Anthropometric characteristics of healthy Italian nonagenarians and centenarians

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Available anthropometric reference values for elderly people do not include specific norms for over-90-year-old subjects despite their increasing number. In the present study, weight, height and a number of anthropometric variables related to body muscle and fat mass were collected from fifty-seven nonagenarian and forty-one centenarian healthy, non-institutionalized subjects living in an Italian area. Recumbent anthropometry was used to avoid errors associated with impaired mobility. Nonagenarians and centenarian men were taller and heavier than women of corresponding age and had a greater amount of muscle and trunk fat, whereas women showed a marked peripheral adipose distribution. Anthropometric values of both age-groups were generally lower than published norms for 70–89-year-old American and European elderly people. However, differences were less marked when comparing Italian nonagenarians and centenarians with French and British people aged 85 years and over than when comparing Italian subjects with American octogenarians and younger European elderly people. Taken together these findings suggest a dramatic loss of muscle and fat mass in over-90-year-old subjects with respect to younger elderly people. However, changes between successive generations and geographical influences cannot be excluded. The need for local and age-specific norms in nutritional assessment of over-90-year-old people is emphasized. It is also suggested that current anthropometric indices may not be reliable when evaluating the oldest elderly subjects.

Anthropometry: Elderly: Body composition

Assessment of nutritional status is essential in the clinical evaluation of the elderly. Nutritional disorders are very frequent in old people and involve a high risk of morbidity and mortality (Kuczmarski, 1989). Clinical and nutritional history, physical examination and routine blood tests, together with anthropometric measurements form the basis for nutritional assessment (Shuran & Nelson, 1986). Anthropometry is a rapid, inexpensive and non-invasive method of obtaining information on the amount and localization of body muscle and fat mass. Anthropometric indices provide physicians with useful information for identifying malnutrition, defining therapeutic objectives and monitoring the effects of nutritional therapy.

Anthropometric standards have been developed using the data collected from adults aged 18–74 years during the National Health and Nutrition Examination Survey (NHANES), from 1971 to 1974 (Bishop *et al.* 1981; Frisancho, 1981; Bishop, 1984; Najjar & Rowland, 1987). As ageing itself leads to significant modifications of body composition that are unrelated to nutritional status (Steen, 1988; Baumgartner, 1993; Going & Lohman, 1994), for a reliable evaluation of individuals aged 75 years and over, age-specific reference values are required. The Cincinnati Anthropometric Survey for the

Elderly (Falciglia *et al.* 1988) has provided anthropometric statistics for Americans aged 80–89 years, but norms for older subjects are scant and almost 20 years old, making them no longer representative of the current generation of over-90-year old Americans (Chumlea *et al.* 1991).

As regards elderly Europeans, anthropometric percentiles have been recorded for French (Vellas *et al.* 1992; Delarue *et al.* 1994), and British (Burr & Phillips, 1984) populations aged over 80 years. None of these studies, however, distinguished between the eighth and ninth decade or included centenarians, although, considering their increasing number, nonagenarians and centenarians currently represent a group that requires its own age-specific percentile distributions.

In order to fill this gap we collected anthropometric information from fifty-seven nonagenarians and forty-one centenarian healthy free-living subjects resident in an Italian area. Our data were also compared with the available anthropometric reference values for elderly people.

MATERIAL AND METHODS

Subjects

The study was conducted in the Northern Italian region Emilia Romagna, whose economy, previously mainly agricultural, is actually based on craftsmanship and small and middle-sized industries. Ninety-eight healthy subjects, aged 90–107 years, fifty-seven nonagenarians (twenty-four women and thirty-three men) and forty-one centenarians (twenty-eight women and thirteen men), whose name and address were obtained from the lists of local general practitioners, volunteered for the study. All subjects lived at their own home and fulfilled the strict health selection criteria of the SENIEUR protocol (Ligthart *et al.* 1984). This protocol describes the admission criteria for immuno-gerontological studies in human subjects, and is based on clinical, pharmacological and laboratory data. (The exclusion criteria for admission to this group may be summarized as follows: (a) clinical evidence of infective, inflammatory, neoplastic and other chronic disease; (b) alteration of one or more of several laboratory variables including erythrocyte sedimentation rate, haemoglobin, mean corpuscular volume, leucocyte count, urea, glucose, cholesterol and triacylglycerols, alkaline phosphatase (*EC* 3.1.3.1), aspartate aminotransferase (*EC* 2.6.1.1), alanine aminotransferase (*EC* 2.6.1.2), serum protein electrophoresis, urine analysis (protein, glucose, sediment); (c) prescribed medication for treatment of chronic disorders.) All subjects were visited at their place of residence and underwent a nutritional interview. Their weight had remained stable in the previous 6 months before the study and their dietary habits did not show any particularities with respect to the dietary habits of the local population.

Anthropometric measurements

All subjects were weighed on the same scales barefoot and in light clothing. The other anthropometric measurements were made with the patient in a recumbent position, in order to make measurement easier and not falsified by any alterations in mobility. No systematic differences have been reported between paired values of corresponding recumbent and standing measurements taken at the same body sites (Chumlea *et al.* 1985*a*). Anthropometric assessment was performed according to the procedures described in *Anthropometric Standardization Reference Manual* (Lohman *et al.* 1988). As the spine's shrinkage with ageing can affect the validity of height measurement in the elderly, height was calculated from the knee-height measurement, according to the formula of Chumlea *et al.* (1985*b*). Knee height was measured with a sliding broad-blade calliper (Anthropometer Lafayette, IN, USA) as the distance between the sole of the foot and top of the knee when ankle and knee are both flexed at 90°. BMI was calculated as weight (kg) divided by height^2 (m). The following body circumferences were measured in each subject by means of a flexible tape (Holtain Ltd, Crymych, Dyfed): (a) mid-arm circumference (MAC), at the mid point between the tip of the acromion and the olecranon process, (b) upper-thigh circumference (UTC) at the *gluteal sulcas* and (c) mid-thigh circumference at the mid point between the inguinal fold and the proximal margin of the patella. Waist and hip circumferences were also measured for each subject but in the present paper we used waist: hip circumference ratio (WHR), taken as an index of intra-abdominal fatness (Seidell *et al.* 1987). Skinfolds were measured at the left side of the body to the nearest 0·002 m with a Holtain skinfold calliper (Tanner Whitehouse, Crymych, Dyfed). The skinfolds were measured in triplicate at four standard sites: biceps, triceps, suprailiac and subscapular, as previously described (Durnin & Womersley, 1974). The average value of the triplicate measurements was used in the statistical analysis. The triceps: subscapular skinfold ratio and the sum of the four skinfolds were calculated. The anterior-thigh skinfold was also measured on the anterior surface of the thigh, at the midpoint between the inguinal fold and the proximal margin of the patella. Commercially available software (Anthropometry. Master; Dietosystem, Milan, Italy) was used to derive arm-muscle circumference (AMC), arm-muscle area (AMA) and arm-fat area (AFA; Frisancho, 1981) and AFA:AMA ratio was calculated.

Statistical methods

Sex-specific mean values, standard deviations and ranges for each anthropometric index were calculated separately for nonagenarians and centenarians. Sex and age-group differences between corresponding values were analysed by Mann-Whitney test for unpaired data.

RESULTS

Tables 1 and 2 present sex-specific mean values, standard deviations and ranges for the measured anthropometric variables of nonagenarians and centenarians. Men of both age-groups were taller and heavier than women of the same age-groups but there was no difference in BMI. Among body circumferences, only UTC differed between men and women of the same decade. Triceps and anterior-thigh skinfold thickness were greater in women than in men aged 90–99 years but the difference was not observed in centenarians. No age- and sex-related difference was found for biceps, suprailiac (data not shown), subscapular skinfold and the sum of the four skinfolds, whereas triceps:subscapular skinfold ratio was significantly higher in both nonagenarian and centenarian women than in men of corresponding age. In both decades, AMC and AMA mean values were greater in men than in women, and although no sex-specific difference in AFA mean values was found, in both age-groups AFA:AMA ratio was greater in women than in men.

Table 3 shows reference norms for height and weight of elderly people derived from the literature. Mean values for height and weight of nonagenarians and centenarians were at the lower percentile values of the distributions reported for elderly American and European subjects, even though in our study (as in the study of Vellas *et al.* 1992) height was calculated on knee height and, therefore, not affected by the physiological shortening

Table 1. *Anthropometric indices for a nonagenarian Italian poplulation*†

(Mean values and standard deviations, with ranges)

	Men (n 24)			Women (n 33)		
	Mean	SD	Range	Mean	SD	Range
Age (years)	96·0	2·1	90–99	95·0	2·6	90–99
Wt (kg)	58·6	7·6	40·0–72·0	48·8***	7·2	38·0–70·0
Knee height (mm)	490	25	425–527	440***	37	380–520
Height (m)‡	1·60	0·05	1·47–1·67	1·43***	0·07	1·31–1·57
BMI (kg/m^2)‡	22·8	3·2	14·5–28·9	23·7	3·7	18·6–32·3
Waist:hip ratio	0·89	0·05	0·73–0·98	0·88	0·06	0·70–1·05
Mid-arm circumference (mm)	221	26	170–290	209	31	160–290
Upper-thigh circumference (mm)	467	49	340–570	447*	55	330–570
Mid-thigh circumference (mm)	372	34	310–435	365	54	270–520
Triceps skinfold (mm)	6·8	2·8	3·2–13·2	10·7***	5·2	2·9–24·0
Subscapular skinfold (mm)	10·7	3·3	5·5–20·1	9·9	5·2	4·1–25·0
Anterior-thigh skinfold (mm)	10·2	3·7	4·2–21·2	15·5**	7·8	4·3–32·3
Four skinfolds (mm)	30·5	8·6	16·0–50·7	36·5	15·5	14·7–79·0
Arm-muscle circumference (mm)	200	19	158–228	183**	22	150–234
Arm-muscle area (AMA; mm^2)	3200	588	1987–4152	2675**	695	1568–4348
Arm-fat area (AFA; mm^2)	607	233	267–1137	830	490	210–2300
AFA:AMA ratio	0·19	0·07	0·11–0·33	0·30***	0·14	0·11–0·82
Triceps:subscapular skinfold ratio	0·65	0·25	0·32–1·47	1·13***	0·34	0·35–1·75

Mean values were significantly different from those for men: $*P < 0·05$, $**P < 0·01$, $***P < 0·001$.
†For details of subjects and procedures, see pp. 10–11.
‡Height was calculated from knee height.

Table 2. *Anthropometric indices for a centenarian Italian population*

(Mean values and standard deviations, with ranges)

	Men (n 13)			Women (n 28)		
	Mean	SD	Range	Mean	SD	Range
Age (years)	100·3	0·4	100–101	101·8	1·9	100–107
Wt (kg)	55·8	11·9	43·0–75·0	45·8**	8·1	34·0–65·0
Knee height (mm)	471	29	419–545	440***	22	390–480
Height (m)‡	1·56	0·06	1·45–1·71	1·41***	0·04	1·31–1·48
BMI (kg/m^2)‡	22·9	4·8	16·6–32·7	23·1	4·4	17·4–34·6
Waist:hip ratio	0·91	0·07	0·82–1·10	0·86	0·07	0·07–1·05
Mid-arm circumference (mm)	219	44	170–310	194	30	150–270
Upper-thigh circumference (mm)	468	69	370–600	416*	65	280–560
Mid-thigh circumference (mm)	380	62	300–480	339	45	240–425
Triceps skinfold (mm)	7·4	4·3	3·2–17·8	9·9	4·6	2·8–22·2
Subscapular skinfold (mm)	12·0	5·8	6·1–23·3	9·0	3·4	3·6–16·7
Anterior-thigh skinfold (mm)	11·1	7·3	4·0–30·2	14·2	7·0	5·0–34·2
Four skinfolds (mm)	34·1	17·0	17·4–74·0	35·1	13·0	17·1–66·1
Arm-muscle circumference (mm)	199	35	159–260	171**	23	134–237
Arm-muscle area (AMA; mm^2)	3249	1157	2004–5394	2385*	674	1425–4488
Arm-fat area (AFA; mm^2)	699	569	237–2252	697	364	214–1584
AFA:AMA ratio	0·20	0·09	0·10–0·42	0·28**	0·10	0·10–0·54
Triceps:subscapular skinfold ratio	0·63	0·25	0·37–1·30	1·13***	0·40	0·35–2·19

Mean values were significantly different from those for men: $*P < 0·05$, $**P < 0·01$, $***P < 0·001$.
†For details of subjects and procedures, see pp. 10–11.
‡Height was calculated from knee height.

of the spine with ageing (Chumlea *et al.* 1985*b*). BMI, however, in both nonagenarians and centenarians, was similar to the available literature values for elderly subjects (see Table 4). Table 5 shows sex-specific percentile distributions for triceps skinfold of elderly subjects from the seventh to the ninth decade, and it is worthwhile to note that mean values for Italian nonagenarians and centenarians are close to the lowest percentiles of the distribution reported for younger elderly American and French people, but when the same population is compared with the British survey, that includes the oldest subjects, the difference is much reduced with regard to women, and there is no difference at all with respect to male subjects.

Table 6 shows age-specific reference values for subscapular skinfold values. Our values were much lower than those recorded in the elderly American and French subjects, but whereas men of the larger but younger NHANES sample had greater values for subscapular skinfold than women, in the older French population, as in our subjects, men and women had similar subscapular skinfold values.

MAC (not shown), AMC and AMA values for Italian over-90-year-old subjects were much lower even than those of American octogenarians. However, as for the triceps skinfold, the difference was less marked when comparing Italian nonagenarians and

Table 3. *Sex-specific reference values for height and weight of American and European elderly subjects*

Percentiles.... Reference	Age (years)	Variable	Men *n*	Men 10th	Men 50th	Men 90th	Women *n*	Women 10th	Women 50th	Women 90th
American subjects										
Frisancho *et al.* (1984)*	55–75	Wt (kg)	47	49	61	73	85	46	54	65
French subjects										
Delarue *et al.* (1994)	+80	Height (m)	62	1·59	1·67	1·75	65	1·46	1·53	1·60
		Wt (kg)		58·1	69·5	79·3		44·0	56·0	75·0
Vellas *et al.* (1992)†	+85	Height (m)	18	1·53	1·62	1·77	26	1·43	1·50	1·75
		Wt (kg)		50·0	64·5	74·0		40·0	58·5	73·0

*Developed from the combined National Health and Nutrition Education Surveys I (1971–1974) and II (1976–1980) data sets.
†Weight and height calculated from knee height; for details, see pp. 10–11.

Table 4. *Sex-specific reference values for BMI (kg/m^2) of American and European elderly subjects*

Percentiles.... Reference	Age (years)	Men *n*	Men 10th	Men 50th	Men 90th	Women *n*	Women 10th	Women 50th	Women 90th
American subjects									
Najar & Rowland (1987)*	65–74	1503		22·0		1670		21·6	
French subjects									
Delarue *et al.* (1994)	+80	62	21·6	23·9	26·5	65	18·3	24·5	29·7
Vellas *et al.* (1992)†	+85	18	21·8	24·5	28·4	26	19·7	23·5	29·7
English subjects									
Burr & Phillips (1984)	+85	41	19·0	23·1	27·2	88	18·2	23·6	29·0

*Developed from data collected during the National Health and Nutrition Education Survey I (1971 to 1974).
†Calculated from knee height; for details, see pp. 10–11.

Table 5. *Sex-specific reference values for triceps skinfold thickness (mm) of American and European elderly subjects*

Percentiles.... Reference	Age (years)	Men				Women			
		n	10th	50th	90th	*n*	10th	50th	90th
American subjects									
Frisancho (1981)*	65–74	1503	6·0	11·0	19·0	1670	14·0	24·0	34·0
Bishop *et al.* (1981)*	65–74	1657	5·5	11·0	19·0	1822	14·0	23·0	33·0
Falciglia *et al.* (1988)	80–89	49	8·0	21·0	37·5	111	12·9	21·8	34·6
French subjects									
Delarue *et al.* (1994)	+80	62	6·1	9·2	13·9	62	10·2	15·9	26·0
Vellas *et al.* (1992)	+85	18	7·2	10·2	12·4	26	8·0	14·5	21·3
English subjects									
Burr & Phillips (1984)	+85	31	3·9	6·5	10·6	75	7	11·5	19·0

*Developed from data collected during the National Health and Nutrition Education Survey I (1971–1974).

Table 6. *Sex-specific reference values for triceps skinfold thickness (mm) of American and European elderly subjects*

Percentiles.... Reference	Age (years)	Men				Women			
		n	10th	50th	90th	*n*	10th	50th	90th
American subjects									
Bishop (1984)*	65–74	1657	7·5	15·0	25·0	1822	8·0	18·0	32·5
French subjects									
Vellas *et al.* (1992)	+85	18	9·1	13·9	18·0	26	6·3	14·4	21·2

*Developed from data collected during the National Health and Nutrition Education Survey I (1971–1974).

Table 7. *Sex-specific percentiles for arm muscle circumference (mm) of American and European elderly subjects*

Percentiles.... Reference	Age (years)	Men				Women			
		n	10th	50th	90th	*n*	10th	50th	90th
American subjects									
Frisancho (1981)*	65–74	1503	235	268	298	1670	195	225	264
Bishop *et al.* (1981)*	65–74	1657	237	269	299	1822	195	225	265
Falciglia *et al.* (1988)	80–89	49	182	228	273	111	167	213	267
French subjects									
Delarue *et al.* (1994)	+80	62	220	253	276	62	197	223	256
English subjects									
Burr & Phillips (1984)	+85	31	180	208	236	75	150	182	214

*Developed from data collected during the National Health and Nutrition Education Survey I (1971–1974).

Table 8. *Sex-specific reference values for arm-muscle area* (mm^2) *in American and European elderly subjects*

Percentiles.... Reference	Age (years)	Men *n*	Men 10th	Men 50th	Men 90th	Women *n*	Women 10th	Women 50th	Women 90th
American subjects									
Frisancho (1981)*	65–74	1503	4410	5720	7070	1670	3020	4020	5570
Bishop (1984)*	65–74	1657	4470	5750	7130	1822	3030	4040	5570
Falciglia *et al.* (1988)	80–89	49	2650	4150	5910	111	2230	3610	5680
English subjects									
Burr & Phillips (1984)	+85	31	2540	3470	4400	75	1700	2690	3680

*Developed from data collected during the National Health and Nutrition Education Survey I (1971–1974).

centenarians with over-85-year-old British subjects (see Table 7 and 8). AFA values were also much lower than NHANES norms for 65–74 year olds (Frisancho, 1981). At the present time, no reference norms exist for thigh anthropometric measurements of elderly subjects. Comparisons between age-groups for all anthropometric variables included in the present study did not reveal trends related to age, except for knee height (and obviously height) in men ($P < 0.001$) and for thigh-root circumference in women ($P < 0.03$), apparently decreased in centenarians.

DISCUSSION

Anthropometric indices provide general information on nutritional status and specific information on the amount and localization of muscle and adipose tissue. Published anthropometric indices provide general information on nutritional status and specific information on the amount and localization of muscle and adipose tissue. Published anthropometric norms do not include subjects over the age of 90 years. Our data represent a preliminary report of anthropometric indices in healthy free-living nonagenarians and centenarians.

Men of both age-groups were significantly taller and heavier than women of corresponding age and had a greater amount of muscle mass, but no sex-related difference was detected for BMI. The examination of the relationship between subcutaneous fat on the upper arm (triceps skinfold) and on the trunk (subscapular skinfold) showed that men aged over 90 years had a mainly central adipose localization whereas women had a mainly peripheral adipose distribution. However, no significant difference between sexes was found with regard to WHR, taken as an index of intra-abdominal fatness (Seidall *et al.* 1987).

For both age-groups, anthropometric values were much lower than the corresponding reference values recorded in American and European surveys, but the differences were less marked with norms derived from the older European populations than with norms derived for American age-groups.

Taken together, these findings suggest a marked decrease in muscle and fat mass in nonagenarians and centenarians with respect to young elderly subjects. Of the two body components (muscle and fat mass), which both decrease with age, the peripheral fat mass seems to be the more affected in women, as suggested by the reduced triceps skinfold thickness of female centenarians and their lower AFA:AMA ratio (in NHANES I (Bishop, 1984) respectively 0·298 and 0·751 for men and women 64–75 year olds), although the triceps:subscapular skinfold ratio of women remained greater than that for men.

A possible objection to our study is that all the anthropometric measurement values for our subjects were at the lowest percentiles of the available reference distributions for elderly people, and that very low values for simple anthropometric indices, e.g. triceps skinfold or MAC, are known to be associated with an increased risk of malnutrition and, therefore, of morbidity and mortaility than are values closer to the 50th percentiles (Mason & Rosemberg, 1994). More than one reason could be given for this apparent condition of undernutrition: senile anorexia, mastication disorders, age-related malabsorption, as well as a number of social and psychological factors specific to the elderly and even more prevalent in subjects aged 90 years and over. As this was a cross-sectional study, moreover, the influence of secular trends cannot be excluded: differences between successive generations may emphasize physiological changes in body composition with ageing. Indeed, longevity itself of our subjects and the strict respect of the SENIEUR protocol (Ligthart *et al.* 1984) in their selection do not support the hypothesis that subjects are affected by a severe nutritional disorder. A potential survivor effect could even be involved: slimmer and shorter people have been suggested to be more likely to live until 100 years of age, perhaps because of a reduced cardiovascular risk (Antonini & Mannucci, 1991). Indeed our centenarian men had a smaller stature than male nonagenarians. However, the great inter-individual variability that characterizes the oldest subjects makes identification of biomedical markers of longevity very difficult; all the more so because reference norms for many biological variables, including anthropometry, have yet not been established for subjects over 90 years of age.

Anthropometric measurements of elderly individuals have to be compared with standards from subjects of similar age and clinical conditions. When the subject belongs to a group (in our case a very advanced age-group) for which there are no reference data, the comparison with values based on lower age-ranges may lead to errors in nutritional-status assessment. Geographical and socio-economic differences may also be responsible for the difference between our values and those recorded by other authors. An intriguing hypothesis is that long-lived people represent a particular, genetically-selected population with very peculiar nutritional characteristics and are not comparable with younger elderly subjects among whom this selection has not yet occurred. It also seems conceivable that the current anthropometric indicators are no longer reliable for nutritional assessment of subjects above the age of 90 years.

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