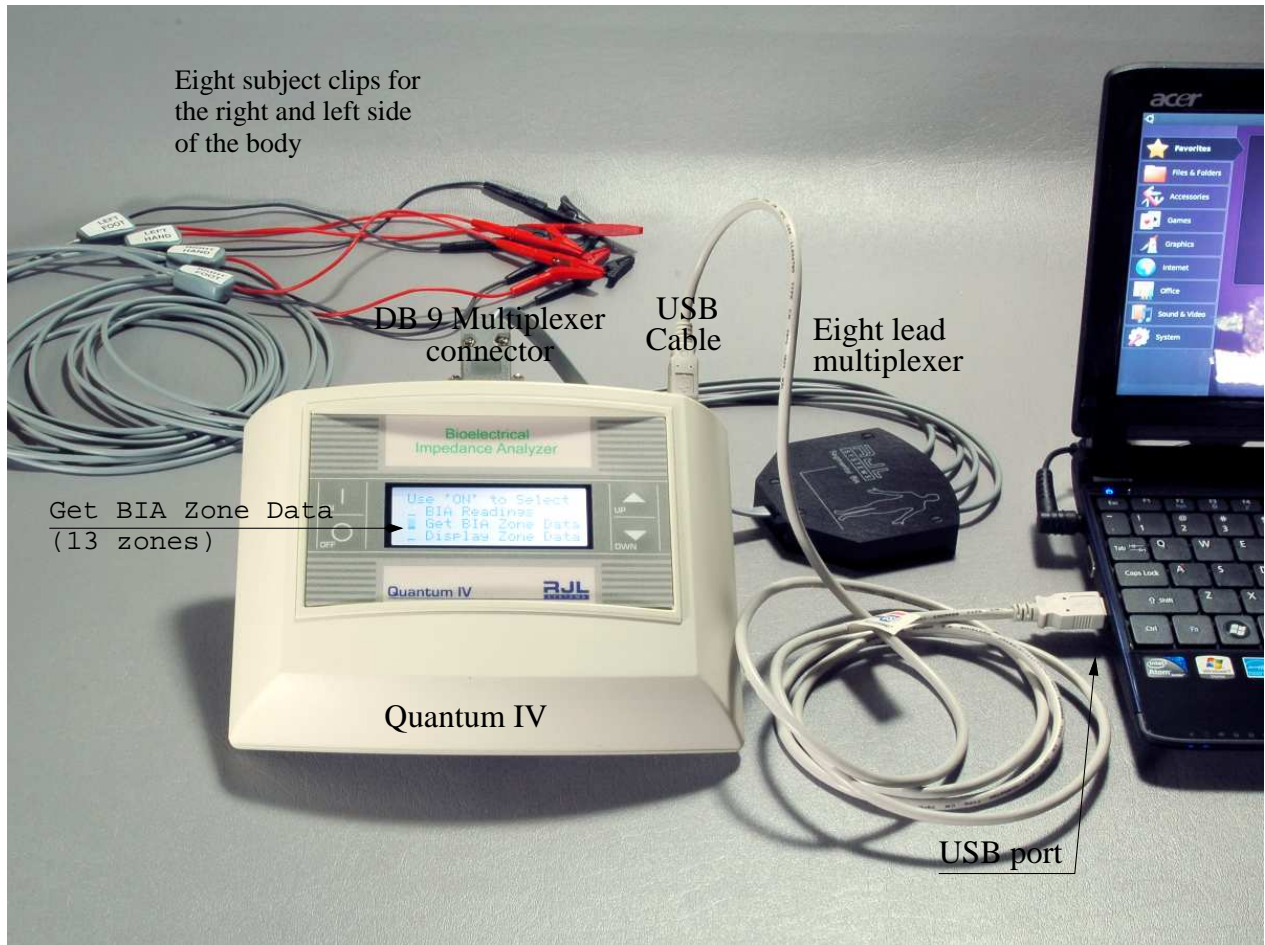
Segmental BIA left and right hand electrode placement
The detecting electrode edge is placed on an imaginary line bisecting the ulnar head (bone on the little finger side of the wrist).



Segmental BIA left and right foot electrode placement
The detecting electrode edge is placed on an imaginary line bisecting the medial malleolus (bone on the big toe side the ankle).



Connecting the Quantum IV segmental BIA instrument to a Netbook computer



Q4 downloader running on a Netbook computer with Ubuntu 10.04 Netbook edition



Eight lead 12 channel isolated BIA multiplexer



The segmental BIA systems contains the following:

- Specially modified Quantum IV BIA instrument
- Eight lead 12 channel multiplexer with four 6 ft subject leads.
- USB cable that connects the Quantum IV to the Netbook for downloading 13 BIA zones
- Acer Netbook computer model 532H dual core atom processor with 1 GB RAM and 160 GB hard drive. Operating system is Ubuntu 10.04 Netbook edition preloaded and configured with the Q4 Downloader application.
- Two "Stay Fresh" electrode packs (400 electrodes) - 50 segmental tests.
- Whole body subject cable (DB-9 connector) including manuals and CD ROM for body composition analysis (whole body).
- Quantum IV and Acer Netbook battery chargers (two).
- Quantum IV carrying case (black).
- Cost \$3490.00 with one year warranty except Netbook computer (90 days).

Getting started - the Quantum IV - Getting the BIA Zone Data

To turn the Quantum-IV on, press the 'ON' button. At any time once text has begun to display on the LCD, press the 'ON' button again to go to the main menu. Use the Up and Down arrows to move the cursor to "Get BIA Zone Data" and press the 'ON' button to begin collecting data.

If there is data from a previous test still on the Quantum-IV, it will ask for permission to replace it with the new test data. Use the arrows and the 'ON' button to answer either Yes or No. Answering No immediately exits to the main BIA readings screen without collecting any new BIA zone data.

While BIA Zone Data is being collected, the screen will display the progress through the list of thirteen zones. Once all zones have been measured (which takes about a minute) the Quantum-IV will return to the main BIA readings screen. At this point, the data is ready to be downloaded to a computer.

Getting started - the Netbook computer and Ubuntu 10.04 netbook edition

Please note:

The initial user login is **rjl** - "RJL Systems" first and last name

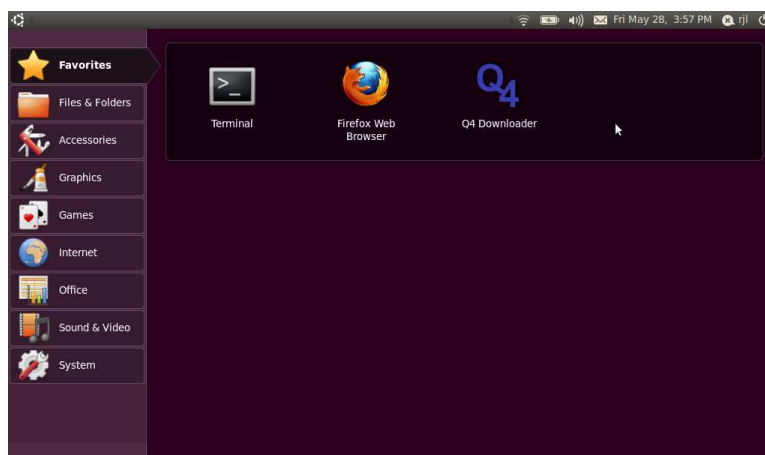
The user password is **rjlsys**

The root login is **root**

The root password is **root**

All the above login and passwords can be changed with the "users and groups" application for more convenient use. See system -> administration. In addition, the wireless WIFI connection will have to be configured with the proper WEP code, if required.

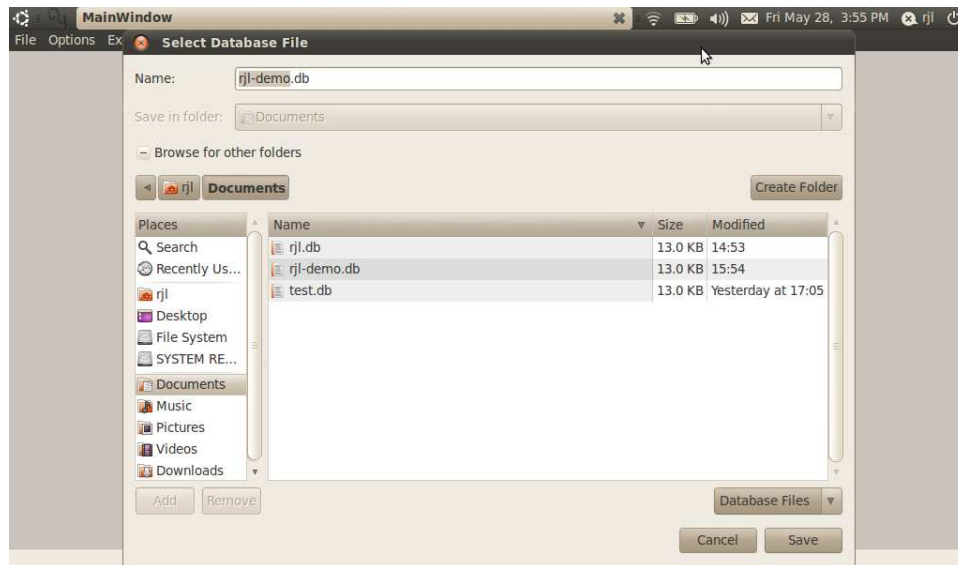
All Q4 downloader databases and exports (.db and .csv) files are stored by default in the **Documents** folder. When reading the .cvs file with Open Office or Excel, make sure the "comma" is set as a field delimitator. Data files located on the Ubuntu netbook computer are transferred to a Windows environment with a simple USB memory "stick".



Clicking on the Q4downloader application



After clicking on the Database menu selection where the RjL_demo.db is loaded, the subjects in the database will be displayed. If there are no databases, **a database must be created by entering an appropriate name in the file selector** on the top. The Q4downloader application will not start without a database to maintain subject records. Databases and subject records are activated by double clicking on them.



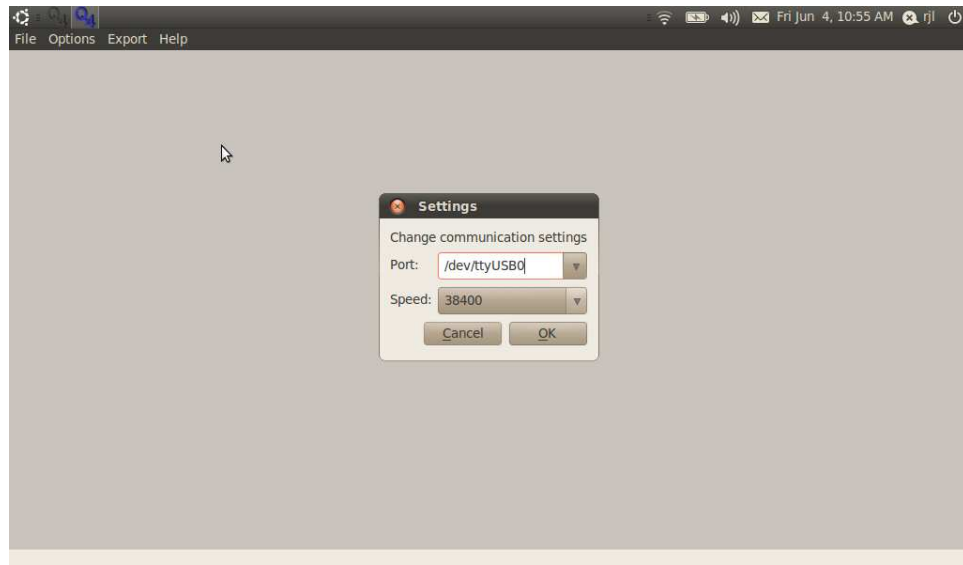
Main menu

Options:

Communications setting:

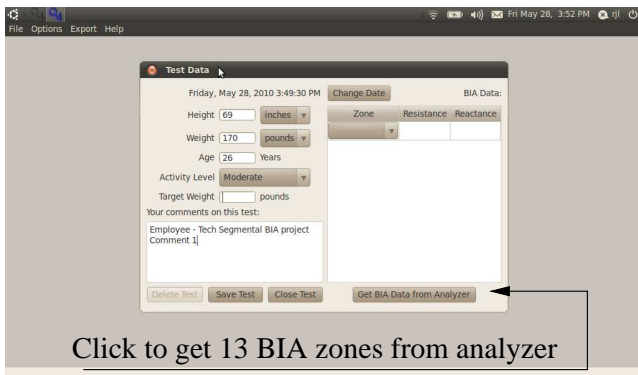
Setting

USB communications rate between the Quantum IV and the Netbook computer is set at 38400 bits/sec (38.4 Kb). The Q4downloader application will automatically detect that the USB cable has been connected to the Quantum IV and display /dev/USB0 or /dev/USB1 in the port selector. It maybe necessary to toggle between these two devices to get the system to work properly.

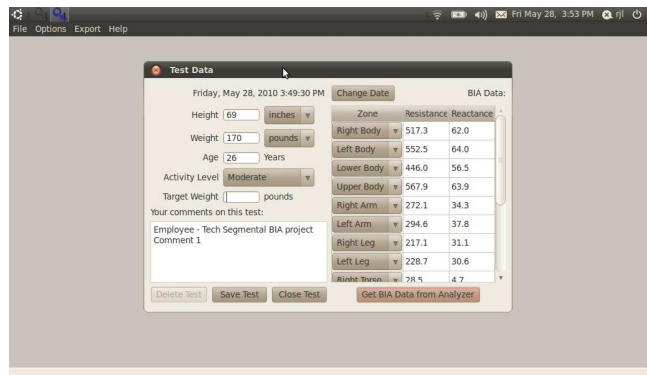


When the USB port setting are configured properly and the Quantum IV completes its 13 zone BIA scan, the saved zones are downloaded by clicking **Get BIA Data from Analyzer** at the bottom of the subject (person) record.

Before zones are downloaded

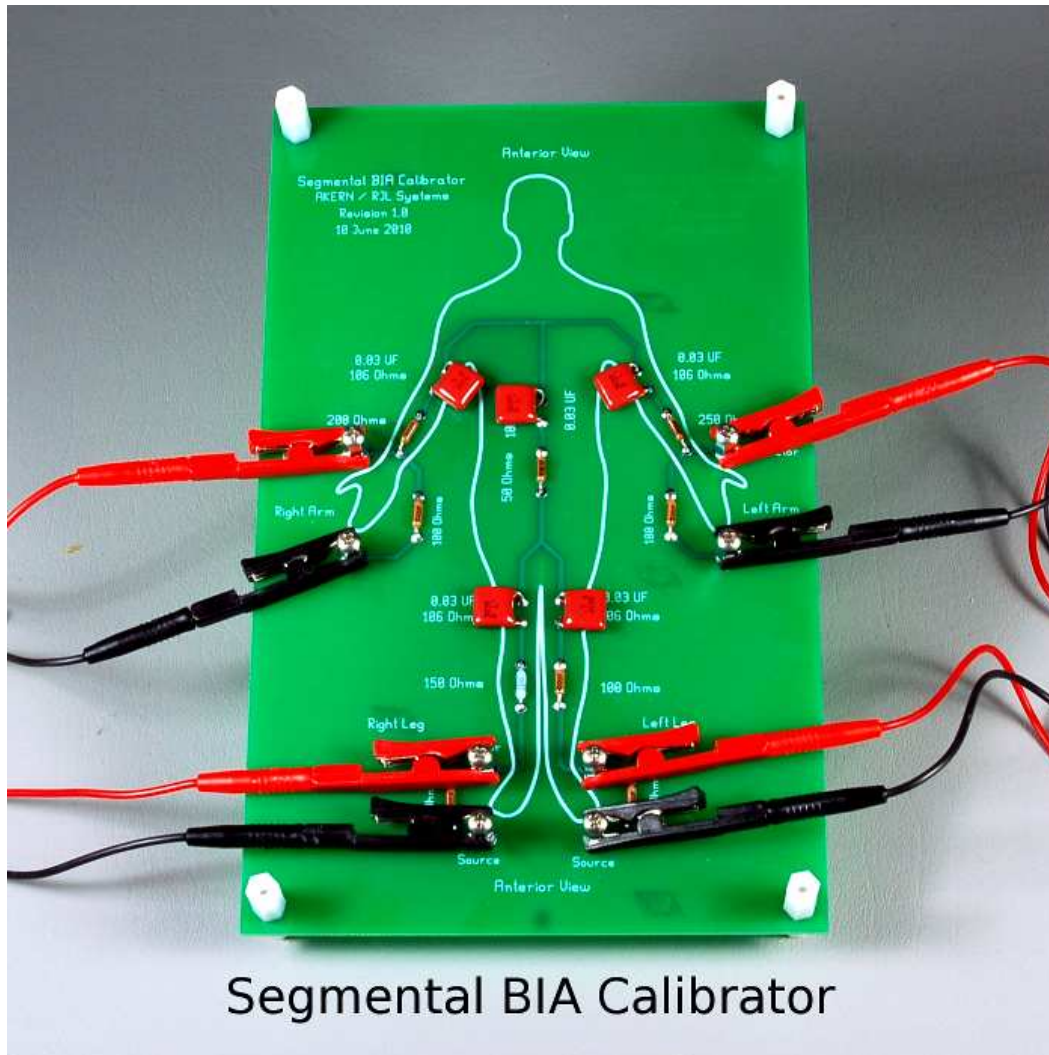


After zones are downloaded



Validating the measurements

A fundamental simulation using electronic standards is necessary to prove the Quantum IV and switching multiplexer are working properly and accurately.



This standard is a combination of series resistors and capacitors that simulate each arm and leg including the torso with known values. Each capacitor and resistor is hand selected to be better than ± 1 percent accurate. The standard is used the same as a human model and returns the same 26 values (13 zones) of resistance and reactance precisely measured for validation. A tolerance acceptance spread sheet is also included for comparison. The segmental BIA validation board is an option and can be included when requested for \$100.00.

Final results

The next three pages were copied from an Excel spread sheet to illustrate what is returned from the Quantum IV after a 13 zone scan. The labels and data were not modified. The comment field (last field) describes the parameters of each measurement. Please note that only resistance and reactance are recorded, there is no interpretation of these measurements such as fat or muscle volume of the segments.

Timestamp	First Name	Last Name	Subject ID	Age	Frame Size	Gender	Height	Height Units	Weight	Target Weight	Weight Units
5/19/2010 3:54:10 PM	Subject 1	Test 1		32	large	male	71.00	inches	255.00	0.00	pounds
5/19/2010 4:03:07 PM	Subject 1	Test 2		32	large	male	71.00	inches	255.00	0.00	pounds
5/19/2010 4:07:07 PM	Subject 1	Test 3		32	large	male	71.00	inches	255.00	0.00	pounds
5/19/2010 3:17:25 PM	Subject 2	Test 1		53	small	female	66.00	inches	120.00	0.00	pounds
5/19/2010 3:23:29 PM	Subject 2	Test 2		53	small	female	66.00	inches	120.00	0.00	pounds
5/19/2010 3:25:52 PM	Subject 2	Test 3		53	small	female	66.00	inches	120.00	0.00	pounds
5/19/2010 2:30:23 PM	Subject 3	Test 1		35	large	male	76.50	inches	218.00	0.00	pounds
5/19/2010 2:34:32 PM	Subject 3	Test 2		35	large	male	76.50	inches	218.00	0.00	pounds
5/19/2010 2:36:45 PM	Subject 3	Test 3		35	large	male	76.50	inches	218.00	0.00	pounds
5/19/2010 2:40:56 PM	Subject 3	Test 4		35	large	male	76.50	inches	218.00	0.00	pounds
5/19/2010 3:43:56 PM	Subject 4	Test 1		49	large	male	69.00	inches	200.00	0.00	pounds
5/19/2010 3:45:47 PM	Subject 4	Test 2		49	large	male	69.00	inches	200.00	0.00	pounds
5/19/2010 3:47:56 PM	Subject 4	Test 3		49	large	male	69.00	inches	200.00	0.00	pounds
5/19/2010 3:06:39 PM	Subject 5	Test 1		26	medium	male	69.00	inches	170.00	0.00	pounds
5/19/2010 3:12:47 PM	Subject 5	Test 2		26	medium	male	69.00	inches	170.00	0.00	pounds
5/19/2010 3:15:30 PM	Subject 5	Test 3		26	medium	male	69.00	inches	170.00	0.00	pounds
5/19/2010 2:48:37 PM	Subject 6	Test 1		39	medium	male	65.00	inches	175.00	0.00	pounds
5/19/2010 2:55:37 PM	Subject 6	Test 2		39	medium	male	65.00	inches	175.00	0.00	pounds
5/19/2010 2:58:01 PM	Subject 6	Test 3		39	medium	male	65.00	inches	175.00	0.00	pounds
5/19/2010 2:59:36 PM	Subject 6	Test 4		39	medium	male	65.00	inches	175.00	0.00	pounds

Activity Level	Right Body resistance	Right Body reactance	Left Body resistance	Left Body reactance	Lower Body resistance	Lower Body reactance
very light	322.8	44.2	361.1	49.4	287.8	38.3
very light	326.4	44.3	363.8	49.2	289.5	38.5
very light	322.7	43.8	360.2	49	290.7	39
very light	573.2	50.3	548.5	50.2	484.7	50.4
very light	574.5	49.5	554.6	50	486.4	49.9
very light	569.3	49.6	551.8	50	488.5	50.6
very light	427.9	61	437.4	63.8	446.2	64.8
very light	429.2	61.1	436.5	63.1	450.2	65
very light	433.2	61.2	438.7	62.7	451.1	65.4
very light	429.5	60.8	435.3	63.1	448.7	65.9
very light	440.8	62.2	436.6	64.1	408.6	56
very light	447	62.2	438.3	62.9	410.6	56.1
very light	438.5	61.4	432.7	62.9	408.6	55.9
very light	537.2	65.4	521.3	67	463.5	59.7
very light	540.1	64.9	524.2	66.7	467.4	60.3
very light	535.8	65.1	520.2	66.8	468.6	61.7
very light	526	72.8	531.2	73.6	521	72.2
very light	533.2	72.1	537.8	72	525.7	72.3
very light	532.2	72.1	537.3	72	525.6	72.4
very light	526.9	71.8	530.9	72.8	525.6	72.9

Upper Body resistance	Upper Body reactance	Right Arm resistance	Right Arm reactance	Left Arm resistance	Left Arm reactance	Left Arm resistance	Right Leg resistance
355.8	49.5	187.8	27	167.3	26.6	114.9	114.9
359.4	49.1	190.7	27	168.6	26.2	115.4	115.4
351.2	48.3	185.9	26.4	164.6	25.9	115.8	115.8
586.4	44.6	309.8	26.7	278.7	26.8	237.4	237.4
591.8	44.2	310.3	26.2	281.9	27.1	237.8	237.8
581.5	44.3	303.6	26	277.9	26.9	239.5	239.5
376.9	53.3	186.6	27.6	189.7	30	219.7	219.7
374.4	52.5	185.5	27.2	188.2	29.7	222.7	222.7
379.4	51.8	188.7	27.1	189.9	29.1	223.1	223.1
372.3	51.5	184.4	26.6	187	29.2	221.8	221.8
421.7	63.8	209.1	31.7	212.2	36.9	208	208
427	62.6	213.5	31.7	213.2	35.9	209	209
413.7	61.9	204.9	30.8	208.5	35.8	208.5	208.5
538.9	65.2	279.8	35.4	257.4	37.2	227.9	227.9
542.4	63.6	281.4	34.7	259.2	36.4	229.8	229.8
531.3	62.9	276.6	34.4	253.7	35.9	230.1	230.1
485.2	68.4	236.6	35	247.8	39.6	263	263
494.8	65.5	241.6	34.1	251.8	38.1	264.6	264.6
493.9	65.3	241.1	34	251.8	37.9	265.4	265.4
480.8	65.5	234.8	33.8	245.1	38	265.5	265.5

Right Leg resistance	Left Leg resistance	Left Leg reactance	Right Torso resistance	Right Torso reactance	Left Torso resistance	Left Torso reactance
17.3	172.7	23.7	20.4	4.4	20.1	4.6
17.3	173.8	23.9	20.6	4.5	20.5	4.7
17.6	174.4	24.2	20.3	4.4	20.3	4.6
28.6	246.6	27.7	27.2	4.2	26.9	4.2
28.4	248.2	27.5	27	4.2	26.7	4.2
28.9	248.8	27.7	27.3	4	27	4
35.1	225.5	35.3	21.6	4.5	21.5	4.5
35.7	226.5	35	21	4.5	20.9	4.4
35.8	227.2	35.3	21.3	4.5	21.3	4.4
36	225.9	35.5	22	4.4	22	4.3
32.1	201.1	28.5	24	5.1	24.6	4.8
32	201	28.3	23.7	5.1	24.3	4.8
31.9	199.6	28.2	24.4	5.1	25	4.8
32.8	234.6	32.3	28.4	5.4	28.4	5.4
33	236.3	32.8	28.2	5.5	28.2	5.5
33.7	237.9	33.7	28.5	5.2	28.5	5.2
41.4	257.1	37.4	27.2	4.6	27	4.5
41.6	259.3	37.6	26.8	4.5	26.6	4.5
41.8	259.5	37.6	26.8	4.5	26.6	4.5
41.7	259.4	38.3	27.5	4.4	27.4	4.4

-3-

RA -> LL resistance	RA -> LL reactance	LA -> RL resistance	LA -> RL reactance	Whole Body resistance	Whole Body reactance
381.3	51.3	302.6	42.5	179.2	25.4
384.8	51.6	305.1	42.2	180.9	25.4
380.3	51	300.6	42	178.4	25.1
580.7	51.4	541	47.9	295.3	27.9
584.3	51	546.1	47.8	296.8	27.7
578.9	50.8	544.5	48.2	295.5	27.7
433.6	62.8	431.5	61.1	227.3	34.1
433	62.2	432.8	61.4	227.3	34
437.4	62.4	434.9	60.9	228.8	33.9
432.3	62	431.6	61.2	227.1	33.8
434.2	60.8	443.2	65.7	232.9	37.1
438.4	60.9	445.1	64.8	234.7	37.7
428.8	59.9	440.1	64.8	231.1	37.3
543.1	67	514.1	64.7	279.8	36.8
547	66.9	518.4	64.5	281.4	36.8
543.3	67.2	512.7	64.5	279.2	36.7
519.8	71.6	538.2	74.4	278.7	39.7
526.8	70.6	544	72.6	281.4	39.4
527.1	70.7	544.5	72.8	281.6	39.5
521.4	71.2	539.2	73.1	279.1	39.5

Comments

Norma supine position
 Leg separation 10 in
 Hip > Rt arm 6 in
 Hip > Lt arm 6 in
 ankles 15, wrists 12
 Legs and arms closed in
 ankles 8, hip->right 4.5, left 6
 ankles 15, wrists 12
 close
 ankles - 6", right wrist 3.5, left wrist 4.5
 ankles 15",
 ankles 15", wrists 12"
 _limbs close
 ankles 12, wrists 7
 ankles 15, wrists 12
 close
 ankles 6.5, right wrist 5.5, left 6
 ankles 15, wrists 12
 close
 ankles 7 (post moving), wrists 5
 ankles 15", wrists 12
 _ankles 15, wrists 12
 limbs close