

understanding body composition analysis

mass and fluid compartments



Body composition analysis is the clinical assessment of tissue and fluid distribution in the human body. The body is modeled as a series of tissue and fluid compartments.

Fat Mass (FM) is the total amount of stored lipids in the body and consists of the following types of fat:

Subcutaneous Fat is located directly beneath the skin. Subcutaneous fat serves as an energy reserve and as insulation against outside cold.

Visceral Fat is located deeper within the body. Visceral fat serves as an energy reserve and as a cushion between organs.

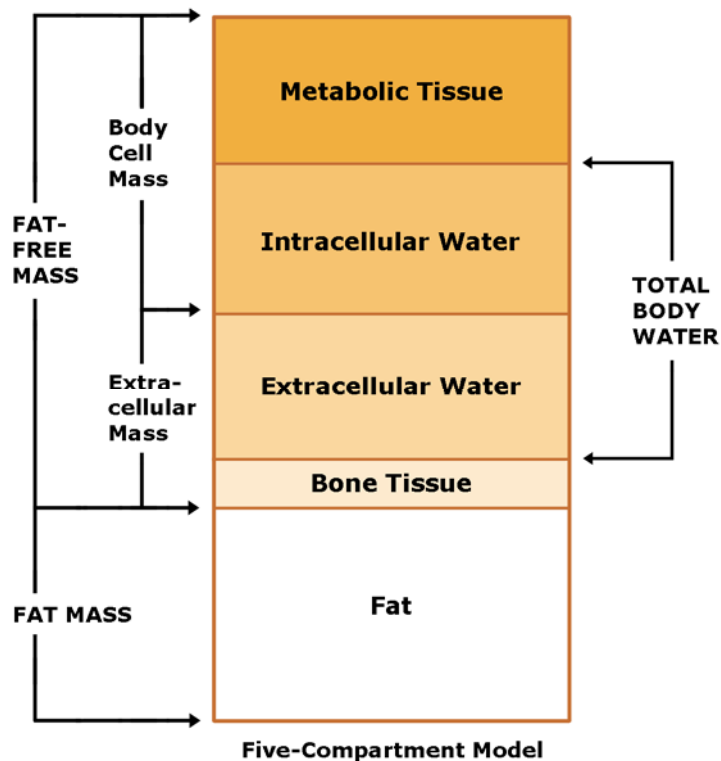
Fat-Free Mass (FFM), also called Lean Body Mass (LBM), is the total amount of nonfat (lean) parts of the body. It consists of approximately 73% water, 20% protein, 6% mineral, and 1% ash.

Fat-free mass is further divided into body cell mass and extracellular mass:

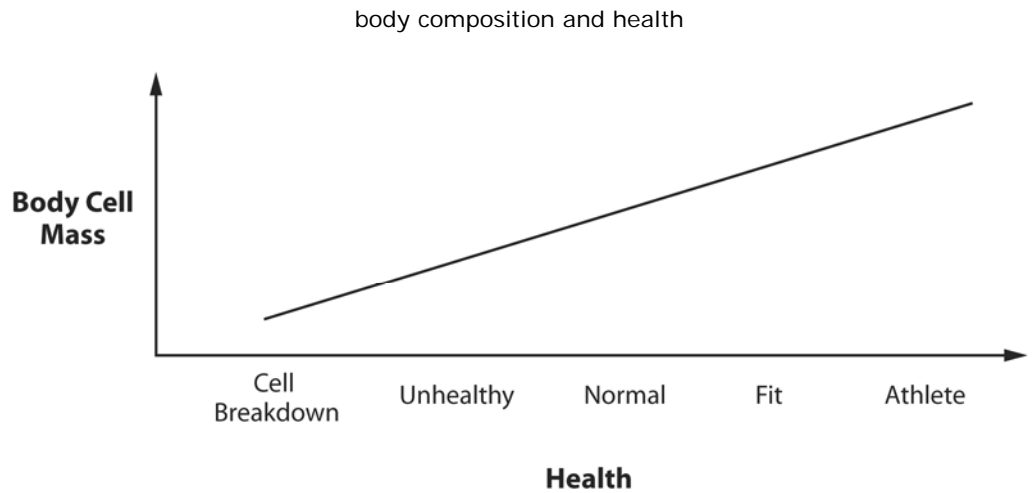
Body Cell Mass (BCM) contains all the metabolically active tissues (living cells) of the body, including muscle cells, organ cells, blood cells, and immune cells. BCM includes the "living" portion of fat cells, but not the stored fat lipids. BCM also includes water inside living cells. This water is called **Intracellular Water (ICW)**. The main electrolyte of intracellular water is potassium.

Extracellular Mass (ECM) contains all the metabolically inactive (non-living) parts of the body, such as bone minerals and blood plasma. ECM includes water contained outside living cells. This water is called **Extracellular Water (ECW)**. The main electrolyte of extracellular water is sodium.

The figure below provides a graphical representation of the relationship of mass and water distribution.



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Research has shown that body composition correlates directly to a continuum of health, ranging from mortality and morbidity to immunity, longevity, high function, and athletic performance.

The purpose of body composition analysis is to monitor and improve function. For healthy patients, analysis of fat-free mass and body cell mass compartments can help maintain function, productivity, immunity, physical performance, and longevity.

References:

Kyle UG, et al. Physical activity and fat-free and fat mass by bioelectrical impedance in 3853 adults. *Medicine and Science in Sports and Exercise*, 2001; 33:576-584.

Mattar JA, et al. Application of total body bioimpedance to the critically ill patient. *New Horizons*, 1995, Vol 4., No. 4; 493-503.

Ott M, et al. Bioelectrical impedance analysis as a predictor of survival in patients with human immunodeficiency virus infection. *Journal of Acquired Immune Deficiency Syndromes and Human Retrovirology*, 1995; 9:20-25.

interpreting test results

understanding the printout



Phase Angle (α)

Capacitance in the human body due to intact cellular membranes causes a lag between potential and current in the human body when stimulated by a 50 kilohertz alternating current. This lag is proportional to the number of intact cellular membranes and is called the phase angle.

Phase angles for adults range from 3 to 15 degrees, with average values of 6 to 8 degrees. A low phase angle is consistent with low reactance, the decreased ability of cells to store energy and an indication of breakdown in the selective permeability of cell membranes. A high phase angle is consistent with high reactance, an indication of large quantities of intact cell membranes and body cell mass.

Monitoring phase angle is highly recommended because its value is proportional to cellular health regardless of a patient's weight, whether weight is increasing or decreasing, and because it can be used to compare the health of two or more individuals.

The phase angle is determined by the measurement of reactance and resistance, and a calculation using the formula for the phase angle.

Body Capacitance (C)

Body capacitance is the absolute amount of energy storage of the body due to intact cellular membranes. A high capacitance indicates large amounts of intact cellular membranes. A low capacitance indicates lower amounts.

Capacitance is proportional to the size of the body cell mass compartment or number of cells and to the integrity of cellular membranes. Increasing capacitance is always good because it represents an increase in the number of cells, their quality, or both. However, if capacitance is decreasing, it is important to remember that this may be due to a decrease in body cell mass related to weight loss in an otherwise healthy patient.

Capacitance in the body affects the flow of alternating current. This effect is called reactance. By measuring reactance, the amount of capacitance in the body can be determined.

Units of capacitance are called picofarads. Values range from 200 to 1500 picofarads (pF), with normal values of 500 to 1000 pF. High capacitance (C) causes high reactance (X).

Resistance (R)

Resistance is the effect on an alternating current that is caused by resistivity or the energy dissipating characteristics of the body. Resistance is measured directly from the human body by the bioimpedance analyzer.

A low resistance is consistent with large amounts of fat-free mass. A high resistance is consistent with low amounts of fat-free mass.

Resistance is related to water in the body. Electrolytic fluid consisting of water and charged ions contained in the body's fat-free mass readily conducts electrical current. Extracellular fluid (water and ionized sodium Na^+) provides a low-resistance pathway. Intracellular fluid (water and ionized potassium K^+) also provides a low-resistance pathway. Low resistance, indicating high conductivity, is due to large amounts of water in the body. Since water is contained solely within fat-free mass, resistance in the body is proportional to the amount of fat-free mass. Units of measurement are called ohms, after the physicist.

Reactance (X)

Reactance is the effect on an alternating current that is caused by the presence of capacitance or the energy storage characteristic of the body due to intact cell membranes. Reactance is measured directly by the analyzer. By measuring reactance, it is possible to determine the body's capacitance and the size and integrity of the body cell mass compartment. Units of measurement are called ohms after the physicist.

Body Cell Mass (BCM)

Body cell mass contains the metabolically active (living cells) components of the body, including muscle cells, organ cells, blood cells and immune cells. BCM includes the "living" portion of fat cells but not the stored fat lipids and also includes the water inside living cells called intracellular water. The main electrolyte of intracellular water is potassium.

Extracellular Mass (ECM)

Extracellular mass contains the metabolically inactive parts of the body components including bone, minerals, and blood plasma. ECM also includes water contained outside living cells called extracellular water. The main electrolyte of extracellular water is sodium.

Fat-Free Mass (FFM)

Fat-free mass, also called lean body mass, is the total amount of nonfat (lean) parts of the body. It consists of approximately 73% water, 20% protein, 6% mineral, and 1% ash. Fat-free mass contains virtually all the body's water, all the metabolically active tissues, and is the source of all metabolic caloric expenditure.

Fat Mass (FM)

Fat mass is all the extractable lipids from adipose and other tissues in the body.

ECM/BCM

The ratio of extracellular mass to body cell mass. A low value is desirable and indicates a high ratio of to body cell (living) mass to extracellular (non-living) mass. Normal values are typically near 1.0, indicating a 50/50 distribution of body cell mass and extracellular mass.

Body Mass Index (BMI)

A commonly used index of body composition equal to the ratio of the body's weight in kilograms to the square of height in meters.

Basal Metabolic Rate (BMR)

Basal metabolic rate is the number of calories consumed at a normal resting state over a 24-hour period. BMR is based solely on an individual's fat-free mass.

Intracellular Water (ICW)

Intracellular water is the water volume of the body cell mass.

Extracellular Water (ECW)

Extracellular water is the water volume outside of the body cell mass.

Total Body Water (TBW)

Total body water is the sum of ICW and ECW. It is the amount of water contained in the body.

TBW/FFM

The percentage of fat-free mass that is water.

TBW/Total Weight

The percentage of total weight that is water.

NORMAL REFERENCE VALUES

MALES	Age	15-24	25-34	35-44	45-54	55-64	65-74	75-84	>85
Anthropometric¹									
Height (in)		69.9	70.0	69.6	68.5	68.2	67.6	67.2	65.2
Weight (lb)		154.6	163.8	166.3	163.2	165.8	167.4	160.1	157.9
Impedance¹									
Phase Angle (°)		7.3	7.5	7.2	7.1	6.6	6.1	5.3	4.6
Body Capacitance (pF)		828	865	843	838	779	723	612	524
Resistance (ohms)		484	474	470	469	468	466	482	486
Reactance (ohms)		61.9	62.1	59.4	58.8	54.3	49.9	45.1	39.1
Mass Distribution									
Body Cell Mass (% wt)		45.4	43.5	41.1	39.6	36.8	34.1	31.5	27.5
Extracellular Mass (% wt)		43.0	41.3	41.3	40.7	41.0	41.3	42.2	41.1
Fat-Free Mass (% wt)		88.4	84.8	82.4	80.3	77.8	75.4	73.7	68.6
Fat Mass (% wt)		11.6	15.2	17.6	19.7	22.2	24.6	26.3	31.4
ECM/BCM Ratio		0.95	0.95	1.00	1.03	1.11	1.21	1.34	1.49
Body Mass Index (kg/m ²)		22.3	23.5	24.1	24.4	25.1	25.7	24.9	26.1
Basal Metabolic Rate (cals/day)		1934	1966	1938	1853	1825	1785	1669	1532
Water Compartments									
Intracellular Water (% tbw)		61.0	60.5	59.1	58.5	56.1	53.8	51.2	48.3
Extracellular Water (% tbw)		39.0	39.5	40.9	41.5	43.9	46.2	48.8	51.7
Total Body Water (% ffm)		72.4	72.4	72.5	72.2	72.0	71.9	71.6	72.5
Total Body Water (% wt)		64.1	61.4	59.7	58.0	56.0	54.2	52.8	49.7
FEMALES									
Anthropometric¹									
Height (in)		65.6	65.2	64.5	64.2	63.4	62.7	62.0	60.3
Weight (lb)		128.6	129.4	129.4	133.4	138.5	144.6	138.0	130.3
Impedance¹									
Phase Angle (°)		6.6	6.6	6.7	6.5	6.0	5.4	4.8	4.5
Body Capacitance (pF)		603	620	641	641	583	539	466	435
Resistance (ohms)		601	582	572	557	563	555	569	570
Reactance (ohms)		69.3	66.8	66.8	63.3	58.7	52.6	47.7	44.7
Mass Distribution									
Body Cell Mass (% wt)		38.1	37.1	36.3	34.5	31.5	27.7	25.7	24.0
Extracellular Mass (% wt)		40.3	40.4	39.8	39.7	39.4	38.0	38.5	38.4
Fat-Free Mass (% wt)		78.4	77.5	76.1	74.2	70.9	65.7	64.2	62.4
Fat Mass (% wt)		21.6	22.5	23.9	25.8	29.1	34.3	35.8	37.6
ECM/BCM Ratio		1.06	1.09	1.10	1.15	1.25	1.37	1.50	1.60
Body Mass Index (kg/m ²)		21.0	21.4	21.9	22.7	24.2	25.8	25.2	25.2
Basal Metabolic Rate		1426	1420	1395	1401	1388	1345	1254	1151
Water Compartments									
Intracellular Water (% tbw)		55.6	54.5	54.3	52.9	50.0	47.3	45.1	43.7
Extracellular Water (% tbw)		44.4	45.5	45.7	47.1	50.0	52.7	54.9	56.3
Total Body Water (% ffm)		72.4	72.5	72.5	71.9	71.5	73.2	73.8	75.0
Total Body Water (% wt)		56.8	56.2	55.2	53.4	50.6	48.0	47.4	46.9

¹Kyle UG, et al. Fat-Free and Fat Mass Percentiles in 5225 Healthy Subjects Aged 15 to 98 Years. *Nutrition*, 17:534-541, 2001.