Introduction

Body composition and its significance: The term Body Composition is used to illustrate the different components that, when taken together, makes up a person's body weight. We can say it is the amount of lean tissue compared to fat. Body composition data can make the basis for a wide variety of therapeutic, health and fitness programs. Clinically, body composition analysis along with non-pharmacological nutrition and physical activity prescriptions provide the foundation upon which further treatment is based. Only body composition analysis can determine how much muscle and fat are lost or gained as the result of any nutrition, exercise, or pharmaceutical prescription. By measuring body composition, a person's health status can be more accurately assessed and the effects of both dietary and physical activity programs better directed. The amount of body fat is variable, but it has a relative constant density of about 900Kg/m3 at 37°C (Allen et al., 1959) and a negligible water and potassium content. The fat free mass consists of three components: total body protein, total body water and bone minerals, with densities at 37°C of approximately 993, 1304 and 3000kg/m3 respectively. In healthy persons, the fat free mass has a relatively constant composition, with water content of 72% to 74% (Sheng and Huggins, 1979) potassium content of about 60-70mmol/Kg in men and 50-60mmol/Kg in women (Womersley et al., 1976) and a protein content of about 20% (Garrow, 1982). On average, the density of the fat-free mass approximates 1100 Kg/ m3 at 370 C (Behnke et al., 1953). The contribution of water and protein to the fat-free weights is shown in Table 1, while Table 2 shows the mean body composition estimates for adult Caucasian males and females (Kenneth, 2000). It is reported that there is a relationship between body composition and morbidity and mortality (Lahmann et al., 2002; Heitmann et al., 2000). Evidence showed that a low fat-free mass index (FFMI) and a high body fat mass index (BFMI) were linked to increased lengths of hospital stay. Thus it is very important to determine fat and lean body masses by direct measures, rather than relying on the body mass index (BMI) only, especially while describing obesity and malnutrition-related mortality risk and clinical outcome (Kyle et al., 2003). Fat-free mass (FFM) and body fat (FM) are helpful tools to evaluate nutritional status by comparing individuals or groups of individuals with themselves or with reference values. Percentile distributions are often useful in declaring whether individuals or groups fall within the particular population range. Percentile values can also be referred to define nutritional depletion and obesity (Kyle et al., 2003). The most commonly used method today for classifying an individual as overweight or obese is based on body mass index (BMI), a value that is determined by dividing body weight (in kilograms) by the square of height (in meters). In adults, regardless of sex, overweight is defined by a BMI of > 25.0 Kg/m2 and obesity is defined by a BMI of > 30.0 Kg/m2 (Allison et al., 1990).

However, The major limitation of BMI is that it does not differentiate between weight that is fat (i.e., fat mass) and weight that is muscle (i.e., fat-free mass) and therefore may lead to misclassification of very muscular individuals as overweight. In addition, older adults may appear to have a healthy BMI despite having excess fat and reduced muscle mass (Baumgartner et al., 1995).

Obesity is a global problem, affecting an estimated 300 million people worldwide. Its prevalence is increasing in both developed and developing countries throughout the world (WHO, 2002).

Table 1: The contribution of water and protein to fat-free weights of six adults (Garrow, 1983)

Sex	Age (Yrs)	Water (g/Kg)	Protein (g/Kg)	Remainder (g/Kg)	Density (Kg/m^3)
Male	25	728	195	77	1120
Male	35	775	165	60	1083
Female	42	733	192	75	1103
Male	46	674	234	92	1131
Male	48	730	206	64	1099
Male	60	704	238	58	1104
Mean		724	205	71	1106
SD		34	28	3	17

table 2: Mean body composition estimates for adults

Age Group	BMI (Kg/m^2)	TBW (Ltr)	TBPr (Kg)	BCM (Kg)	OsMin (Kg)	ICW (Ltr)	ECW (Ltr)	E(
Males								
20-29	24.1	45.4	12.6	34.5	2.97	27.6	17.8	0.
30-39	24.3	39.7	11.3	30.9	2.76	24.7	14.9	0.
40-49	25.2	43.2	11.4	31.4	2.72	25.1	18.1	0.
50-59	26.5	43.7	11.4	29.1	2.64	23.3	20.4	0.
60-69	25.8	39.7	10.6	28.9	2.66	23.1	16.5	0.
70-79	26.5	41.6	9.7	24.9	2.66	19.9	21.6	0.
Females								
20-29	22.1	31.1	9.1	21.1	2.25	16.0	14.2	0.
30-39	22.7	32.0	8.8	22.2	2.06	17.8	14.2	0.
40-49	24.9	30.5	8.4	20.2	2.12	16.2	14.3	0.
50-59	25.6	30.9	7.8	20.0	1.96	16.0	14.9	0.
60-69	25.4	27.6	7.2	16.9	1.74	13.5	14.0	0.
70-79	24.5	25.7	6.8	15.6	1.59	12.5	13.3	0.

Values are for Caucasian males and females in the United States. Estimates are based on tritium dilution, ^{40}K counting and Neutron activation analysis measurements (Wang *et al*., 1992). TBW = Total Body Water; TBPr = total body protein; BCM = body cell mass; OsMin = bone mineral mass; ICW = intracellular water; ECW = extracellular water; FFM = fat free mass.

The occurrence of overweight and obesity is more than almost 60% among U.S. adults and the rate is speedily increasing among children and adolescents as well (Wyatt et al., 2006). Approximately 325,000 deaths in the United States each year among nonsmokers are attributable to obesity (Allison et al., 1999). Obesity and overweight are strongly linked to higher risk of diseases of the metabolic syndrome, including diabetes mellitus and cardiovascular disease, as well as with certain forms of cancer (Kopelman, 2000; Seidell and Flegal, 1997). Simple indicators such as BMI, waist circumference, or waist-to-hip ratio are commonly used to assess obesity (Seidell and Flegal, 1997). But specificity and adequacy of these indicators are, however, still controversial (Bagust and Walley, 2000) because they do not allow a precise assessment of body composition. Body fat, especially visceral fat, is a proper option to be a better predictor of diseases of the metabolic syndrome (Mueller et al., 1991). Therefore, the assessment of body composition is more accurate and reliable tool to estimate the nutritional status of individuals, especially in epidemiological studies. As assessment of body composition is pragmatic approach to classify and diagnose obesity and related problems so it can also be altered in other health consequences associated with obesity which include stroke; type 2 diabetes mellitus (Hu et al., 2001); hypertension; dyslipidemia; cancers of the breast, endometrium, prostate and colon (Stoll, 1999; Wolff, 1987); gallbladder disease; osteoarthritis (Hartz et al., 1986) respiratory problems including asthma (Chen et al., 2002) and sleep apnea (Young et al., 2002) and perhaps depression (Roberts et al., 2000). Researchers are employing advance technologies along with improving the classical methods for better and perfect estimation of body composition. Recently introduced technologies such as positron emission tomography and functional magnetic resonance imaging broaden 'mass' estimates to related 'function' and physiology in humans. Still there is need to work more in this area (Heymsfield et al., 2005).

Different compartment models for assessment of body composition: Body composition studies are rapidly growing into a separate scientific discipline. This growth is fueled by an increasing interest among investigators from assorted backgrounds in the assessment of body composition components in vivo. Scientists divide the whole body in different compartment for measurement of accurate body composition.

Two compartment (2-C) model: In 2-C model, the body is considered into two parts. One is the body fat and all the other tissues are kept together into the part known as the fat-free mass (FFM). The direct measurement of body fat mass has never been simple and remains a major challenge for most body composition techniques.

Table 3: Selected Equations related to the five-level multi-compartment model (Kenneth, 2000)

Elemental Level		Body Wt = TBO+TBC+TBH+TBN+TBCa+TBP+TBK+TBCl+TBNa+ TBMg..................
Molecular level		Body Wt = Lipid Mass (Fat)+Total body water (TBW)+Total body protein (TBPr)+Bone Mineral (
Cellular level		Body Wt = body cell mass (BCM)+Extra Cellular water (ECW)+Exracellular solids+fat
Tissue system level		Body Wt = adipose tissue (Fat+cells)+Skeletal Muscles (SM)+Bone (mineral+fluid+marrow)+othe
Transitional equations between cellular, molecular and elemental levels		
TBCa	=	0.340 BMC
TBN	=	0.161 TBPr
TBC	=	0.759 TBLipid + 0.532 TBPr + 0.018 BMC
TBK	=	120 BCM
TBCl	=	111 ECW
TBLipid	=	1.318 TBC – 4.353TBN – 0.070TBCa
TBPR	=	6.21 TBN
OM	=	2.941 TBCa
STM	=	2.75 TBK + TBNa + 1.43 TBCl – 0.038TBCa

TB = Total Body for the elements; O = oxygen; C = carbon; H = hydrogen; N = nitrogen; Ca = calcium; P = phosphorus; K = potassium;

Cl = chloride; Na = sodium; Mg = magnesium; BMC = Bone mineral contents

However, if the total FFM can be determined, then body fat can be calculated indirectly as the difference between body weight and FFM (Kenneth, 2000). The earliest and probably the most frequently used 2-C model is based on the measurement of total body density. The most common method is hydro densitometry or UWW (Under Water Weighing), which was documented for first time in 1942 (Behnke et al., 1942). However other techniques are also worked using this model, among those nuclear techniques are being paid special attention due to their accuracy and simplicity. For the assessment of body fatness with either of these nuclear-based models, the water or potassium content of the FFM is measured and their relative concentrations are assumed to be constant for all ages: 0.732l/Kg for body water (Pace and Rathbun, 1945) and 68.1meq/Kg for body potassium (Forbes et al., 1961). Likewise, the density of the FFM for the 2-C model is also assumed constant. There may be a little change in these constants during pregnancy and may also vary in different ethnic groups and populations. As in case of healthy young white adults use of these three constants was suitable. However, when the populations included very young or old subjects, different ethnic groups, or subjects with certain diseases, it quickly became evident that these “constants” were, at best, only average values that were often population specific (Kenneth, 2000).

Three compartment (3-C) model: In 3-C model, the FFM is further divided into two parts: its water content and the remaining solids (predominately protein and minerals). So the three compartments are Fat Mass (FM), total body water (TBW) and solids (protein and minerals). The results obtained using this model provided some improvement over the basic 2-C model for healthy adults and older children. However, for patients with significantly depleted body protein mass and/or bone mineral mass, the estimated values for the density for the solids compartment will be incorrect; thus the final estimate of body fat mass will also be inaccurate (Kenneth, 2000).

Four compartment (4-C) model: The basic 2-C model can be extended to four compartments, but it is very important to measure the protein and mineral compartments accurately, in addition to that of total body water. Therefore, to assess of the mass of each of these body compartments, two additional measurements [neutron activation analysis for body protein and dual-energy X-ray absorptiometry (DXA) for bone mineral content] are required. An alternate 4-C model, without the UWW measurement, has also been developed. In this model, the body’s FFM is divided into three basic cellular or physiological compartments: body cell mass (BCM), extra cellular fluid or water (ECW) and extra cellular solids (ECS). BCM can be based on the measurement of whole body potassium (obtained by 40K counting) or dilution with a radioactive 42K tracer in plasma (De Lorenzo et al., 2004). For ECW compartment, the dilution methods using bromide or sulfate compounds as the tracer have been developed (Edelman et al., 1959). The ECS compartment can be defined on the basis of total body calcium or bone mineral content (Cohn et al., 1980; Wang et al., 1992). Fat-free mass is then defined as BCM+ECW+ECS and total body fat mass as body weight minus FFM.

Multi compatrment model: A survey of the literature for the last 50 years shows there is an evolutionary process from the basic 2-C models to the presently popular 4-C models of body composition. On the basis of these informations and experiences scientists have proposed a comprehensive, five-level model of body composition (Wang et al., 1992). This five-level model, illustrated in Fig. 1, has become the standard for body composition research. The five levels of the model are as follows: elemental, molecular, cellular, tissue systems and total body. As each model includes more measurements, it tends to migrate toward the cellular or physiological model. At each level (examples are presented in Table 3), equations can be used to describe that level within the total model. In addition, there are translational equations between levels, as well as hybrid or mixed level models.

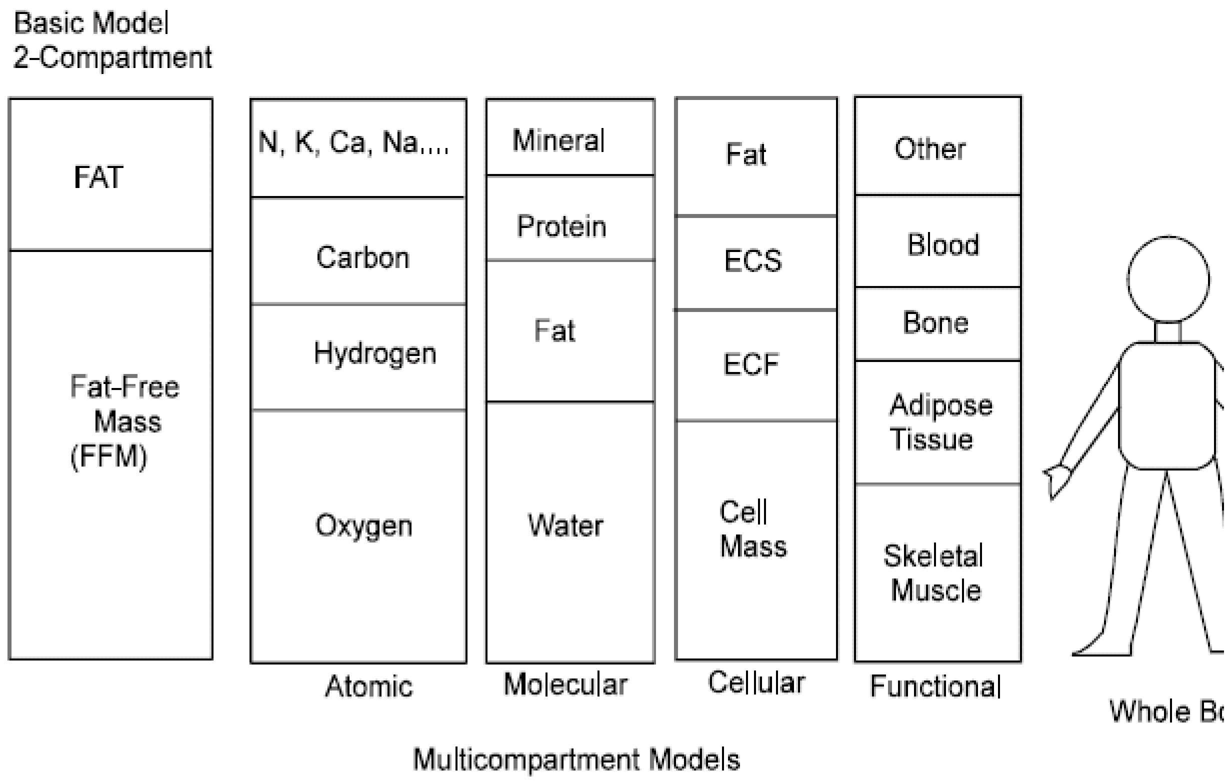

Fig. 1:	Basic Two Compartment model and five level multi-compartment model of body composition ECS = extracellular solids; ECF = Extracellular fluid (Wang *et al*., 1998; Wang *et al*., 1992)

In general, the relationships between chemical or elemental composition (amounts of oxygen, carbon, hydrogen, nitrogen, calcium) and the molecular structure of tissues (water, protein, lipids and bone mineral) remain relatively fixed in both health and disease. Consequently, the reconstruction of body composition from the elemental level is often more reliable and minimizes the assumptions related to tissue density, hydration and/or structure (Kenneth, 2000).