

Malnutrition or healthy senescence

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There are undeniable changes in the body's composition with old age, and these changes can bring about a plethora of physiological consequences affecting levels of function, and current and subsequent health (Rosenberg, 1989; Heymsfield *et al.* 1995). Health and function are interrelated states within the ageing process (Nagi, 1976), and transitions amongst them and disease and disability are affected by alterations in the body's composition through the ageing process. The expression and uniformity of changes in body composition vary among healthy, sick and malnourished elderly men and women. This variation affects our interpretation of estimates, measures, indices, and changes in body composition as related to levels of health and function in the elderly. These relationships are further affected by the fact that the elderly of today are some of the first recipients of the improvements in health and nutrition that have occurred during the twentieth century. The present paper reviews some of the issues relating levels of and changes in body composition with health and function among today's elderly. If body composition changes in old age, from what levels are the changes occurring? What is the timing or age at onset of the changes and how appropriate are existing body composition reference data for elderly people today?

Healthy senescence from adulthood into old age

Within the continuum of adult life, a major characteristic of body composition in normal, healthy adults appears to be that of increasing fatness. Overlaid on this period, if not the entire lifespan, are the effects of a modern lifestyle with its low levels of physical activity and the questionable quality and health benefits of many current diets. Most adults experience a creeping increase in body weight and fatness, and the increased prevalence of adult obesity is clear (Kuczmarski *et al.* 1994). Total body fat increases, as does the percentage of body fat, in both men and women (Guo *et al.* 1997c). Thus, many adults will enter the onset of old age today with potentially high levels of adiposity. Some have argued that this fatness is beneficial for mortality (Andres, 1985), despite the associated cardiovascular health risks. Moderate overweight among the elderly is reported to be associated with lower mortality, implying that a limited increase in weight with old age is beneficial (Andres, 1985; Andres *et al.* 1993). However, this relationship with mortality is confounded by the loss of weight from middle to old age among those

individuals with the highest weight levels who are experiencing poor health (Losonczy *et al.* 1995). The obese in middle age start to lose weight as a result of, or in conjunction with, the onset of chronic disease. At the same time, non-obese middle-aged to elderly individuals, including those who had remained weight stable even at a low level, tended to preserve their health (Losonczy *et al.* 1995).

Most of the early reports of the changes in body composition with increasing old age used trends or values calculated from cross-sectional studies (see Brozek, 1963; Forbes, 1987). These studies indicated that continuous decreases in amounts of water, muscle and bone occur in both men and women, and these trends started as early as the 5th or 6th decade of life. More recently, where healthy adults in the Fels Longitudinal Study have been followed up to 65 years of age, serial measures of amounts of total body water and fat-free mass (FFM) have, on average, remained relatively stable in the men (Chumlea *et al.* 1997b; Guo *et al.* 1997c). This pattern of stability is similar for women also, but only until about 50 years of age and/or the occurrence of menopause. After menopause in these healthy women, there are small decreases in total body water, FFM, and bone mineral content and density (Chumlea *et al.* 1997b; Guo *et al.* 1997c; Zeller *et al.* 1997).

Cross-sectional data from the New Mexico Aging Process Study (see Garry, 1997) indicate that healthy successfully-aged men and women 60–70 years of age, on average, tend to have larger amounts of bone, muscle and fat than similar groups of persons over 70 years of age (Table 1).

Table 1. Mean values for body composition variables in healthy elderly New Mexico Aging Process Study participants (see Garry, 1997)

Age-group . . .		60–70 years	70–80 years	80+ years
Men	<i>n</i>	17	78	37
	FFM (kg)	58.2 ^a	55.4 ^b	53.4 ^c
	TBF (kg)	23.4	20.0	21.8
	TBM (kg)	3.1	2.8	2.8
Women	<i>n</i>	50	80	51
	FFM (kg)	40.0 ^a	37.7 ^b	37.3 ^c
	TBF (kg)	26.5 ^a	24.5 ^b	21.4 ^c
	TBM (kg)	2.1 ^a	1.9 ^b	1.8 ^c

FFM, fat-free mass; TBF, total body fat; TBM, total body mass.
^{a,b,c} Mean values in rows with unlike superscript letters were significantly different ($P < 0.05$).

Abbreviations: FFM, fat-free mass; NHANES, National Health and Nutrition Examination Survey.

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There is approximately a 2–3 kg difference in FFM between the 60–70 years age-group and the 70–80 years age-group for both the men and women. Between the two older age-groups, the differences in average amounts of bone, muscle and fat are generally not as large as these initial changes, although FFM in the men and total body fat in the women continue to decline from 70–80 years of age and the age-group over 80 years of age (Table 1). The average body composition values for these healthy elderly men and women at 60 years of age (Table 1) are similar to corresponding values for persons followed serially in the Fels Longitudinal Study (Chumlea *et al.* 1997b; Guo *et al.* 1997c). After about 60 years of age, the average changes in body composition appear to occur earlier in the ageing process rather than later among the healthy elderly. These current serial and cross-sectional findings from adulthood into old age demonstrate that the accepted or expected loss or decline in body composition with old age is not a continuous process starting early in middle age, except for women. After about 70 years of age, the changes in body composition that have been occurring in healthy men and women appear to abate.

The changes in body composition that occur with old age in the healthy elderly start with menopause in women and appear to continue to about age 70 years. Similar, but less severe, changes appear in healthy men from about age 60–70 years. These changes are, in part, hormonally related in both women and men, but a male climacteric is difficult to determine. Some of the variance in levels of body composition among older adult men and women is due to different levels of physical activity and the onset of menopause in women (Guo *et al.* 1997c; Zeller *et al.* 1997). When significant declines in body composition do occur, early or late in the ageing process, this event may be an expression of individual variation, or it may be a risk factor for subsequent health and functional problems, possibly sooner rather than later in life. Significant changes in body composition in old age, or at any age, appear to herald the onset of, or the concurrence with, disease, poor health and functional disability (Garry, 1997).

Sarcopenia and weight-related health conditions

The amount of muscle mass in the body is an important predictor of the outcome in critical illness (Hill, 1992), and low body weight in old age may be an indicator of possible sarcopenia. Sarcopenia has been defined at a recent National Institute on Aging workshop (Lexell & Dutta, 1997) as a loss of muscle function at the impairment level within the framework of the disablement process (Guo *et al.* 1997a). A loss of muscle mass can affect the outcome of chronic disease and increase the risk for functional limitation and disability, all of which can also affect the amount of muscle mass (Chumlea *et al.* 1997a; Dutta *et al.* 1997; Guo *et al.* 1997a; Schwartz, 1997). A loss of weight during old age is an important health indicator, but reliable valid assessments or indices of levels of FFM in the elderly are necessary to help screen for sarcopenia. However, the amount of muscle mass that delineates the degree and prevalence of sarcopenia has not been determined clearly, due to the limited quality of current reference data. In addition, understanding the relationship between declines in muscle mass and morbidity, function, disability and mortality is complicated by several factors;

these include the accuracy and reliability of the methods of measuring body composition, and the effects of age, sex, race, genetic and behavioural factors. We should expect the levels or amounts of muscle mass that might distinguish sarcopenia to vary depending on the population in question, and as a function of age, sex, race and possibly cohort differences.

Weight-related health conditions, including sarcopenia and obesity, limit an individual's physical ability to move around freely, and their social interaction with friends and neighbours. Weight-related health conditions also include osteoarthritis, cardiovascular disease, vascular disease, diabetes and glucose intolerance. The prevalence of weight-related conditions among the elderly is approximately 47 % of community-based 65-year-old individuals (Seeman *et al.* 1989). With this prevalence, it is important to measure the presence and onset of weight-related health conditions so that co-morbid associations can be determined. The complex interactions resulting from co-morbidity should be considered, especially since the incidence of co-morbidity (excluding sarcopenia) in community-based elderly is 60 % and has a major effect on individual health (Guralnik *et al.* 1989; Kaplan *et al.* 1992). The contribution of changes in body composition to this co-morbidity needs to be established, as well as its effect on the prevalence of all weight-related health conditions in the elderly.

Body composition screening in the elderly

A major difficulty in quantifying body composition among the elderly is the questionable validity of assumptions underlying measures and estimates of muscle, fat and bone during the ageing process, especially when confounded by disease and disability. For example, FFM can also be estimated from measures of total body water based on the assumption that approximately 73 % of total body water resides in the FFM. However, the universality of this assumption in the elderly is suspect, because chronic disease can affect the retention or loss of body water or alter the proportions of extra- and intracellular water (Steen *et al.* 1985; Roubenoff & Kehayias, 1991). Dual-energy X-ray absorptiometry is recommended for body composition analyses of the elderly (Haarbo *et al.* 1991; Johnson & Dawson-Hughes, 1991; Laskey *et al.* 1991). This technique is now widely used, but has not been universally accepted because of methodological problems and systematic differences among manufacturers (Roubenoff *et al.* 1993; Kohrt, 1995; Guo *et al.* 1997b). Bioelectrical impedance, both single and multifrequency, remains a potentially useful method of measuring body composition in the elderly (Chumlea & Guo, 1994). However, the validity of bioelectrical impedance has not been well established, except in small samples of the elderly with limited age-ranges (Deurenberg *et al.* 1990). Thus, there is no universally suitable method of measuring body composition in the elderly that is immune to problems of non-universal assumptions, limited by available methodology or affected by aspects of chronic disease and functional disability. Our knowledge of body composition and its changes with old age are further compromised when applied to women or members of non-white racial or ethnic groups of elderly individuals around the world.

Anthropometric measurements primarily infer information about body size, amounts of skeletal muscle and fatness. These inferences are meaningful as long as the body's systems are homeostatic, but can change with disease and disability. Anthropometric measurements can be used to screen for levels of body composition in a variety of health, nutritional and functionally-related contexts to monitor or account for elderly individuals at risk. For example, calf circumference is a sensitive measure of the loss of muscle mass in the elderly, and is recommended by the World Health Organization (1995) as a measure of nutritional status in the elderly. Calf circumference is also used together with arm circumference as a validated nutritional screening instrument for malnutrition in the elderly (Guigoz *et al.* 1994). Low values of arm and calf circumference are related to greater degrees of malnutrition than BMI, and more so in the sick elderly (Chumlea *et al.* 1995).

Body composition and function

Muscle mass is the functional component of body composition, but its interaction with function is not always clearly delineated. Functional status is a measure of physiological mechanisms and of biological abilities (Katz *et al.* 1963), and functional health is a significant predictor of positive health outcomes in the elderly, as well as being a prognostic indicator of disability (Guralnik & Kaplan, 1989). Objective tests of physical performance have improved measures of functional status (Guralnik *et al.* 1994). Performance-based assessments are related to measures of muscle strength, but not to levels of muscle mass (Cress *et al.* 1995). Strength, however, is directly determined by the amount of muscle mass (Pearson *et al.* 1985; Frontera *et al.* 1991), and changes in muscle strength are related to concurrent changes in muscle mass (Young *et al.* 1984). A decrease in strength with age may also be produced by alterations in the neurological and contractile properties of muscle tissue. The decrease in strength with age results from the atrophy of some fibres and the loss of others caused by degeneration of the number of neuromuscular junctions (Lexell *et al.* 1983; Balice-Gordon, 1997). All these changes are probably related to reduced levels of physical activity (Bassey, 1997). Thus, measures of strength should be considered as a possible screening tool for elderly subjects to assess their ability to live independently, and their risk for future health and functional problems. For example, measures of lower body strength are related to changes in muscle mass of the legs, and predict the occurrence of falls and problems with gait and balance (Shephard *et al.* 1991; Fiatarone *et al.* 1994; Wolfson *et al.* 1995). Strength of the quadriceps is a valid indicator of lower-body functional capacity and performance in elderly subjects. Also, dual-energy X-ray absorptiometry allows regional measures of muscle in the legs, and these measures could be correlated with levels of strength in the legs in the elderly.

Reference values

Among the available sets of reference data for the elderly, some are no longer representative of the sample of elderly persons living today. For example, Damon & Stoudt (1963) published data for elderly men. These data were collected

from Spanish-American War Veterans, many of whom were born in the 1870s, and all of whom are now dead. The report by Masters *et al.* (1960), has been recommended as 'the best data currently available' for the elderly (Ham, 1991); however, it includes individuals who were born between 1865 and 1895. Most of these individuals are now deceased also. The present living very old elderly were born between about 1900 and 1913. Because of the occurrence of what is called the secular trend among world populations during the twentieth century (Eveleth & Tanner, 1976), it is very doubtful that data from persons born in the ninetieth century are relevant for elderly persons living on the eve of the twenty-first century.

Subsequent generations born during the twentieth century were significantly larger in stature and weight than previous generations and reached maturation earlier. This phenomenon was reported in the USA about 1932 (Blackfan, 1932), and eventually it occurred worldwide (Eveleth & Tanner, 1976). The secular trend has now stopped in the USA (Roche, 1979) and in many other developed countries (Eveleth & Tanner, 1976). The generation that fought in World War II was the first to be widely identified with this phenomenon (Blackfan, 1932), and this is the generation that comprises the majority of the elderly people alive today. The causes of this secular trend are reportedly numerous, but improved nutrition and public health are high on the list. Thus, the present generation of elderly is probably the first to have benefitted fully from the effects of improved nutrition and health during childhood, that helped to make them taller and heavier as adults than their parents (Stini, 1981). These beneficial effects (and improvements) have persisted as this generation has aged, and may be affecting the course of their ageing as compared with that of previous generations, especially in terms of the prevalence of healthy ageing. However, it is important to recognize that even among cohorts of elderly persons today, significant group and racial differences existed during their growth and maturation, health and living conditions, and levels of nutritional status as children and adults (Boyd, 1980). The results of these effects and initial differences among these groups may have increased in old age.

Current reference data

Mean values and distribution statistics for stature, weight and other selected body measures of the elderly are available from several national health surveys and large clinical studies in several different countries (Abraham *et al.* 1979; Najjar & Rowland, 1987; DeGroot *et al.* 1991; Vellas *et al.* 1992; World Health Organization, 1995). For those 80 years of age and older, available reference data are scarce, even though proportionately this is the fastest growing segment of many world populations (Chumlea & Baumgartner 1989; Czajka-Narins *et al.* 1991; World Health Organization, 1995). Suitable reference data for the present generations of elderly in the USA are available from the National Health and Nutrition Examination Survey (NHANES) III (Woteki *et al.* 1988). For elderly persons in Europe, a primary current source of data is the Survey in Europe on Nutrition and the Elderly, a Concerted Action (SENECA) study (DeGroot *et al.* 1991). The increase in the prevalence of obesity in the

Table 2. Approximate samples for elderly data in National Health and Nutrition Examination Survey III by selected age-groups

Age-group . . .	60–69 years	70–79 years	80–85 years	85–90 years	90+ years
White men	481	634	456	176	40
White women	474	564	426	210	48
Black men	266	224	32	20	8
Black women	296	202	76	28	6
Mexican-American men	312	160	50	16	0
Mexican-American women	294	134	36	14	6

US adult population including the elderly (Kuczmarski *et al.* 1994), raises concerns about the use of NHANES III data as a health reference, especially for determining levels of low muscle mass or sarcopenia.

The data for the elderly in NHANES III (Woteki *et al.* 1988) consists of a sex- and racial or ethnic-stratified sample of approximately 4750 persons from the US population aged 60 years and older. This includes approximately 1369 Caucasian men 60–102 years, 1472 Caucasian women 60–98 years, 474 non-Hispanic Black men 60–97 years, 481 non-Hispanic Black women 60–92 years, 497 Mexican-American men 60–97 years and 457 Mexican-American women 60–97 years. These large numbers would appear to indicate an adequate sample size, but when the sample is broken down by 10- and 5-year age-groups (Table 2), it becomes clear that few persons are represented above 85 years of age for the non-Hispanic Whites and even fewer above 79 years for the non-Hispanic Blacks and Mexican-Americans. In addition, these data are not suitable for the calculation of percentiles for BMI, weight, etc. even after adjusting the data to be representative of the US population (Landis *et al.* 1982). The calculation of precise conventional percentiles for BMI from the 5th to the 95th levels requires 250–300 individuals within a 5-year age-group (S. Guo, unpublished results). Calculation of such percentiles for White women from 60 to 100 years of age would require a sample of 2700, and the calculation of such percentiles for White women from 60 to 85 years of age would require a sample of 1800. Calculation of precise percentiles from the 25th to the 75th levels requires 100 individuals within each and every 5-year age-group, so that the calculation of such percentiles for White women from 60 to 100 years of age would require a sample of 900. In terms of numbers of individuals, the NHANES III sample of elderly is limited to the determination of precise reference percentiles at the 25th and 75th levels from 60 to 90 years of age for non-Hispanic Whites, but only from 60 to 79 years of age for non-Hispanic Blacks and Mexican-Americans.

There are numerous small sets of data for elderly persons living in the USA and in other countries around the world. Many of these studies are well designed and have provided much important and valid information. Such data sets are frequently from samples of convenience and they are not representative of the general population of elderly. The utility or suitability of these data sets in describing levels of body composition for large segments of the elderly population and across national borders are limited, and should be approached with caution.

Conclusion

With the onset of old age, we are hampered in describing relationships between body composition and health and function by the limited availability of adequate serial data, and possibly by cohort and health effects among study groups reported over the past several decades. Much of our information on the changes in the body's composition with old age is from several important studies that are 30 years old. These reports, along with some limited survey data for body weight and anecdotal reports from small samples, provide the basis of much of our current understanding of the changes in body composition with old age. More recent data for body composition in the elderly is presenting a picture that is different from that reported for earlier generations or cohorts. No one would argue that changes in body composition with age are not real, but their individual expression and age of occurrence among elderly people today who are ageing successfully and subsequent generations have been affected by improved levels of lifelong health and nutrition. Obviously, there remains a distinct need for more national reference data for body composition measures that have larger samples and are suitable for describing differences between individuals, relationships with function, and levels of muscle mass related to malnutrition and the risk of sarcopenia.

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