Influence of Age and Gender on Fat mass, Fat-Free Mass and Skeletal Muscle Mass Among Australian Adults: The Australian Diabetes, Obesity and Lifestyle Study (AusDiab).

Claudia Strugnell [1]*, David W. Dunstan [2], Dianna J. Magliano [2], Paul Z. Zimmet [2], Jonathan E. Shaw [2] Robin M. Daly [1,3]

[1] School of Exercise and Nutrition Sciences, Deakin University, Melbourne, Australia; [2] Baker IDI Heart and Diabetes Institute, Melbourne, Australia; [3] Centre for Physical Activity and Nutrition Research, Deakin University, Melbourne, Australia

Address for correspondence and reprints

Professor Robin M. Daly

Centre for Physical Activity and Nutrition Research

Deakin University, 221 Burwood Highway,

Burwood, Melbourne, AUSTRALIA 3125

Ph: +61-3-9244 6040; Fax: +61-3-9244-6017

E-mail: rmdaly@deakin.edu.au

Email addresses:

CS: claudia.strugnell@deakin.edu.au

DD: daivd.dunstan@bakeridi.edu.au

DM: Dianna.Magliano@bakeridi.edu.au

PZ: paul.zimmet@bakeridi.edu.au

JS: jonathan.shaw@bakeridi.edu.au

RD: rmdaly@deakin.edu.au

Abstract (288/350 words)

Background

Bioelectrical impedance (BIA) represents a simple, inexpensive and non-invasive method that is often used to assess fat-mass (FM) and fat-free mass (FFM) in large population-based cohorts.

Objective

The aim of this study was to describe the reference ranges and examine the influence of age and gender on FM, FFM and skeletal muscle mass (SMM) as well as height-adjusted estimates of FM [fat mass index (FMI)], FFM [fat-free mass index (FFMI)] and SMM [SMM index (SMI)] in a national, population-based cohort of Australian adults.

Design and Participants

The analytical sample included a total of 8,582 adults aged 25-91 years of Europid origin with complete data involved in the cross-sectional 1999-2000 Australian, Diabetes, Obesity and Lifestyle (AusDiab) Study.

Measurements

Bioelectrical impedance analysis was used to examine components of body composition. Demographic information was derived from a household interview.

Results

For both genders, FFM, SMM and SMI decreased linearly from the age of 25 years, with the exception that in men SMI was not related to age and FFM peaked at age 38 years before declining thereafter. The relative loss from peak values to ≥75 years in FFM (6-8%) and SMM (11-15%) was similar between men and women. For FM and FMI, there was a curvilinear relationship with age in both genders, but peak values were detected 6-7 years later in women with a similar relative loss thereafter. For FFMI there was no change with age in men and a modest increase in women.

Conclusion

In Australian adults there is heterogeneity in the age of onset, pattern and magnitude of changes in the different measures of muscle and fat mass derived from BIA, but overall the age-related losses were similar between men and women.

Introduction

Globally the continual rise in obesity [1] is of critical public health importance due to the myriad of associated chronic conditions, morbidity and mortality and subsequent burden placed on health care systems.[2] Currently, most estimates of overweight and obesity are based on the measurement of body mass index (BMI) because of its ease of assessment and well established relationship with mortality.[3] However, since BMI is an index of weight-for-height (kg/m^2) it only provides a measure of body size and not composition.[4] This means that the different components of body composition, including fat-mass (FM) and fat-free mass (FFM) which represents all bodily components apart from FM (skeletal muscle, organ tissue, total body water and bone tissue),[5] are not taken into consideration. Thus, any changes in weight could reflect a combination of changes in FM and FFM, which can have markedly different effects on disease risk. Indeed, there is evidence that both FM and FFM may be stronger predictors of disease risk than BMI.[6-9] For example, several studies have reported that % FM is a better predictor of cardiovascular disease risk,[6] serum lipid profiles,[8] breast cancer incidence[9] and coronary events [7] than BMI. Others have reported that low skeletal muscle mass or FFM, which is often referred to as sarcopenia, is associated with physical disability,[10, 11] decreased physical function,[12-15] insulin resistance and glucose intolerance [16] and an increased risk of mortality.[17, 18]

Bioelectrical impedance analysis (BIA) is a simple and accurate method for assessing FM and FFM, [19, 20] and is particularly useful in large population-based studies due to its low cost, accessibility and ease of use.[5] Worldwide there have been a number of epidemiological studies which have used BIA to assess age, gender and ethnic differences in FM and FFM, often with contrasting results. In the NHANES III study involving 15,912 participants aged 12 to 80 years, FFM was shown to be higher among males compared to females and increased

until 60 years of age among males and 45-55 years among females before declining.[21] In contrast, in a cohort of 5,635 Swiss adults aged 15 to 98 years it was found that FFM peaked in men aged 35-44 years and women aged 45-54 years before declining.[22] However, in both these studies FM (and % body fat) were higher in females at all ages and tended to increase progressively throughout life in both sexes up until old age when it decreased.[21, 22] Together, these findings highlight that there are likely to be population-specific differences in the different body composition components. Therefore, using data from a national sample of Australian adults enrolled in the 1999-2000 Australian Diabetes, Obesity and Lifestyle (AusDiab) study, the aim of this study was to describe the reference ranges and examine age and gender related differences in FM, FFM and skeletal muscle mass (SMM) as well as height-adjusted estimates of FM [fat mass index (FMI)], FFM [fat-free mass index (FFMI)] and SMM [SMM index (SMI)], which provide size adjusted estimates of body composition.

Methods

Study design and participants

The AusDiab study is a national population-based study which included adult Australians aged ≥25 years.[23] A detailed description of the methodology is published elsewhere.[23] In brief, a population-based sample of men and women were drawn from 42 randomly selected urban and nonurban areas (Census Collector Districts [CDs]) across Australia, with six CDs in each of the six states and the Northern Territory selected. CDs that had fewer than 100 individuals aged ≥25 years or had more than 10% of the residents as Aborigines or Torres Strait Islanders, and those classified as 100% rural were excluded. All homes within each CD were approached and usual residents aged ≥25 years were invited to attend the survey, which consisted of a short household interview followed by a biomedical examination. Of the 19,215 households contacted for the AusDiab study, 17,129 were eligible for inclusion and

20,347 non-institutionalised adults aged ≥25 years completed a household interview. Of these, 11,247 attended a biomedical and clinical evaluation (5049 males; 6198 females) in 1999-2000. For the present study, adults who were of Europid origin based on reported country of birth were eligible for inclusion (N=10,465). This included those born in Australia (78.6%), the United Kingdom (11.7%), Europe (6.8%), New Zealand (2.3%) and Canada or the USA (0.6%). Adults with known conditions that might influence body composition or with incomplete data were excluded as follows: 52 pregnant women, 428 diabetic adults, 790 women who self-reported they were going through menopause and 258 adults with missing BIA data. As outlined in the statistical analysis, a further 355 adults were excluded based on extreme values.

Anthropometry

Height (cm) was measured using a stadiometer to the nearest 0.5 cm without shoes. Weight (kg) was measured to the nearest 0.1 kg with subjects wearing light clothing and no shoes, using a mechanical beam balance. BMI was calculated as kg/m^2 with classifications of normal weight, overweight and obesity based on the WHO BMI cut-offs.[3]

Body composition

Body composition was measured via bioelectical impedance using the Tanita TBF 105 BIA system (Tanita Corporation, Tokyo, Japan). Briefly, a 50kHz and 800μA electrical current is applied via 4-foot contact electrodes (heel and sole) with the voltage drop compared across the heel electrode plates.[24] The computer software automatically measures resistance (R) (ohms), fat-free-mass (FFM, kg), fat mass (FM, kg) and weight (kg). To calculate FM %, we first had to calculate body density (BD) which was derived from the equations below developed by Tsui and Zinman. [25] The rationale for using these equations in this study were

twofold: 1) they reported that there was a strong correlation between BIA FM % with FM % derived from dual energy x-ray absorptiometry (DXA) (r=0.89; 95% CI: 0.84, 0.93) [25], and 2) they used the same BIA system (Tanita TBF 105) that was used in the AusDiab study.

Male $BD = 1.1008 – 0.1129\ WmR/H^2 + 0.000178R$

Female $BD = 1.0907 – 0.1120\ WmR/\ H^2 + 0.000134R$

FM % was then calculated using the densitometric formula developed by Brozek:[26] $FM\ (\%) = [(4.57/BD) – 4.142] \times 100$

The FFM index (FFMI) was calculated by dividing FFM (kg) by height (m) squared (FFM/H^2) to give an estimate of height adjusted lean tissue mass. This procedure was repeated for the FM index (FM/H^2). The absolute amount of skeletal muscle mass (kg) was initially calculated using the equation developed by Janssen, Heymsfield and Ross:[12]

$Skeletal\ muscle\ mass\ (SMM, kg) = [(H^2/R) \times 0.401] + (sex \times 3.825) + (age \times -0.071) + 5.102$

In this equation height is measured in centimetres (cm), R is equal to the BIA resistance (ohms), sex is equal to 1 for males and 0 for females and age is measured in years. The height adjusted skeletal muscle mass index (SMI) was subsequently calculated by dividing SMM (kg) by height (m) squared (SMM/H^2).

Statistical analysis

All statistical analyses were conducted using STATA release 11.0 (Stata Corp, College Station, TX, USA, 2009). Participants whose FM (kg) + FFM (kg) was not within ± 1.0 kg of

measured weight (N=32) or whose BIA weight was not within ± 1.0 kg of measured weight by the mechanical beam balance (N=51) were excluded. All measures were checked for normality and participants with a BMI, FFM, FM, FM(%) or SMM values ±3 SD from the mean were excluded from the analyses (N=131 males, N=141 females). In order to account for the clustering and stratification of the survey design and participant non-response, data were weighted to match the age and sex distribution of the estimated 1998 residential population of Australia aged ≥25 years. Independent t-test were used to examine differences in means and the z-statistic tests was used to examine significant differences in proportions.[27] Multiple regression analyses were used to analyse associations between SMM, FM, FFM and indexes (dependant variables) and age (independent variable). Linear and non-linear models were explored to determine the model of best fit. The final model examined the sex-specific age by age^2 interaction between FM, FFM and indexes, except for FFM among women, the SMI and SMM which was linear and only included the linear age interaction. The turning point of the quadratic model was investigated by finding the extreme via the delta method.[28] For all analyses significance was defined as $P<0.05$.

Results

A total of 8,582 adults (47.2% men) aged 25 to 91 years (mean 47.9 years; 95% CI: 46.0, 49.8) were included in this study. Table 1 and 2 summarises the mean and reference ranges (5th – 95th percentile) for the various anthropometric and body composition characteristics of participants by gender and by 10-year age-groups. On average, women were shorter, lighter and had lower BMI, FFM and SMM values than men, but greater FM (all $P<0.001$). These findings were also reflected in the size (height adjusted) indexes with women having a significantly lower mean FFMI and SMI compared to men but higher FMI. Overall, the

average Australian adult male had a body composition comprising 24% FM and 76% FFM, whilst for females the corresponding compositions were 39% for FM and 61% for FFM.

Table 1 and 2 here

Figure 1 shows the relationship between age as a continuous variable and FM, FFM and SMM by gender. For SMM and FFM there was a linear decline from the age of 25 years onwards for both men and women, with the exception of a curvilinear relationship between age and FFM in men. In addition, SMI declined in a linear manner from 25 years of age in women, but no significant relationship was observed for men. For all measures of fat mass and fat-free mass (FM, FFMI and FMI), there was a curvilinear relationship with age, with evidence of a J-shaped curve for the relationship between age and FFMI among women (Figure 2).

Linear and quadratic regression analyses were also used to predict the magnitude of the decline (from mean peak values) in mean body composition values across the lifespan (Table 3). In general, the magnitude of decline for both muscle and fat mass indices did not vary markedly between men and women when expressed as a percentage. Across the lifespan, the average decline from peak values in SMM and FFM was 11.3% and 7.9% among men and 15.4% and 6.0% among women. FM declined by 18.9% among men and 16.3% among women from peak values, but when adjusted for height there was no marked change in the FFMI in men (-0.5%) and a small increase among women (+5.3%). However, there were some gender differences in the age of onset for the decline. In women, FFM declined earlier compared to men (25 years vs. 38 years), which was also reflected in the height adjusted FFMI (35 years vs. 67 years). Measures of fat mass (FM and FMI) peak 6 to 7 years later (mean age 56 and 59 years) in women compared to men, but declined similarly thereafter.

Discussion

The results from this cross-sectional national population-based study involving 8,582 Australian men and women aged 25 to 91 years demonstrated that the pattern and magnitude of body composition changes varied for the different indices of muscle and fat mass, but was similar for both men and women. SMM, as an estimate of muscle mass, decreased linearly from the age of 25 years in both genders with a similar relative (%) magnitude of decline into older age (men 11.3%; women 15.4%). The relative loss in FFM was also comparable between men and women, but the age of onset for the decline occurred earlier in women. For the different estimates of fat mass (FM and FMI), there was a curvilinear relationship with age in both genders, but peak values were detected at a later age in women with a similar relative loss thereafter. Together, these findings highlight that there is heterogeneity in the age of onset, pattern and magnitude of changes in the different measures of muscle and fat mass derived (or estimated) from BIA, but overall the age-related losses were similar between Australian men and women.

Influence of age and gender on measures of muscle mass

In both men and women, previous research has consistently shown that age-related muscle loss begins around the fourth decade (~30 years of age), with an accelerated loss occurring after the age of 50 years. [29-35] In our study we found that most measures of skeletal muscle mass decreased linearly from the age of 25 years in both men and women, with the exception of FFM that decreased from the age of 38 years in men. Previous population-based studies using BIA to document age- and gender-specific reference values for FFM have reported either no association for specific genders [36] or a curvilinear relationship with age,[22, 37, 38] with peak FFM values typically observed between the age of 18 to 54 years in both men and women before declining thereafter. This study found the mean relative (%) loss in SMM and

FFM from peak values to the age 75 years and older was 11.3% and 7.9% in men and 15.4% and 6.0% in women. These findings are consistent with the relative loss in FFM measured by BIA in a cohort of 5,225 healthy subjects aged 15 to 98 years.[22] In this study, FFM decreased by 14.8% in men from the age of 35-44 years to >85 years, and 14.3% in women from 45-54 years to >85 years. Although others have reported losses in muscle mass of up to 40% from the age of 20 up to 60 to 90 years.[34, 39-41] it is difficult to compare the findings across studies due to the different modalities and/or prediction equations used to quantify muscle (lean tissue) mass as well as differences in the cohort characteristics.

Influence of age and gender on measures of fat mass

A number of previous studies examining age-related changes in BIA-measured FM among males and females have reported that FM values either increase progressively with age.[22, 36-38] or plateau up to around the age of 50-80 years before declining thereafter.[21, 37] In our study we found that there was a curvilinear relationship between age and FM, with peak values observed at age 49 years in men and 56 years in women. While the average peak FM was more than 8 kg greater in women than men, the loss in FM with advancing age (peak to ≥75 years) was similar between genders (men, 19%; women, 16%). Consistent with these findings, BIA data from the NHANES III Study involving 15,912 adults aged 12-80 years showed that the mean total body fat (kg) increased with age up until approximately 60 years in both men and women, after which it decreased.[21] While the reason(s) for the mixed findings with respect to age-related changes in FM is no clear, a recent review reported that age-related changes in body fat % (BF%) varied for different populations. Within European populations there was a progressive increase in BF% with age, whereas in Japanese and US populations it tended to plateau at the age of 60 years.[42] These findings highlight the importance of developing population specific normative values for body composition.

Influence of age and gender on height adjusted body composition indexes

This study also provided the first Australian national age- and gender-specific means for height adjusted FMI, FFMI and SMI. Since FFM is related to height,[43, 44] an absolute cut-point for FFM or SMM would not be appropriate for all individuals (e.g. very short or tall persons), thus requiring an adjustment for height. In our study, we observed a J-shaped curve between age and FFMI for women. These results are likely to be due to the age-related changes in body weight, since gains in weight are usually explained by gains in FM where small increases in FFM are also observed.[38, 45] For example, if a 45 year-old adult gained 5kg in weight over a 2-year period, the proportion of FFM (%) to total body weight would decrease, despite increases in FFM (kg) and FM (kg) assuming a constant height. In older adults aged >65 years, weight and height typically decrease resulting in increases to the FFMI, despite an overall decrease in FFM (kg), which was more pronounced for women.

Previous studies investigating the relationship between age and FFMI have reported mixed findings.[38, 46-49] For instance, several studies in Caucasians and multi-ethnic cohorts have reported a curvilinear relationship between FFMI and age, with an accelerated rate of decline with advancing age.[46 48] In contrast and consistent with our findings, the results from a cohort of 5,635 apparently healthy adults aged 24-98 years revealed that FFMI increased modestly with age among Caucasian women but not men.[38] In our study, SMI which is a height adjusted component of FFM, was not significantly associated with age among men and declined linearly among women. Given that FFM is comprised of all bodily components apart from FM (SMM, organ tissue, total body water and bone tissue),[5] the differing relationship between the SMI and FFMI with age is likely to reflect the differing body components examined.

Limitations

There are a number of limitations associated with this study. The use of BIA involves several assumptions and requires careful selection of an appropriate prediction equation.[5] While a multitude of equations exist, [5] for the present study % FM and SMM were calculated using validated equations [12, 25] whereas FM and FFM was automatically calculated using the internal BIA system equations. As manufacturers rarely supply the equations for their internal BIA machines, care was taken to find a validated equation using an identical brand and model for %FM, which was not possible for SMM. Furthermore, it should be noted that the equations used for SMM in our study may not be reflective of Australian adults. Further research is needed to examine the validity of the Tanita TBF-105 system among Australian adults. In addition, these analyses were restricted to adults of Europid origin, therefore, composition estimates are not precise for all population groups within Australia. Finally, this is a cross-sectional study which cannot infer causation and thus longitudinal results may differ in the pattern and magnitude of changes in body composition. Nevertheless, our findings provide important insights into the age and gender-specific pattern of changes in body composition in a large cohort of Australian adults across the lifespan.

Conclusion

The findings from this population-based cohort study of Australian adults indicates that there is heterogeneity in the age of onset, pattern and magnitude of changes in the different measures of muscle and fat mass derived from BIA, but overall the age-related losses were similar between men and women. From a practical perspective, these findings could be applied in a variety of public health, clinical and policy settings to monitor and improve the health of Australian adults, but further research is need to determine which estimates of fat

and muscle mass derived from BIA are likely to be most the effective for monitoring nutritional status and/or predicting disease risk and mortality.

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Conflict of Interest

The authors have no conflict of interest to declare.

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Table 1: Anthropometric and body composition estimates of Australian adult men by 10-year age-categories from the 1999-00 AusDiab study.

	All Men	**Age (years)**					
	25-91	25-34	35-44	45-54	55-64	65-74	≥75
N	*4221*	*507*	*920*	*1158*	*768*	*583*	*285*
Height, cm	176.3 ± 7.01*** (165.0, 176.8)	178.9 ± 6.4 (169.5, 189.2)	178.0 ± 6.7 (167.0, 189.3)	176.4 ± 6.5 $^{\Phi}$ (165.5, 187.5)	174.0 ± 7.1 $^{\Phi}$ (163.0, 185.0)	172.8 ± 6.2 $^{\Phi}$ (163.0, 183.5)	169.6 ± 6.4 $^{\Phi}$ (159.5, 179.0)
Weight, kg	83.3 ± 12.7*** (63.8, 105.5)	83.5 ± 13.8 (62.7, 106.4)	84.7 ± 12.6 (65.1, 107.0)	84.3 ± 12.1 (65.6, 106.1)	83.2 ± 11.7 (65.6, 103.8)	81.1 ± 11.8 (62.3, 103.2)	75.7 ± 11.1 $^{\Phi}$ (57.1, 93.5)
BMI, kg/m^2	26.8 ± 3.6*** (21.0, 33.2)	26.1 ± 3.9 (19.7, 32.4)	26.7 ± 3.5 (21.5, 33.2)	27.1 ± 3.4 § (21.8, 33.2)	27.5 ± 3.5 $^{\Phi}$ (21.9, 33.8)	27.1 ± 3.5 $^{¤}$ (21.7, 33.2)	26.3 ± 3.4 (21.2, 32.2)
FFM, kg	62.6 ± 6.1*** (52.6, 72.7)	63.3 ± 6.1 (53.6, 73.7)	63.6 ± 5.8 (54.6, 73.5)	63.1 ± 6.0 (53.1, 73.1)	61.7 ± 5.9 $^{\Phi}$ (51.6, 71.1)	60.9 ± 5.7 $^{\Phi}$ (52.5, 71.6)	58.5 ± 5.8 $^{\Phi}$ (49.4, 67.0)
FFMI, kg/m^2	20.1 ± 1.3*** (18.2, 22.3)	19.8 ± 1.3 (17.5, 21.8)	20.0 ± 1.2 $^{¤}$ (18.2, 22.1)	20.2 ± 1.2 $^{\Phi}$ (18.2, 22.6)	20.4 ± 1.2 $^{\Phi}$ (18.4, 22.5)	20.4 ± 1.2 $^{\Phi}$ (18.5, 22.5)	20.3 ± 1.4 $^{\Phi}$ (18.4, 22.9)
SMM, kg	32.1 ± 3.9*** (25.9, 38.7)	33.2 ± 3.7 (27.2, 39.1)	32.8 ± 3.4 (26.8, 39.0)	32.2 ± 3.7 $^{\Phi}$ (26.4, 38.7)	31.1 ± 3.7 $^{\Phi}$ (24.9, 37.6)	30.5 ± 3.8 $^{\Phi}$ (24.8, 36.9)	29.6 ± 4.8 $^{\Phi}$ (23.0, 37.2)
SMI, kg/m^2	10.3 ± 1.1*** (8.8, 12.2)	10.4 ± 1.0 (8.5, 12.2)	10.4 ± 1.0 (8.8, 12.0)	10.3 ± 1.0 (8.9, 12.2)	10.3 ± 1.1 (8.6, 12.2)	10.2 ± 1.1 (8.6, 12.0)	10.3 ± 1.7 (8.2, 13.1)
FM, kg	20.7 ± 8.5*** (8.3, 37.1)	20.2 ± 9.4 (7.0, 39.7)	21.2 ± 8.5 (9.3, 36.8)	21.3 ± 7.9 (9.9, 36.1)	21.5 ± 8.0 (10.0, 37.1)	20.3 ± 8.1 (8.1, 35.0)	17.2 ± 7.4 § (6.7, 31.0)
FM, %	24.1 ± 6.9*** (12.7, 36.1)	23.2 ± 7.5 (11.1, 36.7)	24.3 ± 6.6 (13.7, 35.2)	24.6 ± 6.2 $^{¤}$ (15.0, 35.6)	25.2 ± 6.4 § (15.0, 36.2)	24.2 ± 6.8 (13.2, 36.2)	21.9 ± 7.0 (11.9, 35.8)
FMI, kg/m^2	6.7 ± 2.7*** (2.7, 11.8)	6.3 ± 2.9 (2.1, 12.0)	6.7 ± 2.6 (3.0, 11.7)	6.9 ± 2.5 $^{¤}$ (3.3, 11.7)	7.1 ± 2.7 § (3.2, 11.9)	6.8 ± 2.7 (2.9, 12.2)	6.0 ± 2.5 (2.5, 11.1)

All values represent means ± standard deviation with 5th and 95th percentiles weighted to represent the Australian population. *** P<0.001 versus females; $^{¤}$ P<0.05, § P<0.01, $^{\Phi}$ P<0.001, 25-34 year olds (reference) versus group of interest; BMI = Body mass index (kg/m^2); FFM = fat-free-mass; FFMI = fat free mass index; FM = fat mass and FMI = fat mass index.

Table 2: Anthropometric and body composition estimates of Australian adult women by 10-year age-categories from the 1999-00 AusDiab study.

	All Women	**Age (years)**					
	25-91	25-34	35-44	45-54	55-64	65-74	≥75
N	*4361*	*626*	*1130*	*811*	*761*	*683*	*350*
Height, cm	162.6 ± 6.8 (151.5, 173.5)	165.2 ± 6.5 (155.0, 176.2)	164.4 ± 6.3 (154.5, 175.4)	162.9 ± 6.2 $^{\Phi}$ (152.5, 172.8)	161.3 ± 6.1 $^{\Phi}$ (151.1, 171.5)	159.4 ± 6.0 $^{\Phi}$ (149.0, 169.5)	156.5 ± 6.0 $^{\Phi}$ (146.3, 167.0)
Weight, kg	68.1 ± 13.0 (50.6, 93.0)	66.5 ± 13.1 (50.2, 94.2)	68.2 ± 12.8 (51.6, 93.2)	69.5 ± 12.6 $^{¤}$ (50.7, 92.3)	72.5 ± 13.5 $^{\Phi}$ (53.8, 98.8)	68.9 ± 11.9 (51.8, 89.5)	62.6 ± 12.1 (46.8, 83.1)
BMI, kg/m^2	25.8 ± 4.7 (19.4, 34.7)	24.3 ± 4.1 (19.0, 32.4)	25.2 ± 4.5 $^{¤}$ (19.5, 34.7)	26.3± 4.7 $^{\Phi}$ (19.7, 34.7)	27.9 ± 5.1 $^{\Phi}$ (20.6, 38.4)	27.1 ± 4.5 $^{\Phi}$ (20.5, 35.3)	25.4 ± 4.6 (18.5, 34.6)
FFM, kg	40.8 ± 4.6 (33.6, 48.6)	41.6 ± 4.5 (35.3, 49.2)	41.4 ± 4.4 (34.9, 49.4)	40.8 ± 4.6 (33.0, 48.3)	40.4 ± 4.8 § (32.5, 48.1)	39.4 ± 4.6 $^{\Phi}$ (32.3, 46.9)	39.6 ± 4.5 $^{\Phi}$ (33.1, 47.1)
FFMI, kg/m^2	15.4 ± 1.3 (13.7, 17.5)	15.2 ± 0.9 (13.8, 16.8)	15.3 ± 1.1 (13.7, 17.0)	15.3 ± 1.3 (13.4, 17.6)	15.5 ± 1.4 $^{¤}$ (13.2, 17.7)	15.5 ± 1.4 $^{¤}$ (13.6, 17.9)	16.2 ± 1.8 $^{\Phi}$ (14.0, 19.4)
SMM, kg	21.7 ± 3.7 (16.6, 27.7)	23.0 ± 3.1 (18.5, 29.0)	22.4 ± 2.9 (18.1, 27.7)	21.8 ± 3.0 § (17.3, 27.1)	21.3 ± 3.3 $^{\Phi}$ (16.5, 28.0)	19.9 ± 3.2 $^{\Phi}$ (15.4, 23.3)	19.8 ± 3.9 $^{\Phi}$ (14.0, 27.9)
SMI, kg/m^2	8.2 ± 1.1 (6.7, 10.1)	8.4 ± 0.9 (7.0, 9.8)	8.3 ± 0.9 (7.0, 10.0)	8.2 ± 1.0 $^{¤}$ (6.8, 10.1)	8.2 ± 1.2 (6.6, 10.7)	7.8 ± 1.2 $^{\Phi}$ (6.2, 9.8)	8.1 ± 1.7$^{¤}$ (5.9, 11.0)
FM, kg	27.4 ± 11.9 (12.7, 52.1)	24.9 ± 11.2 (12.2, 52.8)	26.8 ± 11.8 (13.1, 51.4)	28.8 ± 12.1 $^{\Phi}$ (13.1, 52.1)	32.2 ± 12.7 $^{\Phi}$ (14.6, 58.8)	29.5 ± 11.1§ (13.4, 49.4)	23.0 ± 10.4 (10.4, 42.2)
FM, %	38.6 ± 9.9 (24.5, 57.4)	36.0 ± 8.9 (23.8, 52.4)	37.8 ± 9.8 $^{¤}$ (25.0, 57.2)	39.9 ± 10.3 $^{\Phi}$ (24.8, 59.1)	42.8 ± 10.0 $^{\Phi}$ (27.0, 59.5)	41.5 ± 9.6 $^{\Phi}$ (26.3, 57.9)	35.3 ± 9.3 (20.5, 52.6)
FMI, kg/m^2	10.4 ± 4.5 (4.8, 19.4)	9.1 ± 3.9 (4.6, 16.4)	9.9 ± 4.4$^{¤}$ (5.0, 19.5)	10.9 ± 4.7 $^{\Phi}$ (4.9, 19.6)	12.4 ± 5.0 $^{\Phi}$ (5.6, 23.1)	11.6 ± 4.4 $^{\Phi}$ (5.3, 19.3)	9.4 ± 4.1 (3.7, 17.7)

All values represent means ± standard deviation with 5th and 95th percentiles to represent the Australian population. $^{¤}$P<0.05, §P<0.01, $^{\Phi}$ P<0.001, 25-34 year olds (reference) versus age group of interest; BMI = Body mass index (kg/m^2); FFM = fat-free-mass; FFMI = fat free mass index; FM = fat mass and FMI = fat mass index.

Table 3: Predicted peak age and mass for the various muscle and fat mass indices and mean magnitude of decline from peak values to age ≥75 years of age in Australian men and women.

	Age at Peak (years)	Peak Value	Mean absolute change from peak to ≥75 years of age (%)
Men			
SMM, kg	25	33.7	- 3.8 (-11.3%)
FFM, kg	38	63.5	- 5.0 (-7.9%)
FM, kg	49	21.7	- 4.1 (-18.9%)
SMI, kg/m^2 #	25	10.4	N/A
FFMI, kg/m^2	67	20.4	- 0.1 (-0.5%)
FMI, kg/m^2	53	7.0	- 0.8 (-12.1%)
Women			
SMM, kg	25	23.3	- 3.9 (-15.4%)
FFM, kg	25	41.9	- 2.5 (-6.0%)
FM, kg	56	30.1	- 4.9 (-16.3%)
SMI, kg/m^2	25	8.4	- 0.4 (-4.8%)
FFMI, kg/m^2	35	15.2	+ 0.8 (+5.3%)
FMI, kg/m^2	59	11.5	- 1.2 (-10.4%)

All values represent means weighted to represent the Australian population. SMM = skeletal muscle mass; FFM = fat-free-mass; FM = fat mass; SMI = skeletal muscle index; FFMI = fat free mass index; FMI = fat mass index. # SMI was not significantly associated with age among men and thus the magnitude of decline cannot be predicted using multiple regression analysis.

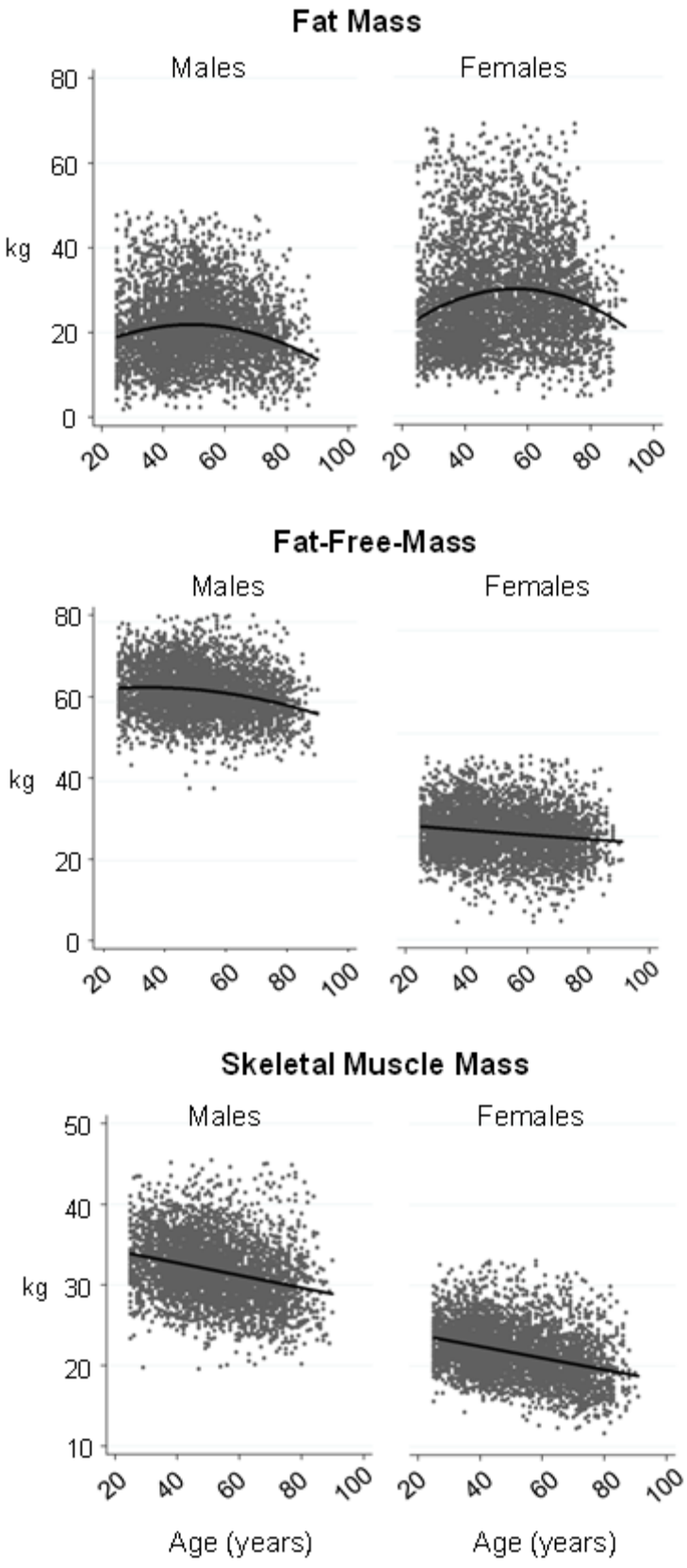

Figure 1. The relationship between age and fat-mass, fat-free mass and skeletal muscle mass in men and women. All results are based on unweighted population data.

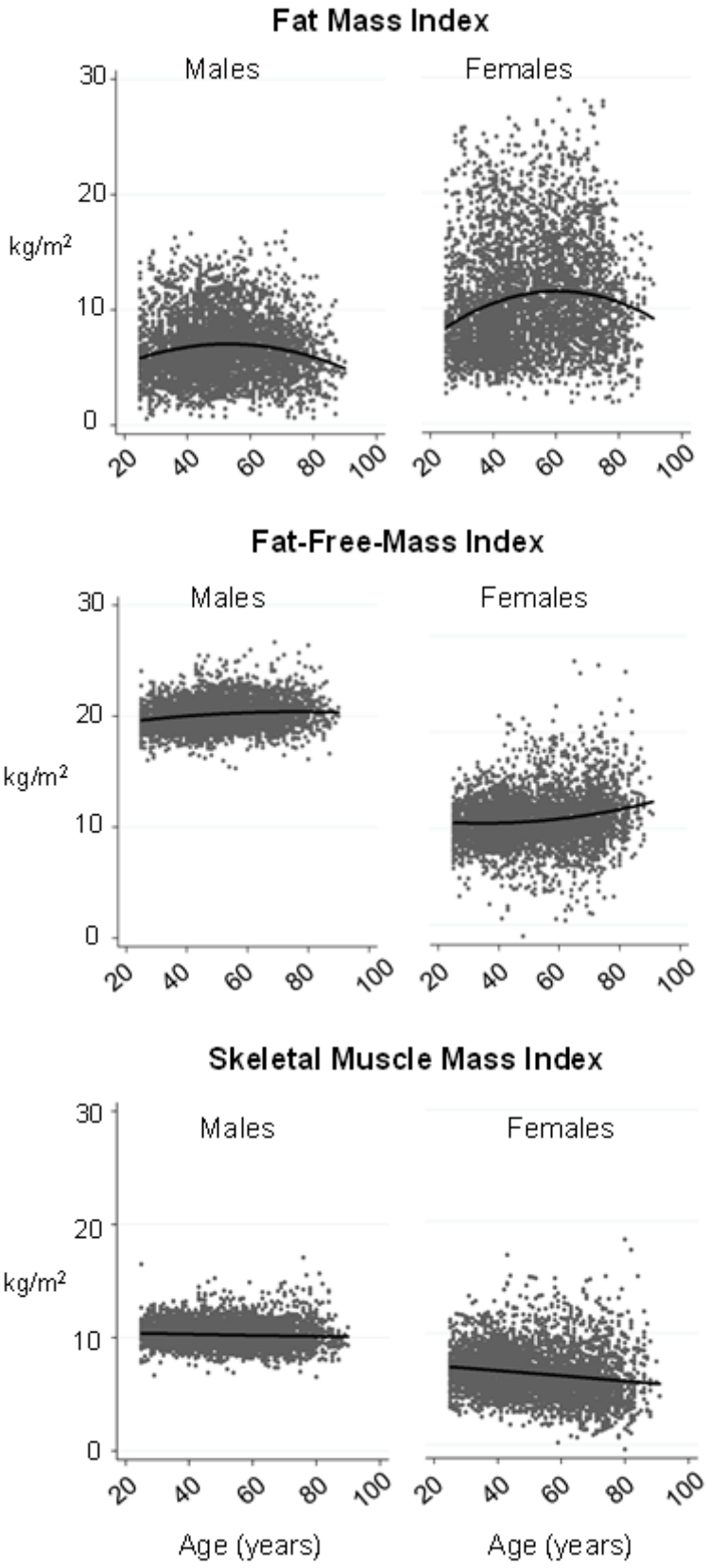

Figure 2. The relationship between age and the fat mass index (FMI), fat-free mass index (FFMI) and the skeletal muscle index (SMI) in men and women. All results are based on unweighted population data.