A New Method of Classifying Adiposity Using Height, Volume and Surface Area

Introducing the ***Barix***^{sm}

Part I

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Introduction

It has always been difficult to *quantify* the shape of the body. Known methods of categorization can be misleading. For example, the Body Mass Index, or BMI, can falsely categorize a bodybuilding athlete as obese. Various other ratios have also been employed to give an indication of the general shape of the body. The waist-to-hip ratio is one such common calculation. In general, it is thought that a waist-to-hip ratio of less than 1 indicates a favorable shape, the lower the number, the more ideal the shape. Thus an obese person with a waist-to-hip ratio of 0.70 could be thought to be more ideal than a person of shapely frame with a waist-to-hip ratio of 0.80. One reason for misclassification is that these traditional calculations do not take into account the subject's volume and surface area information.

The search for a "universal" value that quantifies and classifies a subject's general level of adiposity has been uncovered with the help of modern 3D body scanning technology. It is well known within the medical community that the shape of the torso is an excellent proxy for the overall shape of a subject. This new technique utilizes the subject's torso height, torso volume and torso surface area to calculate a *dimensionless* value known as the ***Barix***^{sm}. A subject's ***Barix***^{sm} can be compared to the ***Generalized Barix Scale***^{sm} to determine where the subject's ***Barix***^{sm} falls within the general population. The ***Generalized Barix Scale***^{sm} classifies the degree of adiposity for the general adult population. Moreover, by monitoring the changes to the subject's ***Barix***^{sm}, known as the ***Barix Trajectory***^{sm} and the ***Barix Rate of Change***^{sm}, medical, fitness or nutrition professionals can determine the direction and pace of weight loss or weight gain over a period of time.

Medical disciplines can use ***Specialized Barix Scales***^{sm} to classify the degree of adiposity for particular subjects of interest. ***Specialized Barix Scales***^{sm} include but are not limited to ***The Bariatric Index, The Pediatric Index, The Obstetric Index, The Geriatric Index, The Diabetic Index and the Anorexic Index.*** Monitoring the changes to the ***Barix, Barix Trajectories*** and ***Barix Rates of Change*** of subjects within a ***Specialized Barix Scale*** can assist the medical professional in determining whether the subject is experiencing a normal growth pattern, a normal aging pattern or help understand when a subject has responded to surgery or treatments to such a degree that the subject has moved out of a ***Specialized Barix Scale*** and into the ***Generalized Barix Scale***.

Another practical use of the ***Barix, Barix Trajectory*** and ***Barix Rate of Change*** is to help monitor the recovery progress of subjects that have undergone a surgical procedure affecting general body contours. Examples of such surgical procedures include bariatric surgery, as well as aesthetic contouring procedures such as breast augmentation, breast reduction/reconstruction, abdominoplasty and lipoplasty.

The *Barix* and the Relationship between Volume and Surface Area and Height

To understand the ***Barix***, one must move beyond common circumferential measurements such as waist, hips, bust and chest, measured in centimeters into the realm of squared centimeters and cubic centimeters.

Surface area measurements are made in centimeters, squared (cm^2), volume measurements are made in centimeters, cubed (cm^3). It is important to note that there is no direct relationship between volume and surface area. As an example, a sheet of paper has a large surface area, but because it is thin, it occupies a correspondingly small volume.

The formula for calculating the ***Barix*** is:

$$\textbf{\textit{Barix}} = \frac{\text{TORSO HEIGHT (CM)}}{\left[\dfrac{\text{TORSO VOLUME (CM}^3\text{)}}{\text{TORSO SURFACE AREA (CM}^2\text{)}}\right]}$$

The (torso volume/torso surface area) product reduces to centimeters in the denominator. The torso height units are in centimeters, which cancels the centimeters in the denominator, leaving a *dimensionless* value.

The ***Barix*** is a *descending* value, the smaller the ***Barix***, the greater the subject's degree of adiposity.

Before calculating the ***Barix*** values for particular subjects, it is appropriate to understand how the ***Barix*** changes for a simple shape.

The examples below begin with a simple cylinder closed at each end. The cylinder height, volume and surface area are calculated using tools within a 3D CAD program.

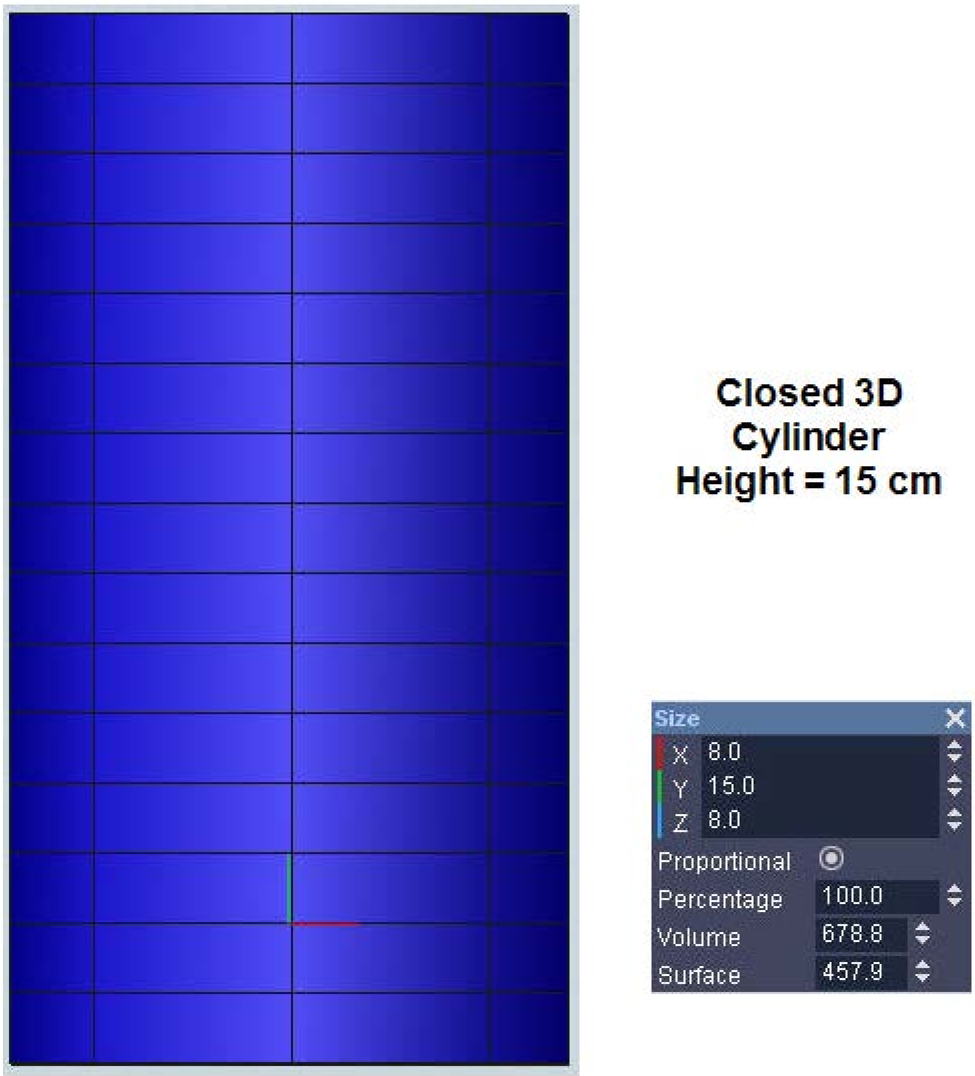
The ***Barix*** is calculated for this initial cylinder. Using tools in the CAD program, the cylinder was gradually shaped into the form of a torso.

The ***Barix***, volume and surface area for each example were then tabulated.

From these examples, one can see that the ***Barix*** increases as the torso begins to take shape. It can also be seen that the volume and surface area change at different rates with respect to each other.

Figure 1 depicts a closed cylinder, along with its dimensions, volume and surface area.

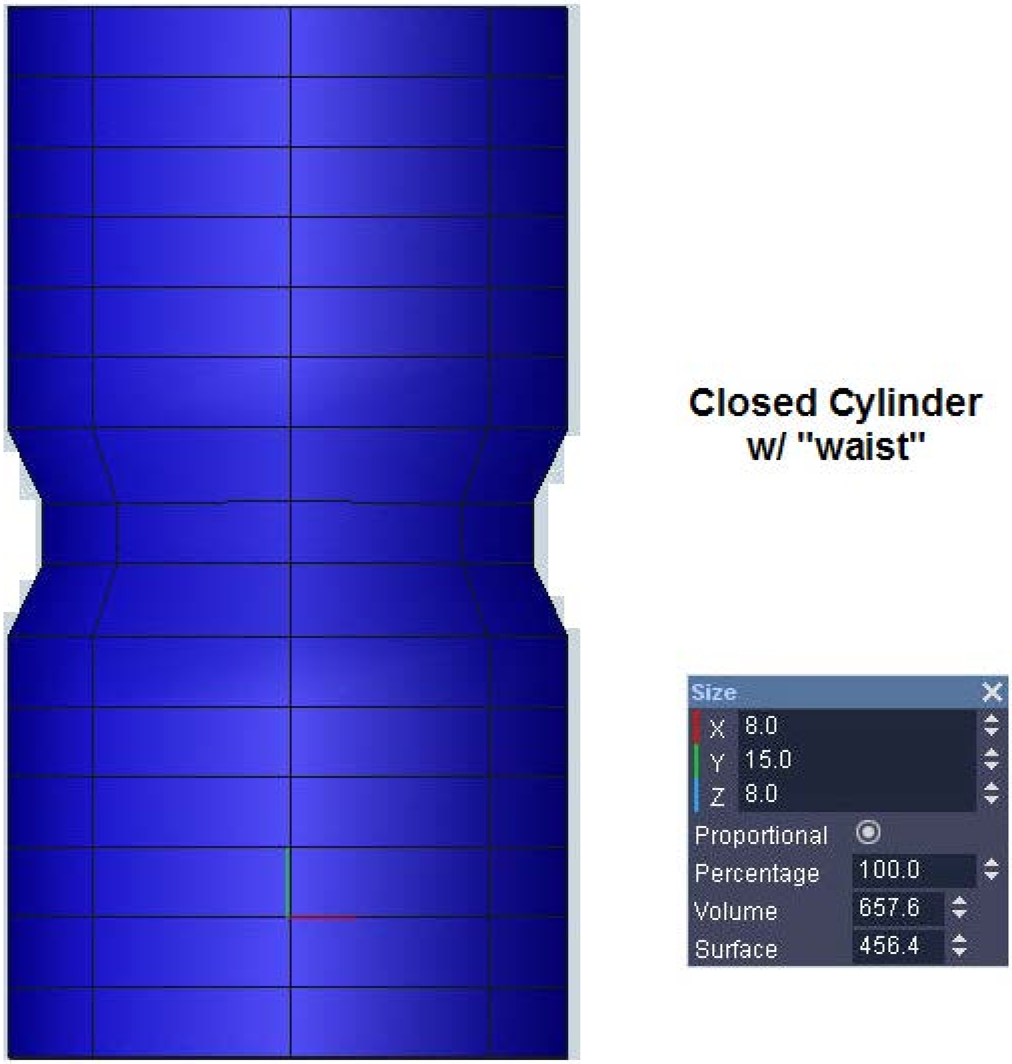
Figure 1
Closed Cylinder, Dimensions, Volume and Surface Area



Note that the volume of the cylinder is 678.8 cm^3 and the surface area is 457.9 cm^2.The ***Barix*** for this cylinder is (15 cm/(678.8 cm 3 /457.9 cm^2)), or 10.119.

Figure 2 depicts the creation of a “waist” in the middle of the cylinder.

Figure 2
Creating a “waist” in the middle of the cylinder



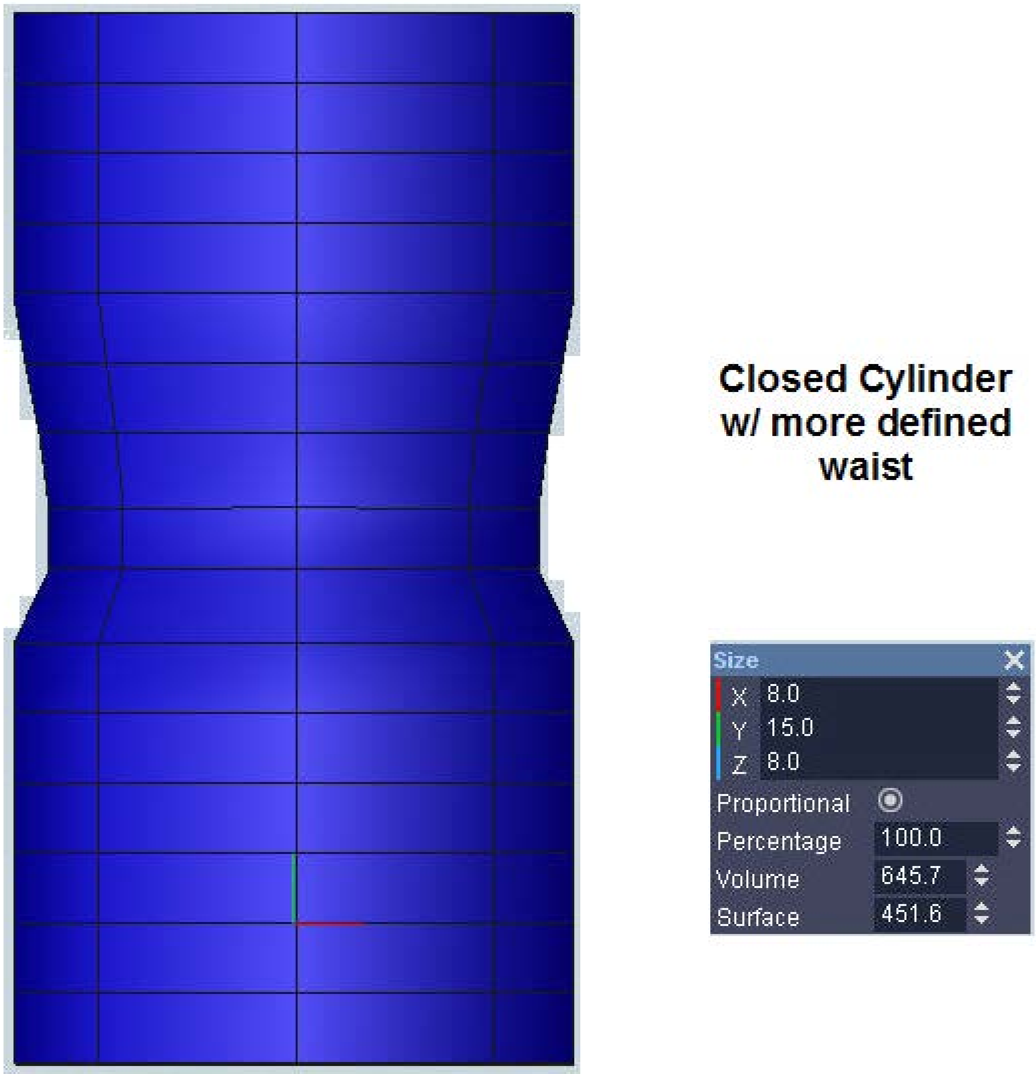
In this case, the volume changed from 678.8 cm^3 to 657.6 cm^3, a difference of 22.2 cm^3. The surface area changed only slightly from 457.9 cm^2 to 456.4 cm^2.

The ***Barix*** for this example is (15 cm/(657.6 cm^3 /456.4 cm^2)), or 10.411.

The ***Barix*** has increased from 10.119 to 10.411, indicating an improving "shape".

Figure 3 depicts shaping the "waist" of the cylinder further.

Figure 3
Further Shaping of the Cylinder's "Waist"



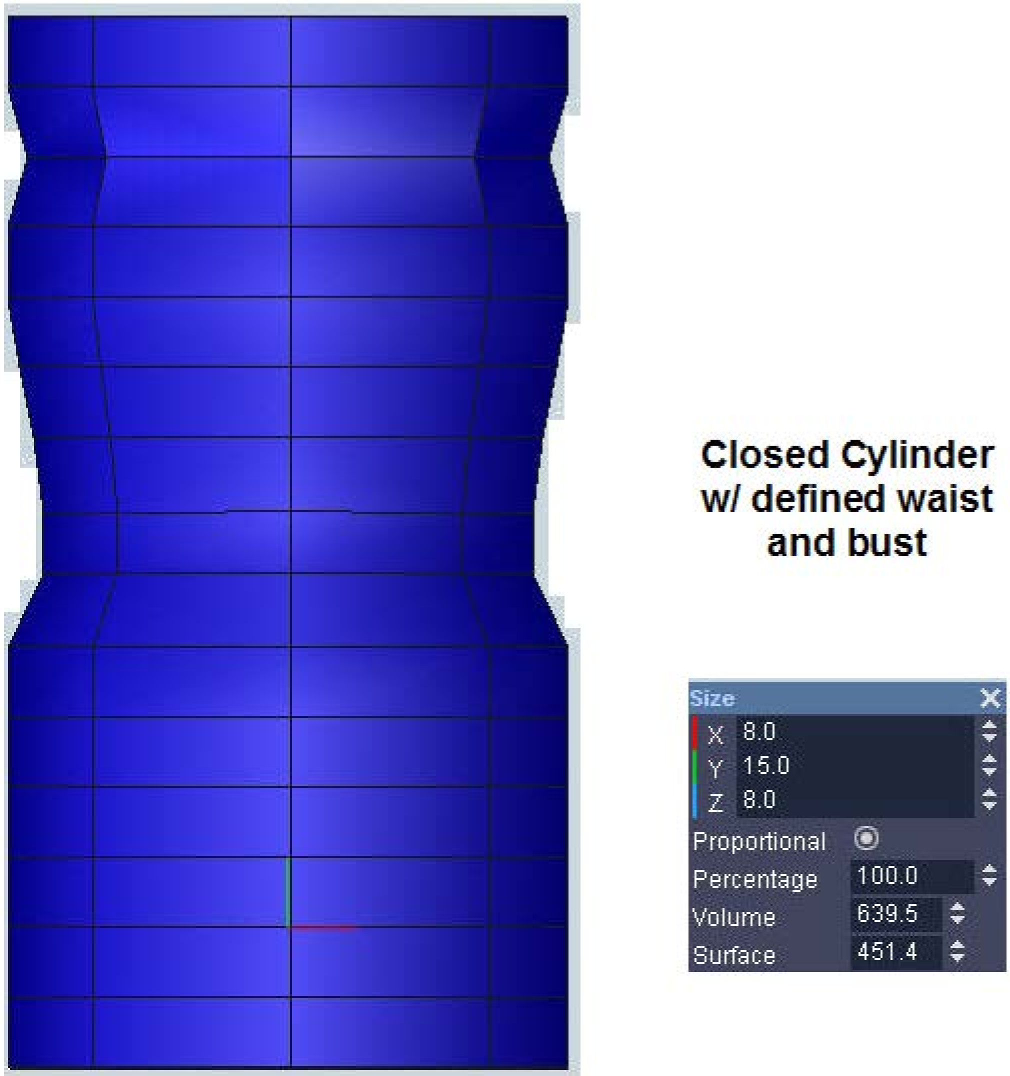
In this case, the volume changed from 657.6 cm^3 to 645.7 cm^3, a difference of 9.9 cm^3. The surface area changed from 456.4 cm^2 to 451.6 cm^2.

The ***Barix*** for this example is (15 cm/(645.7 cm^3 /451.6 cm^2)), or 10.491.

This is an improvement from a ***Barix*** of 10.411 to 10.491.

Figure 4 depicts shaping the cylinder further by introducing a “bust”.

Figure 4
Shaping the Cylinder Further by Introducing a “Bust”



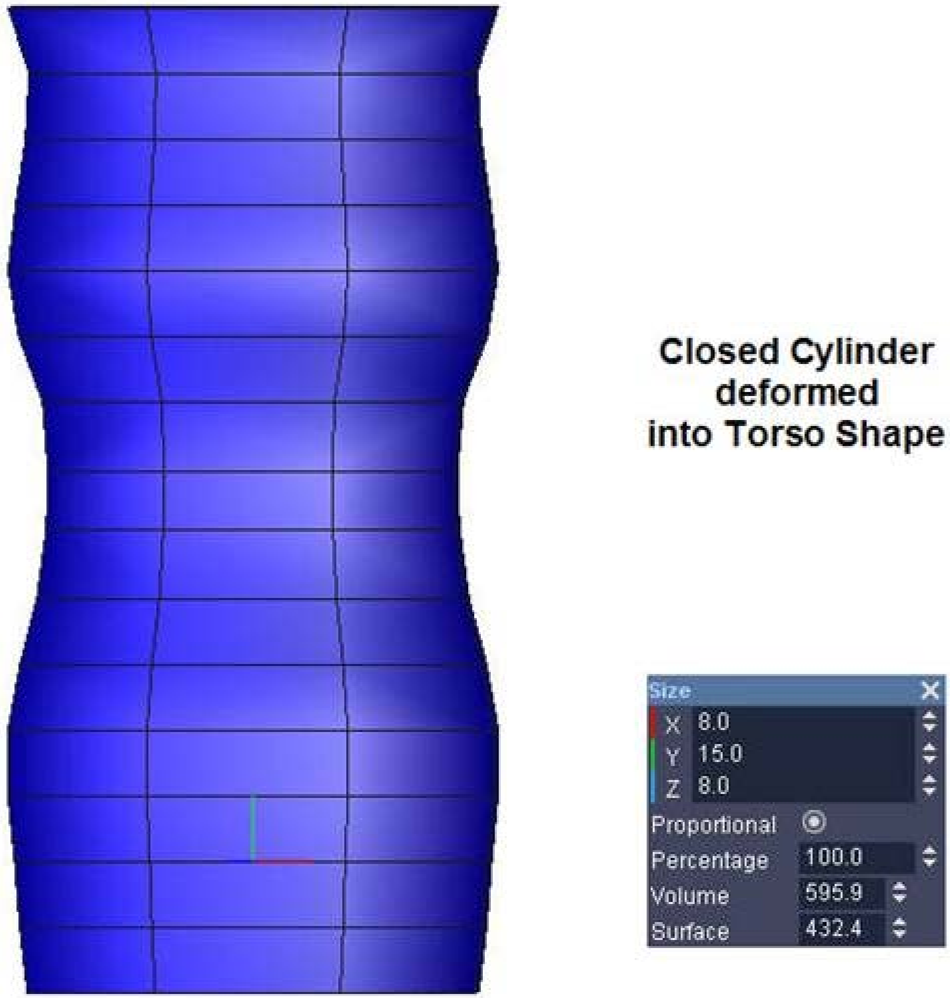
In this case, the volume changed from 645.7 cm^3 to 639.5 cm^3, a difference of 6.2 cm^3. The surface area changed from 451.6 cm^2 to 451.4 cm^2.

The ***Barix*** for this example is (15 cm/(639.5 cm^3 /451.4 cm^2)), or 10.590.

This is an improvement from a ***Barix*** of 10.491 to 10.590.

As a final example, Figure 5 depicts the cylinder formed into a torso.

Figure 5
The Cylinder Formed into a Torso



In this case, the volume changed from 639.5 cm^3 to 595.9 cm^3, a difference of 44.6 cm^3. The surface area changed from 451.4 cm^2 to 432.4 cm^2.

The ***Barix*** for this example is (15 cm/(595.9 cm^3 /432.4 cm^2)), or 10.884.

This is an improvement from a ***Barix*** of 10.590 to 10.884.

Table 1 tabulates the cylinder examples.

Table 1
Tabulating the Cylinder Examples

Description	**Volume**	**Surface Area**	***Barix***
Cylinder	678.8	457.9	10.119
Cylinder/Waist 1	657.6	456.4	10.411
Cylinder/Waist 2	645.7	451.6	10.491
Cylinder Waist/Bust	639.5	451.4	10.590
Cylinder as Torso	595.9	432.4	10.884

Close examination of Table 1 indicates that there is no direct (linear) relationship between the volume and surface area of the cylinder as the cylinder undergoes transformation. In each successive example, the ***Barix*** of the cylinder is increasing as the cylinder is transformed from its original shape to a shape resembling a torso.

This is an important concept to understand when calculating the ***Barix*** of a particular subject.

In general, obese people have a ***larger (torso volume/torso surface area)*** product than thinner people.

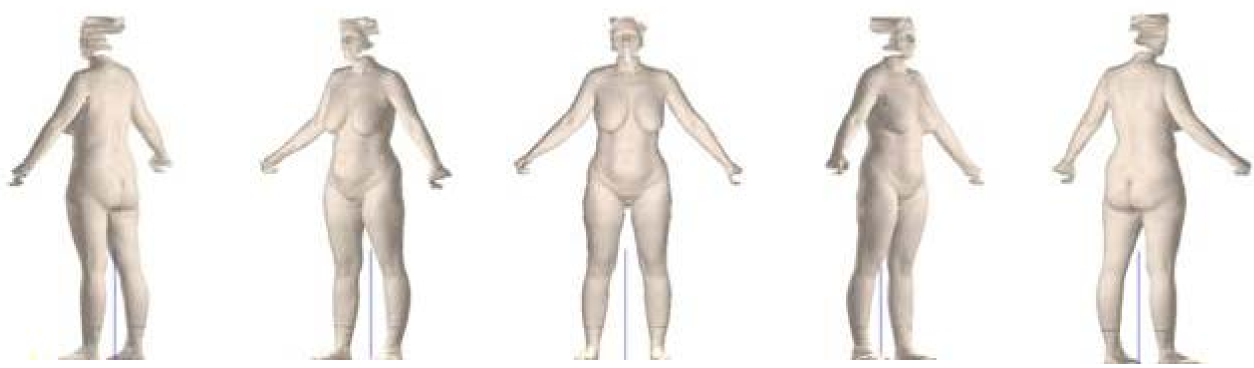
Put another way, obese people have a larger torso volume ***relative*** to their torso surface area and thinner people have a larger torso surface area ***relative*** to their torso volume.

Barix **Calculation Examples**:

The following are examples of calculating the ***Barix*** . There are five examples in total. The first example details the determination of the torso, the torso height value, and how the torso surface area and torso volume are calculated. Other ***Barix*** calculations are made for a morbidly obese subject, an endomorphic body type, a mesomorphic body type and an ectomorphic body type.

Figure 6 depicts views of a three-dimensional scan image. This scan image was produced by a [TC][2] white light scanner, provided by Novaptus Systems, Incorporated. The calculations and statistical computations were also provided by Novaptus Systems, Incorporated.

Figure 6
Composite Images of Subject's Three Dimensional Scan Shown in "Surface" Mode



Linear and circumferential measurements as well as measurement height locations can be extracted from the 3D scan image by applying a programmable measurement-specific Measurement Extraction Profile (MEP) to the scan image. In this fashion, hip, waist, abdomen, chest, bust circumferential among other measurements can be automatically extracted and documented. For further information on Measurement Extraction Profiles applied to particular surgical procedures, refer to www.novaptus.com.

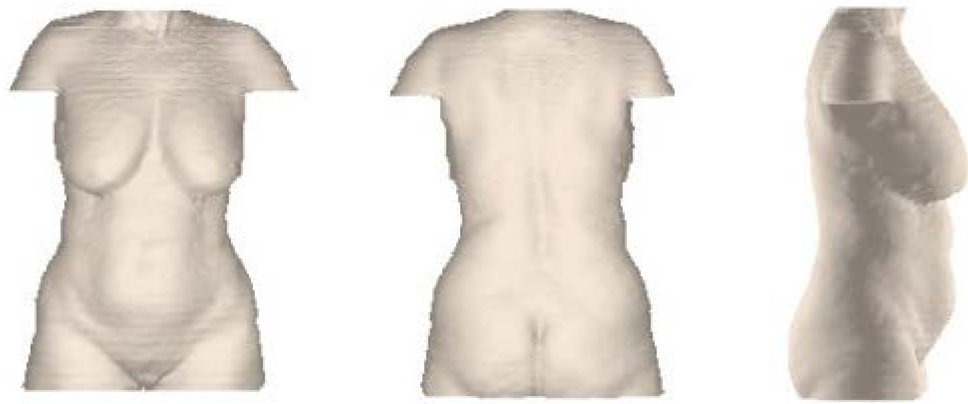
A Measurement Extraction Profile file has been programmed to determine the torso height, torso surface area and torso volume.

For ***Barix*** calculation purposes, the torso is defined to be between the front of the neck location and slightly under the buttocks, known as the *crotch point*. This torso definition excludes the head, arms, hands, leg and feet, but includes the entire buttocks area.

Torso height is calculated by finding the back of neck height point and the crotch point as measured from the floor.

Figure 7 depicts the torso of the subject.

Figure 7
Composite Images of the Subject's Torso



The MEP file slices the torso into 1 cm "segments". Each segment is integrated around its surface contour by using a finite triangular summation to calculate the surface area of each segment. Each slice segment is then closed on the top and bottom, treated as a solid, and integrated within to calculate the volume of each segment.

For illustrative purposes, Figure 8 depicts the torso sliced into 1 cm segments. Note that the torso surface area and volume calculations are made along the *contours* of the torso.

Figure 8
The torso sliced into 1 cm segments.

The output of this Measurement Extraction Profile consists of the height of the torso segments, along with each segment's surface area and volume.

The overall torso height is calculated by determining the difference, in centimeters between the crotch point and the back neck point. The total torso surface area is calculated by summing each segment's surface area value. The total torso volume is calculated by summing each segment's volume value.

Table 2 below depicts the output of the Measurement Extraction Profile used to determine Torso Height, Torso Surface Area and Torso Volume.

Table 2
Subject's Torso Height Segments and Associated Volume and Surface Area

Units = centimeters, volume in CC		
Torso		
Height	Volume	Surface Area
69	265.5	63.9
70	642.9	111.3
71	680.2	109.9
72	697.2	108.3
73	709.5	106.3
74	721	105.2
75	722.2	104.3
76	721.6	103.4
77	719	102.4
78	713.2	101.7
79	708.4	101.7
80	708.5	100.7
81	716.2	100.2
82	722	100
83	719.8	99.3
84	712.4	98.6
85	697.7	97.4
86	679.3	96.3
87	660.8	95.1
88	639.6	93.7
89	614.8	92.1
90	587.4	90.1
91	555.9	87.3
92	526	84.4
93	507.6	82.6
94	500	81.8
95	492.1	81
96	485.2	80.3
97	476.6	79.4
98	465.7	78.5
99	460.1	78
100	458.6	77.9
101	462.8	80.5

102	499.7	88.3
103	517.1	93.8
104	539.3	96.1
105	629.6	99
106	645.1	99.8
107	660.4	100.1
108	675.1	100
109	676.1	99.4
110	672.8	98
111	664.3	96.6
112	654.9	95.6
113	649	94.9
114	641.8	94.5
115	632.6	93.9
116	626.5	93.2
117	611	92
118	595.9	91.2
119	581.5	90.5
120	562.5	89.6
121	536.6	88.1
122	513.3	87.3
123	481.8	85.3
124	454.8	84.2
125	424.1	82.7
126	395.3	81.2
127	360.9	79
128	327	77.4
129	286.1	74.4
130	233.2	68
131	170.6	55.4
62	36068.7	5743.1

The last row indicates that the subject's torso height is 62 cm, the subject's torso volume is 36068.7 cubic centimeters and the subject's torso surface area is 5743.1 centimeters, squared. The crotch point is located 69 cm from the floor, and the back neck point is located 131 cm from the floor, for a difference of 62 cm.

The ***Barix*** is calculated using the formula:

$$\text{Barix} = \frac{\text{Torso Height}}{\left\langle \dfrac{\text{Torso Volume}}{\text{Torso Surface Area}} \right\rangle}$$

Accordingly, the subject's ***Barix*** is (62)/(36068/5743), or 9.872. The ***Barix*** is a dimensionless quantity.

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Part II

Morbidly Obese Example Subject *Barix* Calculation:

Figure 10 depicts a scan image of a morbidly obese subject.

Figure 10
Scan Image of Morbidly Obese Subject

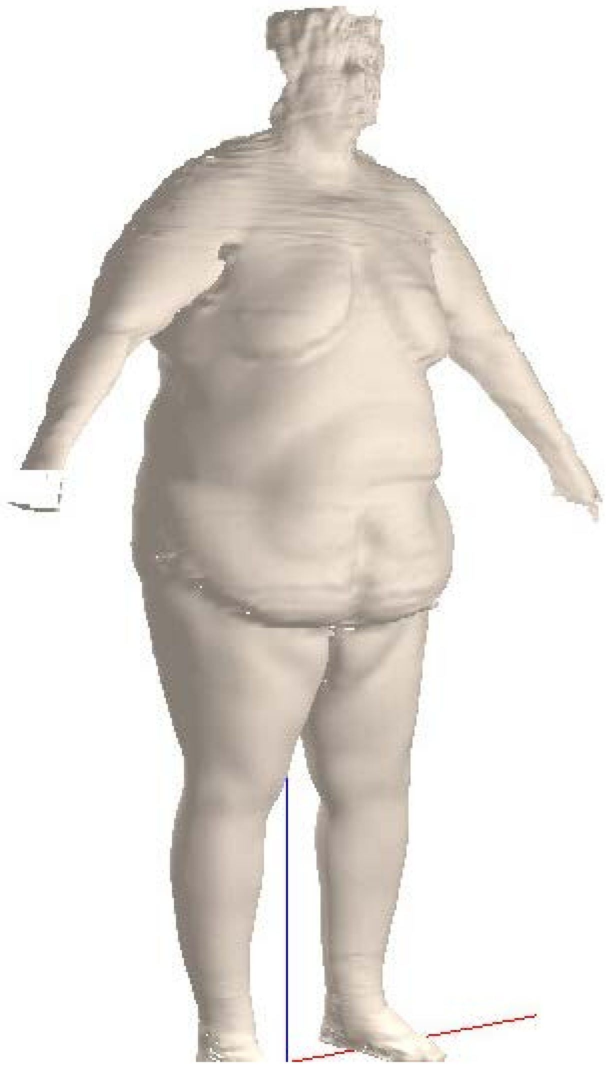

Figure 11 depicts the morbidly obese subject's torso. It is to be noted that the head is not included in the torso height, surface area and volume calculations.

Figure 11
Scan Image of Morbidly Obese Subject's Torso

Table 3 depicts the torso height segments, and long with each segment's surface area and volume calculations.

Table 3
Morbidly Obese Subject's Torso Height Segments and Associated Volume and Surface Area

Units = centimeters, volume in CC		
Torso		
Height	Volume	Surface Area
66.7	528.2	64.8
67.7	1140.9	132.2
68.7	1230.1	136.2
69.7	1223	137.6
70.7	1342	138.8
71.7	1418.7	140.4
72.7	1445.2	141.8
73.7	1447.5	142.9
74.7	1506.2	144.5
75.7	1500.5	144.8
76.7	1540.7	145.7
77.7	1599.7	146.8
78.7	1630.9	147.3
79.7	1635.7	146.6
80.7	1635.1	146.3
81.7	1631.7	145.6

82.7	1621.3	144.8
83.7	1606	144.1
84.7	1585.2	143.3
85.7	1562.7	142.2
86.7	1546.1	141.3
87.7	1535	140.2
88.7	1529.7	139.6
89.7	1517.5	138.7
90.7	1506.7	138.1
91.7	1488	137.1
92.7	1463.4	135.9
93.7	1433.7	134.6
94.7	1396.5	133
95.7	1359.8	131.7
96.7	1326.6	130.4
97.7	1296.7	129.1
98.7	1251.9	127.4
99.7	1212.5	125.8
100.7	1179	124
101.7	1160.8	122.9
102.7	1150.8	122.4
103.7	1147.5	122.6
104.7	1174.1	125.3
105.7	1233.5	130
106.7	1292.5	133.1
107.7	1334.6	135.1
108.7	1343.6	134.8
109.7	1345.4	134.7
110.7	1331.5	135.1
111.7	1323.7	135.1
112.7	1312.5	134.6
113.7	1289.3	134
114.7	1269	134.2
115.7	1246.5	132.1
116.7	1220	130.4
117.7	1193.6	128.7
118.7	1166.7	126.6
119.7	1141.6	124.8
120.7	1114.6	122.8
121.7	1097	122.9
122.7	1075.1	122.3
123.7	1052	120.7
124.7	1044.7	120.6
125.7	1014.3	120
126.7	977.8	119.2
127.7	926.9	117.1
128.7	873	115.1
129.7	815.8	112.8

130.7	760.4	110.2
131.7	692.9	106.1
132.7	620.3	101.4
133.7	533.7	93.5
134.7	444.1	83.4
135.7	370.8	74.9
69	86965	9023.1

The morbidly obese subject's Torso Height is 69 cm, the Torso Volume is 86965 cubic centimeters (cc), and the Torso Surface Area is 9023 centimeters squared (cm^2).

The morbidly obese subject's ***Barix*** is 69/(86965/9023), or 7.159.

Barix Calculation for a Typical Ectomorph Body Shape:

Figure 12 depict a scan image of an ectomorphic body type. An ectomorphic build is generally slight and thin.

Figure 12
Scan Image of Ectomorphic Body Type

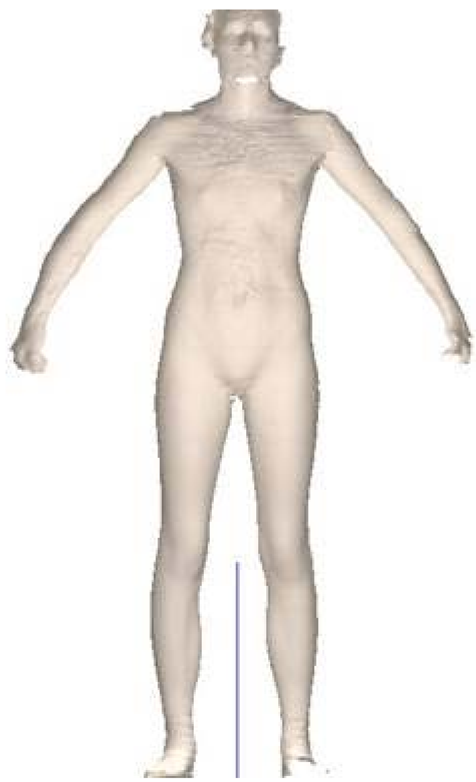

Figure 13 depicts the torso of the ectomorphic body type example. It is to be noted that the head is not included in the torso height, surface area and volume calculations.

Figure 13
Torso of the Ectomorphic Body Type Example

Table 4 depicts the torso height segments, and long with each segment's surface area and volume calculations.

Table 4

Ectomorph Example Torso Height Segments with Associated Volume and Surface Area

Units = centimeters, volume in CC		
Torso		
Height	Volume	Surface Area
87.2	287.3	52.8
88.2	595	102.9
89.2	612.2	101.1
90.2	627.4	100.3
91.2	639.6	99.6
92.2	649.1	99.2
93.2	653.1	98.8
94.2	655.6	98.3
95.2	655.3	97.8
96.2	652.5	97
97.2	646.8	96.1
98.2	641.6	95.3
99.2	636.2	94.3
100.2	632.1	93.5
101.2	628.2	92.7
102.2	621.8	91.7
103.2	616.7	91.1
104.2	610.9	90.5
105.2	602.5	90
106.2	587.7	89.1
107.2	569.9	88.1
108.2	548.3	86.8
109.2	526.4	85.6

110.2	503.7	84.2
111.2	484.6	82.6
112.2	464.5	80.4
113.2	446.5	78.5
114.2	432.8	76.9
115.2	422.4	75.6
116.2	413.4	74.5
117.2	408.5	73.7
118.2	404.8	73.2
119.2	403.8	72.9
120.2	403.5	72.9
121.2	406.1	73.2
122.2	410.7	73.6
123.2	416.1	74.1
124.2	421.1	74.7
125.2	427.6	75.6
126.2	434.2	76.3
127.2	440.6	77
128.2	449.5	77.8
129.2	461.6	78.8
130.2	474.9	79.9
131.2	488.3	81.2
132.2	501.2	82.5
133.2	512.3	83.7
134.2	520.6	84.6
135.2	524.7	85.1
136.2	526.8	85.7
137.2	529.2	86.5
138.2	534.7	87.6
139.2	539.7	89
140.2	543.6	90.2
141.2	547.8	91.7
142.2	552.2	93.4
143.2	541.5	93.3
144.2	524.9	92.9
145.2	509.9	92.9
146.2	496.1	92.6
147.2	480.5	92.4
148.2	468.7	92.9
149.2	453.5	93
150.2	424.2	91.4
151.2	391.2	89.4
152.2	329.4	82.5
153.2	240.4	67.4
154.2	191.6	57.1
67	34400.1	5818

The ectomorph body type example's Torso Height is 67 cm, the Torso Volume is 34400 cubic centimeters (cc), and the

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Torso Surface Area is 5818 centimeters squared (cm).

The ectomorph body type example's ***Barix*** is 67/(34400/5818) or 11.331.

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Barix Calculation for a Typical Mesomorph Body Shape:

Figure 14 depict a scan image of a mesomorph body type. A mesomorphic build is generally muscular.

Figure 14
Scan Image of Example Mesomorph Body Type

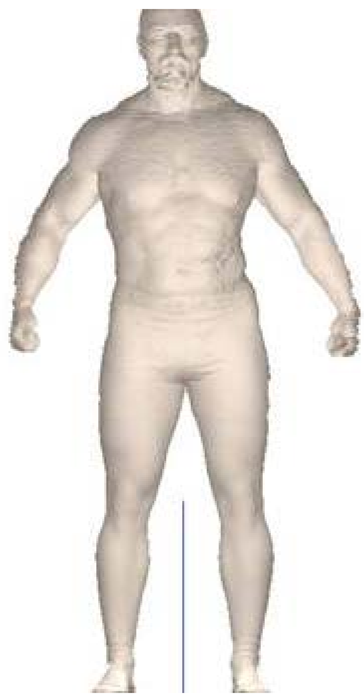

Figure 15 depicts the torso of the mesomorphic body type example. It is to be noted that the head is not included in the torso height, surface area and volume calculations.

Figure 15
Torso of the Mesomorphic Body Type Example

Table 5 depicts the torso height segments, and long with each segment's surface area and volume calculations.

Table 5

Mesomorph Example Torso Height Segments with Associated Volume and Surface Area

Units = centimeters, volume in CC		
Torso		
Height	Volume	Surface Area
80	307.9	70.3
81	741.4	117.4
82	798	113.7
83	830.8	112.7
84	854.5	112.2
85	871.2	112
86	882.3	111.8
87	886.9	111.6
88	886.4	111
89	879.1	110.3
90	869.1	109.5
91	856.1	108.7
92	841	107.6
93	828.7	106.7
94	819.5	106
95	812.3	105.2
96	807.6	104.6
97	806.7	104.1
98	807.3	103.8
99	805.3	103.5

100	800.6	103.1
101	789.8	102.3
102	769.1	101
103	757.6	100.3
104	749.9	99.9
105	735.7	98.6
106	720	96.9
107	710.2	96.1
108	705.7	96.4
109	710.4	97.7
110	718.5	97.6
111	719.6	98
112	714.5	98
113	716.7	98.1
114	721.8	98.5
115	731.8	99.4
116	741.7	100
117	752.4	100.9
118	763.6	101.8
119	778	103
120	800.9	104.9
121	820.1	106.2
122	837.1	107.4
123	851.5	108.8
124	866.1	110
125	884	111.2
126	910.3	113.3
127	939.9	115.9
128	968.3	118.1
129	997.2	120.3
130	1024.7	121.8
131	1051.4	123.5
132	1069.9	124.4
133	1081.7	125
134	1090.2	125.5
135	1092.4	125.7
136	1093.7	125.7
137	1076.9	124.7
138	1055.2	123.4
139	1036.9	122.3
140	1014.7	121.3
141	992.2	120.4
142	963.6	118.8
143	936.7	117.5
144	892.4	115.2
145	844.9	113.1
146	792.8	110.8
147	729.8	107.5

148	660.7	103.2
149	580.8	97.6
150	496.4	90.4
151	428.2	83.1
152	374.7	76.5
153	325.8	71.1
154	274.9	65
155	247.9	63.8
156	237.6	64.2
157	222.4	59.6
77	61564.6	8187.5

The mesomorph body type example's Torso Height is 77 cm, the Torso Volume is 61565 cubic centimeters (cc), and the Torso Surface Area is 8188 centimeters squared (cm^2).

The mesomorph body type example's ***Barix*** is 77/(61565/8188) or 10.241.

As an aside, the mesomorphic example subject's height is 5' 11” and his weight at the time of the scan was 225 lbs. The traditional BMI calculation for this subject is 32. A BMI of 32 is considered to be obese.

Barix Calculation for a Typical Endomorph Body Shape:

Figure 16 depict a scan image of an endomorph body type. An endomorphic build is generally disposed toward greater adiposity.

Figure 16
Scan Image of Endomorphic Body Type Example

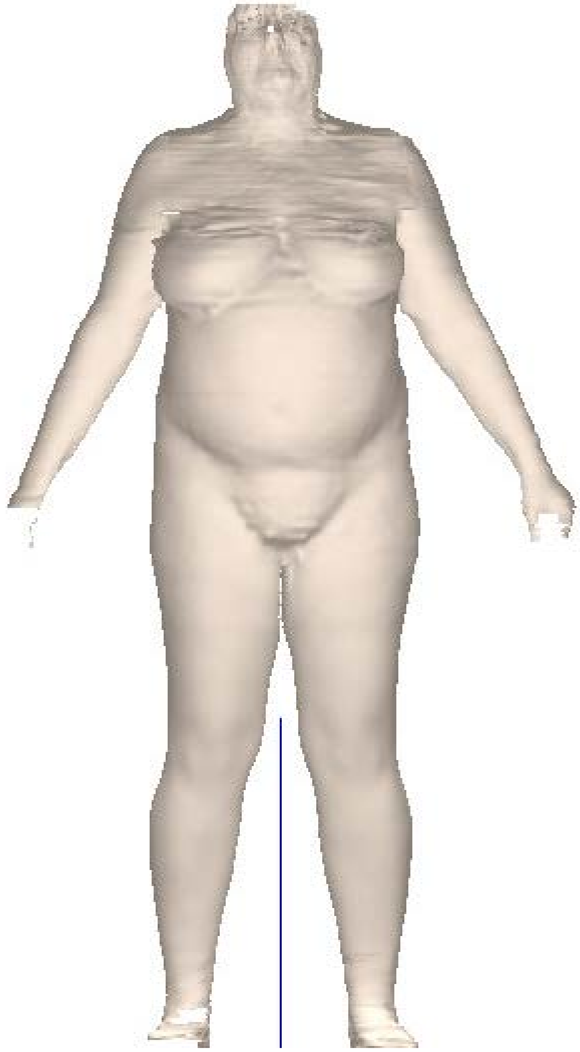

Figure 17 depicts the torso of the endomorphic body type example. It is to be noted that the head is not included in the torso height, surface area and volume calculations.

Figure 17
Torso of the endomorphic Body Type Example

Table 6 depicts the torso height segments, and long with each segment's surface area and volume calculations.

Table 6
Endomorph Example Torso Height Segments with Associated Volume and Surface Area

Units = centimeters, volume in CC		
Torso		
Height	Volume	Surface Area
72.8	380.1	54.8
73.8	780.8	109.1
74.8	804.2	108.7
75.8	829.7	108.4
76.8	864.1	109.7
77.8	881.9	110
78.8	894.2	110.2
79.8	901.5	110.5
80.8	907.9	110.8
81.8	908.7	110.7
82.8	913	110.7
83.8	912.8	110.5
84.8	908	110
85.8	903	109.5
86.8	900.6	109.5
87.8	904	110
88.8	909.4	110.5
89.8	914.5	110.6
90.8	919.5	110.6
91.8	920	110.3
92.8	920.4	110

93.8	921.8	109.8
94.8	921.1	109.8
95.8	919.1	109.5
96.8	920.2	109.5
97.8	920.7	109.6
98.8	926	109.9
99.8	924.6	109.9
100.8	919.9	109.6
101.8	916.7	109.3
102.8	912.3	108.8
103.8	906.6	108.3
104.8	898.8	107.6
105.8	890.2	106.8
106.8	889.5	106.8
107.8	896.6	107.3
108.8	902.8	107.8
109.8	909.4	108.2
110.8	922.2	109.5
111.8	946	112.9
112.8	973.2	117.3
113.8	1006.2	120.5
114.8	1033.2	124.1
115.8	1047.4	126.1
116.8	1069.9	129
117.8	1079.4	130.7
118.8	1078.7	131
119.8	1071	132.1
120.8	1044.7	130
121.8	1003	126.6
122.8	988	119.9
123.8	953.1	115
124.8	918	111.6
125.8	891.3	109.6
126.8	864	108.6
127.8	825.8	106.9
128.8	786	105.1
129.8	740.9	102.7
130.8	687.7	99.8
131.8	638.7	97.5
132.8	589	95.2
133.8	543.1	93.3
134.8	496.6	91.6
135.8	438.8	88.2
136.8	372.5	82.3
137.8	272.8	66.5
138.8	199.4	52.5
66	57155.2	7239.7

The endomorph body type example's Torso Height is 66 cm, the Torso Volume is 57155 cubic centimeters (cc), and the Torso Surface Area is 7240 centimeters squared (cm^2).

The endomorph body type example's ***Barix*** is 66/(57155/7240) or 8.360.

Table 7 summarizes the Barix Calculations for the morbidly obese, endomorph, mesomorph and ectomorph body types.

Table 7
Summary of Example Barix Calculations for Body Types

	Morbidly Obese	Endomorph	Mesomorph	Ectomorph
Barix	7.159	8.360	10.241	11.331

Table 7 gives an indication of the descending nature of the ***Barix***. The lower the ***Barix*** is, the greater the adiposity, or degree of the bariatric condition of the subject.

Interpretation of an Individual's *Barix* and the *Generalized Barix* Scale:

The ***Barix*** is a dimensionless quantity that indicates the general adiposity of an individual. To fully understand the implication of this number, an individual's ***Barix*** must be interpreted against a ***Generalized Barix Scale*** . The preliminary ***Generalized Barix Scale*** is a scale that has been developed by calculating the ***Barix*** from a sample population of adult subjects.

The ***Generalized Barix Scale*** is a general scale taking in all adult body types. An individual's particular ***Barix*** can then be compared to the scale in order to understand what *percentile* the individual's ***Barix*** falls within.

The individual and/or the individual's physician can utilize this information to understand if any corrections in lifestyle are needed to improve the individual's ***Barix.***

Specialized Barix Scales may be developed for pediatrics, geriatrics, obstetrics, the extreme morbidly obese, the anorexic as well as other medical disciplines. These ***Specialized Barix Scales*** categorize the degree of adiposity of specific subjects of interest within these particular medical disciplines. ***Specialized Barix Scales*** area needed because inclusion of the ***Barix*** numbers of the subjects within a ***Specialized Barix Scale*** would skew the ***Generalized Barix Scale.***

It is important to note that a ***Specialized Barix Scale*** may or may not be a subset of the ***Generalized Barix Scale***. The ***Pediatric Index***, for instance, is not a subset of the ***Generalized Barix Scale*** as the ***Generalized Barix Scale*** is composed of ***Barix*** calculations for adults. The ***Bariatric Index*** is applied to morbidly obese subjects undergoing bariatric surgery. As they lose mass, the individuals that have undergone some form of bariatric surgery may move out of the ***Bariatric Index*** and into the ***Generalized Barix Scale***. The ***Geriatric Index*** is a ***Specialized Barix Scale*** designed to interpret an elderly individual's ***Barix*** to elderly peers. The ***Anorexic Index*** is a ***Specialized Barix Scale*** designed to interpret an anorexic subject's ***Barix*** within a population of anorexic individuals.

All of the ***Specialized Barix Scales***, with the exception of the ***Pediatric Index*** may be interpreted against the ***Generalized Barix Scale*** to gauge where the individual's ***Barix*** stands in comparison with the overall population sample.

The Development of *Generalized Barix Scale*:

A total of 200 adult subjects of various body types participated in a study to develop the preliminary ***Generalized Barix Scale***. 200 samples appear to be enough to form the outline of a general scale. The ***Generalized Barix Scale*** will be calibrated as additional samples are added.

The main thrust of the ***Generalized Barix Scale*** is to derive the existence of certain *cut-off* points that categorize an individual's adiposity within the general population.

The ***Barix*** was calculated for each subject. Circumferential Waist and Hip measurements were extracted from each scan image and recorded. The waist-to-hip ratio was calculated, and the torso height was recorded.

Descriptive statistics were then calculated, including the arithmetic mean, median, standard deviation and variance.

Table 7 summarizes the statistical analysis of the 200 adult subjects.

Table 7
Descriptive Statistics for Preliminary
Generalized Barix Scale

Barix Sample Descriptive Statistics	
Mean	9.670515
Standard Error	0.095358
Median	9.814
Mode	9.872
Standard Deviation	1.348573
Sample Variance	1.818648
Kurtosis	-0.46183
Skewness	-0.32477
Range	6.815
Minimum	5.781
Maximum	12.596
Sum	1934.103
Count	200

The arithmetic mean for this population is 9.671. The confidence level used to calculate the mean was 95%. The median is 9.814, meaning that half the sample population's ***Barix*** is above 9.814 and half is below.

The standard deviation is 1.349. In this case 63% of the population had a ***Barix*** of between 11.020 and 8.465. 18% if the population had a ***Barix*** above 11.02. 19% of the population had a ***Barix*** below 8.465. Those with a ***Barix*** higher than 11.02 were generally thin and/or physically fit. Those with a ***Barix*** below 8.465 were considered very obese to morbidly obese.

Only one of the samples was 2 standard deviations above the mean. Three of the samples were below 2 standard deviations from the mean.

To understand how an individual's ***Barix*** relates to this population, rank and percentile calculations were made.

Table 9 summarizes the preliminary ***Generalized Barix Scale***:

Percentile	***Barix***	Indication
91 - 100	12.596	Problematically Thin
50 - 90	11.345	Proportionally Ideal to Thin
Below 50	9.814 (median)	Slightly Overweight
Below 40	9.470	Overweight

Below 30	8.944	Obese
Below 20	8.518	Extremely Obese
Below 10	7.783	Morbidly Obese

The ***Barix*** is designed to indicate the degree of adiposity in a subject, the lower the ***Barix,*** the greater the degree of adiposity. The ***Generalized Barix Scale*** emphasizes the percentiles below 50%. Individuals with a ***Barix*** that is near or above the median tend to appear fit or well proportioned. However, an extremely high ***Barix*** number could indicate a medical condition, such as anorexia. The anorexic individual's ***Barix*** would be interpreted against the ***Anorexic Index***, which is a ***Specialized Barix Scale***.

There exists an ***Optimal Barix Range*** for each individual, regardless of what category the individual is in. The ***Optimal Barix Range*** is defined as a narrow range of the highest feasible ***Barix*** values that an individual can obtain without generating medical risks (anorexia, anemia, etc.). The ***Optimal Barix Range*** can also be a useful indicator to track post-operative recovery from surgical procedures that affect contour changes in a subject's torso.

Medical or fitness professionals can assess the individual's ***Barix*** and body type and suggest lifestyle changes to help each individual towards their ***Optimal Barix Range***.

Independencies and Dependencies of the *Barix*:

An individual's ***Barix*** has strong (negative) correlation to the individual's circumferential waist measurement and circumferential hip measurement, but weak correlation to the individual's waist-to-hip ratio (a traditional indicator) or the individual's torso height. In general, the smaller the waist and/or hip measurement, the larger the individual's ***Barix***. This makes intuitive sense. Thinner individuals generally have a higher ***Barix***.

The low degree of correlation (independence) between an individual's ***Barix*** and waist-to-hip ratio is beneficial since it has been shown that the waist-to-hip ratio can be a misleading aesthetic indicator.

The low degree of correlation (independence) between an individual's ***Barix*** and torso height is beneficial since many subjects may have the same torso height, but subjects with the same torso height are unlikely to have the same (volume/surface area) product.

Table 10 shows correlations between the ***Barix***, Waist and Hip Measurements, Waist-to-Hip Ratio and Torso Height for the sample population.

Table 10

Correlation Values between the ***Barix***, Waist and Hip Measurements, Waist-to-Hip Ratio and Torso Height for the Sample Population

	Waist	*Hips*	*Waist-to-Hip Ratio*	***Barix***	*Torso Height*
Waist	1				
Hips	0.874692	1			
Waist-to-Hip Ratio	0.735066	0.320518	1		
Barix	-0.77236	-0.786	-0.41706861	1	
Torso Height	0.264922	0.142504	0.342166981	0.307661	1

Table 10 indicates that the correlation between the ***Barix*** and the waist measurement is -0.772. The correlation between the ***Barix*** and the hip measurement is -0.786. These values indicate a high degree of negative correlation.

In contrast, the correlation between the ***Barix*** and the waist-to-hip ratio is -0.417. The correlation between the ***Barix*** and the torso height is 0.308. These values are insufficient to declare any dependencies.

Correlations between the ***Barix*** and other linear or circumferential measurements can be made as well. In addition, correlation between the ***Barix*** and a sample population's height, weight and BMI can be made.

September 2005

A New Method of Classifying Adiposity Using Height, Volume and Surface Area

Introducing the ***Barix***^{sm}

Novaptus Systems, Inc.
Medical, Health and Wellness Technology Systems

Part IV

The *Barix Trajectory* and the *Barix Rate of Change* : Interpreting Changes in an Individual's *Barix* over Time

Positive *Barix* Trajectory Example

An individual's ***Barix*** will change over time. This can be due to the normal effects of aging, or changes in the individual's lifestyle, such as a new diet or exercise regimen. Such changes to an individual's ***Barix*** will most likely be measured. Dramatic changes to an individual's ***Barix*** in either direction may be cause for concern if that individual is not participating in a severely calorie restricted diet or undergoing a surgical procedure that affects the physical contours of the body.

Monitoring changes to an individual's ***Barix*** can assist the physician or surgeon in evaluating post-operative recovery. Monitoring changes to an individual's ***Barix*** can also assist the fitness or nutrition professional in assessing the progress of an individual's change in lifestyle (diet, exercise, undue stress, cessation from smoking, etc).

Each individual has their own ***Barix Trajectory***. The ***Barix Trajectory*** is simply the direction or trend that an individual's ***Barix*** takes over time. If the individual's ***Barix*** is increasing slightly over time (positive), that individual is enjoying the results of a new exercise or diet regimen. If the individual's ***Barix*** decreases slightly over time (negative), it could indicate the normal aging process or a trend toward gaining weight.

The following is an example of interpreting the *Positive* ***Barix Trajectory*** of subjects that have undergone cosmetic surgical procedures. In this case, the subject has undergone an abdominoplasty.

The same techniques can be used to monitor the recovery process for subjects that have undergone bariatric surgical procedures.

Figure 18a and 18b depict the scan image profile of a pre-operative bariatric patient and the 3 month post-operative scan image profile.

Figure 18a
Scan Image Profiles of an Abdominoplasty Surgery Subject

Pre-op Scan 3 Mo Post-op 6 Mo Post-op

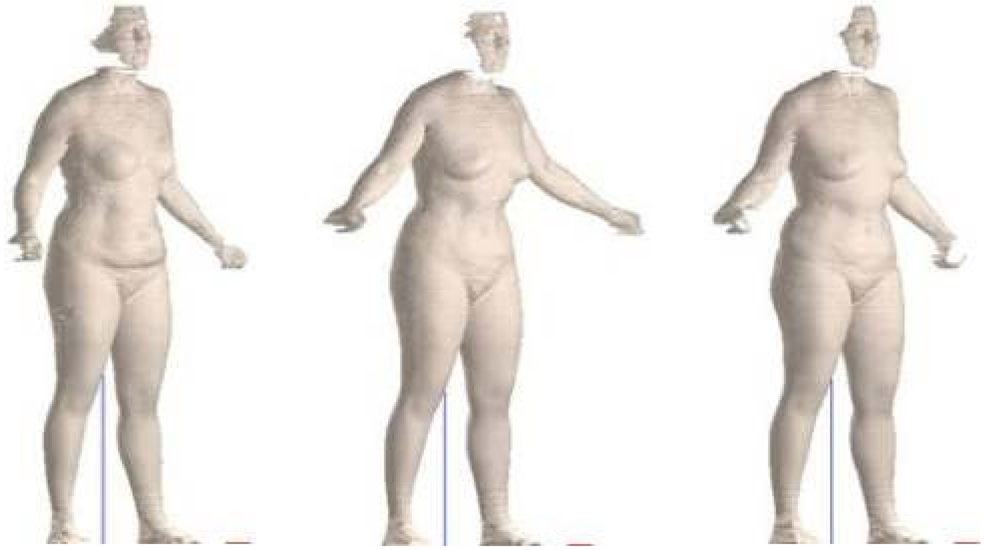

Figure 18b
Scan Image Profiles of an Abdominoplasty Surgery Subject

9 Mo Post-op Scan Image

12 Mo Post-op Scan Image

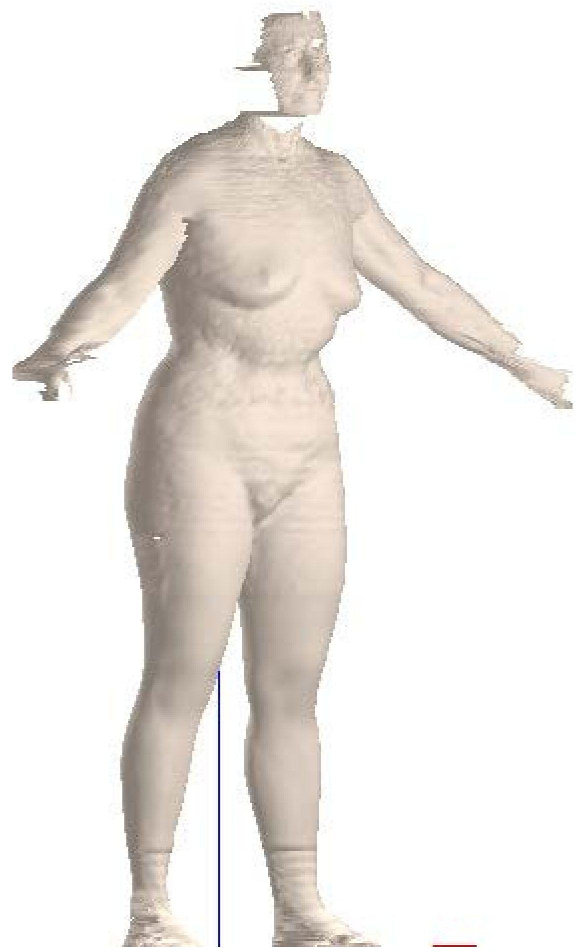

Table 15 displays the waist and hip measurements in centimeters, torso height, torso volume, torso surface area and ***Barix*** for the pre-operative and the 3 month post-operative scan images.

Table 15

Pre-operative and Periodic Post-Operative ***Barix*** Information

	Waist, cm	Hips, cm	Torso Height	Torso Volume	Torso Surface Area	***Barix***
Pre-op	78.5	97.5	57 (57.3)	32393	5079	8.937
3 Mo Post	71.7	100.5	58 (57.7)	33178	5187	9.068
6 Mo Post	73.3	102	58	33249	5152	8.972
9 Mo Post	71.4	98.6	58	31939	5058	9.185
12 Mo Post	69.6	97.6	57	30415	4961	9.298

Note that the torso height has been rounded to the nearest digit.

Close inspection of Table 15 yields some interesting insights into the effects of the swelling associated with the abdominoplasty procedure.

The subject's pre-operative waist measurement was 78.5 cm and her hip measurement was 97.5 cm. The subject's initial ***Barix*** was 8.937. Three months after the procedure, the subject's waist measurement was 71.7 cm. This was expected as the abdominoplasty procedure effectively removes tissue around the waist region. The subject's hip measurement rose from 97.5 cm to 100.5 cm, indicating the effects of post-operative swelling. The subject's ***Barix*** rose from 8.937 to 9.068. This is a positive Barix Trajectory, reflecting the removal of tissue.

The *rate of change* of the subject's ***Barix*** is an additional measure of recovery. The ***Barix Rate of Change*** is defined as the change of the ***Barix*** between sequential periods of time divided by the time period, usually in months. In the example above, the subject's ***Barix*** *rate of change* from her pre-operative state to her 3 month post-operative condition is (9.068-8.937)/3 (months), or 0.044. This is a positive rate of change, indicating that the subject has lost mass due to removal of tissue.

The subject's 6 month post-operative waist measurement rose from 71.7 to 73.3 cm and her hip measurement rose from 100.5 cm to 102 cm. The subject's ***Barix*** decreased from 9.068 to 8.972. This is a *negative* ***Barix Trajectory***, indicating that swelling did not diminish between the 6 month post-operative and 3 month post-operative period. Indeed, swelling had increased as reflected by the increased hip and waist measurements.

The ***Barix Rate of Change*** from her 6 month post-operative condition and 3 month post-operative condition was (8.972 – 9.068)/3 (months), or -0.032. This is a negative rate of change, indicating that the subject's body experienced more swelling between the 3 and 6 month post-operative period.

The subject's 9 month post-operative waist measurement decreased from 73.3 cm to 71.4 cm and her hip measurement decreased from 102 cm to 98.6 cm. The subject's ***Barix*** increased from 8.972 to 9.185. This is a positive ***Barix Trajectory***. Moreover, the subject's ***Barix Rate of Change*** between the 9 month and 6 month post-operative period was (9.185 – 8.972)/ 3 (months), or 0.071. This is an increasing ***BarixRate of Change*** . This indicates that post-operative swelling has begun to abate and the effects of the abdominoplasty procedure are becoming manifest.

The subject's 12 month post-operative waist measurement decreased from 71.4 cm to 69.6 and her hip measurements decreased from 98.6 cm to 97.6 cm. The subject's ***Barix*** increased from 9.185 to 9.298. This is a positive ***Barix Trajectory***. The subject's ***Barix Rate of Change*** between the 12 month and month post-operative period was (9.298 – 9.185)/ 3 (months), or 0.038. This is an increasing ***Barix Rate of Change***, though less than the ***Barix Rate of Change*** during the 6 month to 9 month post-operative period. This indicates that the *rate* of swelling reduction is decreasing.

The subject's 15 month and 18 month ***Barix*** values indicate that she is nearing her ***Optimal Barix Range*** and is receiving the full benefits of the abdominoplasty procedure. The ***Optimal Barix Range*** is a narrow band in which periodic ***Barix*** calculations remain within.

Figure 19 depicts this information in a chart.

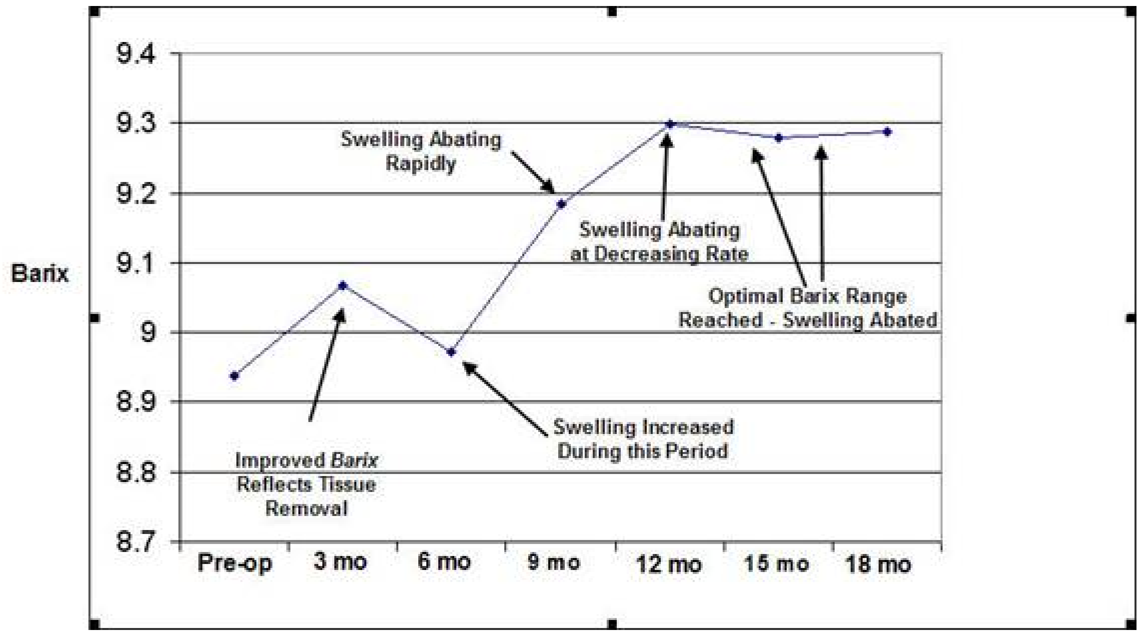

Figure 19 depicts that immediately after the surgical procedure, the subject's ***Barix*** improved. This is because the amount of tissue removed was greater than the resultant swelling. However, swelling increased during the 3 month to 6 month post-operative period. At some point within the 6 month to 9 month period, swelling peaked and began to abate. Swelling continued to abate during the 9 month to 12 month period, but at a diminished rate. Finally, the subject reached her ***Optimal Barix Range***, indicating manifestation of the full benefit of the abdominoplasty procedure.

Should the subject's ***Barix*** depart from her ***Optimal Barix Range***, a condition could be developing that may require medical attention.

Each subject's ***Barix Rate of Change*** can be compared to other subjects that have undergone a similar surgical procedure.

The ***Barix, Barix Trajectory*** and ***Barix Rate of Change*** can be calculated for each periodic scan. Eventually, sequential ***Barix*** *rate of changes* will decrease to a narrow band around a *steady state* point. The ***Barix Trajectory*** may also in turn change its magnitude. At this stage, the post-operative subject that underwent contouring surgical procedure will have manifested the full effects of the surgical outcome. The ***Optimal Barix Range*** for this individual will have been reached.

This same approach can be used to monitor reduction of mass from bariatric surgical procedures.

Periodic post-operative scans, calculation of the ***Barix, Barix Trajectory*** and the ***Barix Rate of Change*** can assist the bariatric surgeon in understanding the point in time that maximum post-operative weight loss has been reached and the subject's torso reaches a “*steady state*”.

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A New Method of Classifying Adiposity Using Height, Volume and Surface Area

Introducing the ***Barix***sm

Part V

Breast Augmentation *Barix* Trajectory Example

In general, a subject's subsequent descending ***Barix*** calculation and negative ***Barix Trajectory*** indicates that the subject is gaining weight and/or the (torso volume/surface area) product is increasing.

There are circumstances in which the subject's descending ***Barix*** can occur suddenly, such as a subject that has undergone breast augmentation surgery, or over a finite period of time, such as an expectant mother going through pregnancy.

The following example depicts a subject that has undergone a breast augmentation procedure. Breast augmentation is an invasive surgery. Breast implants are placed within the subject's chest wall. Swelling of the chest area occurs immediately after surgery. Over a period of time the swelling diminishes and the implants settle.

By utilizing the ***Barix,*** the ***Barix Trajectory*** and the ***Barix Rate of Change***, the surgeon can determine when swelling has diminished and the breast implants have settled.

Figure 20 depicts a series of scans of a subject that underwent a breast augmentation procedure.

Figure 20
Breast Augmentation Subject Scans

Pre-op Scan Image 1 Month Post-op 3 Month Post-op

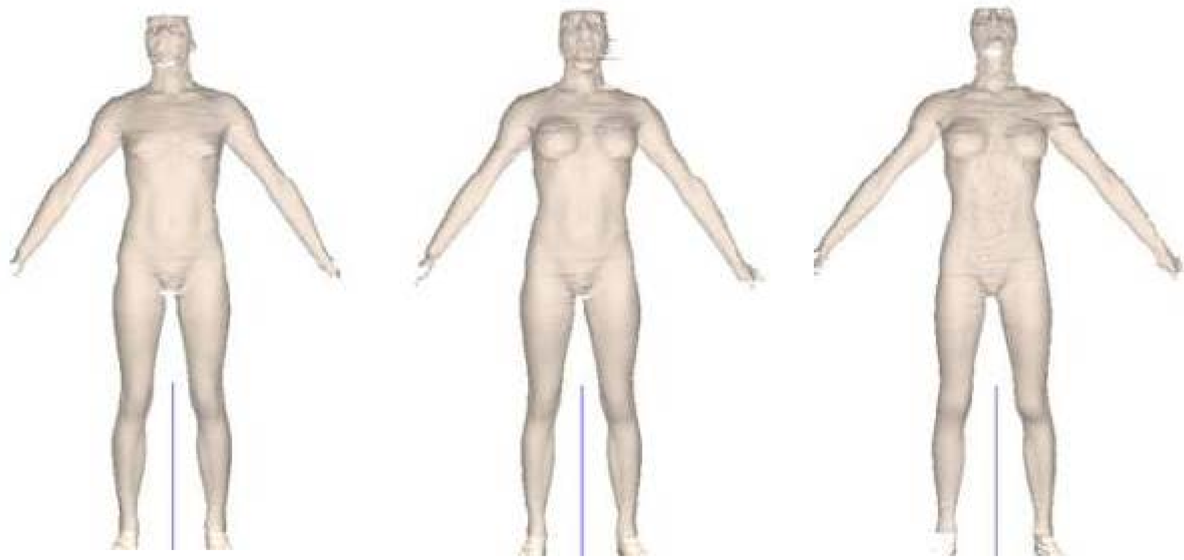

Table 16 displays the torso height, torso volume, torso surface area and ***Barix*** for the pre-operative, 1 month and the 3 month post-operative scan images.

Table 16
Pre-operative, 1 month and 3 Month Post-Operative ***Barix*** Information
– Breast Augmentation Example

	Torso Height	Torso Volume	Torso Surface Area	***Barix***
Pre-op	61	27510	5022	11.135
1 mo post	61	28189	5044	10.915
3 mo post	61	28010	5038	10.972

Figure 16 graphically illustrates the ***Barix Trajectory*** and ***Barix Rate of Change*** and ***Optimal Barix Range*** concept for a subject that has undergone a breast augmentation surgical procedure.

Figure 16
Graphical Representation of ***Barix Trajectory, Barix Rate of Change*** and ***Optimal Barix Range*** for Breast Augmentation Subject

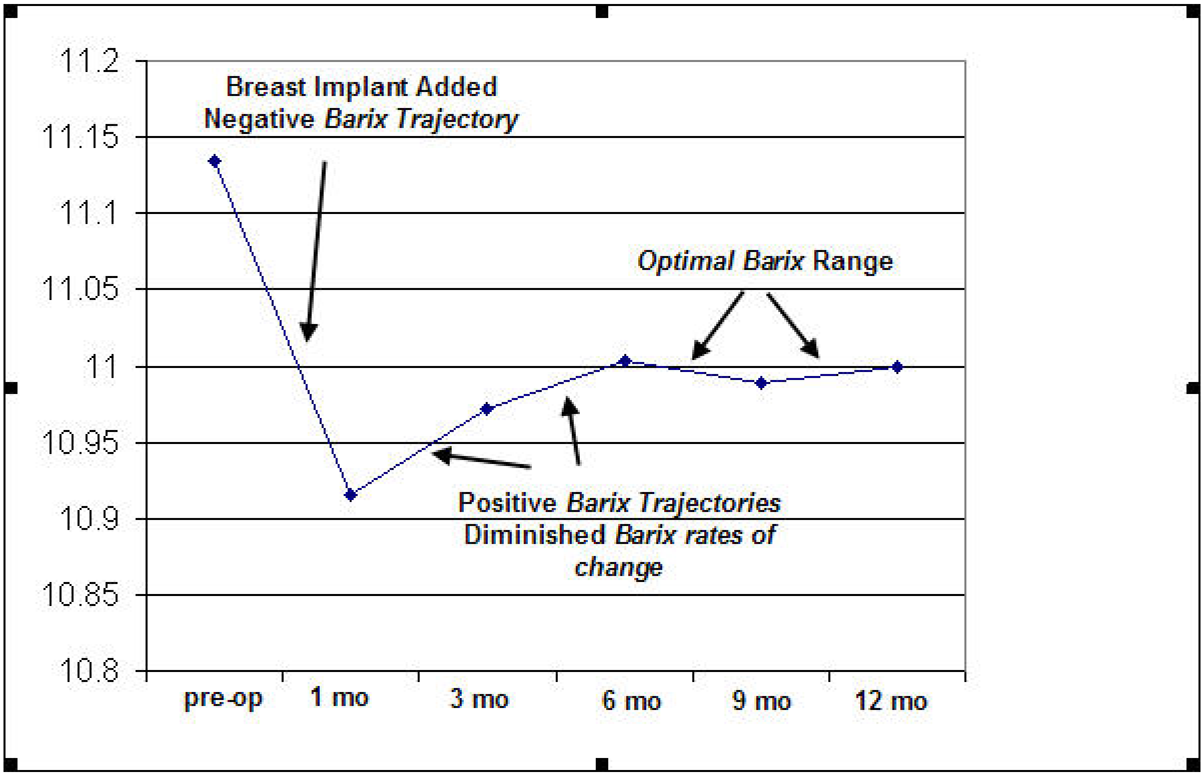

Table 16 and Figure 16 indicate that the subject's pre-operative ***Barix*** was 11.135. 1 month after breast augmentation surgery the subject's ***Barix*** was 10.915, reflecting the addition of the breast implants into the subject's torso. During this period the subject had a negative ***Barix Trajectory***. The ***Barix Rate of Change*** was (11.135 – 10.915)/1 month, or 0.22.

The subject's 3 month post-operative ***Barix*** was 10.972. Between the 3 month post-operative scan and the 1 month post-operative scan, the subject's ***Barix Trajectory*** changed from negative to positive. This indicates that the swelling has begun to abate. The ***Barix Rate of Change*** between the 3 month post-operative scan and the 1 month post-operative scan was (10.972 – 10.915)/ 2 months, or 0.03. This ***Barix*** rate of change is nearly zero, indicating the subject is reaching her ***Optimal Barix Range***.

Conclusions

The new adiposity indicator, the ***Barix***sm, has general application to the adult population. The ***Barix***sm is computed using a combination of torso height, torso surface area and torso volume as a proxy to categorize the general shape of the body. These measurements are gleaned from the subject's white light scan. No weight information is required. This technique supercedes conventional Body Mass Index calculations, which can lead to falsely categorizing subjects as obese.

Adults can compare their ***Barix***sm to the ***Generalized Barix Scale***sm to determine where they fall within the general adult population. Periodic ***Barix***sm calculations tell whether the individual is gaining or losing weight.

The ***Barix***sm can also be utilized by medical, health and fitness professionals. ***Specialized Barix Scales sm*** have already been applied to bariatric surgery. Other applications include post-operative recovery from various surgical procedures.

Monitoring the ***Barix***sm***, Barix Trajectory***sm***, Barix Rate of Change***sm ***and Optimal Barix Range***sm allows the surgeon to determine the patient's rate of surgical recovery and when the patient has reached full recovery.

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