ORIGINAL ARTICLE

Age- and Sex-Specific Reference Intervals for Visceral Fat Mass in Adults

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Abstract

Background/Objectives: Dual-energy x-ray absorptiometry (DXA) is becoming a method of choice for the assessment of visceral adipose tissue (VAT) but the lack of robust reference ranges presents a challenge to the interpretation of VAT in clinical practice, research settings, and the athletic environment. The objective of this study was to develop age- and sex-specific reference intervals for DXA-derived VAT mass.

Subjects/Methods: The reference group comprised 3219 adults (1886 general population, 42% women; 1333 athletes, 11% women) in the United Kingdom, aged 18 to 83 years. Total body scans were performed using a GE Lunar iDXA and VAT analyses were enabled through Corescan software (Encore version 15.0). Age-specific reference ranges were derived in samples stratified by sex and general population/ athlete status. We modelled the mean and SD of Box-Cox transformed VAT mass as a function of age with a generalised least squares method using fractional polynomials (Stata® -xrigls- program). Centile values were then back-transformed to provide reference intervals on the original scale.

Results: In general population samples, average VAT mass increases with age up until around 65-70 years, and then begins to decline at older ages, though data are relatively sparse at the upper end of the age range. In athletes, on average, VAT mass increases with advancing age in men and women. Both 95% and 98% reference ranges are presented in 5-year increments in all samples, and we provide equations to enable the calculation of any centile, for any age within the range.

Conclusion: These reference data can aid the interpretation of VAT mass specific to an individual's sex, age, and athletic status, increasing the utility and applicability of DXA-derived VAT assessments. Additional research is needed in adults over 65 years and female athletes, with different DXA devices, across different ethnic groups and specific sports.

Key words: DXA; Adiposity; Visceral Fat; Reference Standards

Introduction

Visceral adiposity is implicated in the development of chronic low grade inflammation (1) and with medical conditions including insulin resistance, diabetes, and cardiovascular disease (2,3), and has been associated recently with vertebral fracture in women (4). Visceral adipose tissue (VAT) is also an important predictor of all-cause mortality (5). Magnetic resonance imaging (MRI) and computed tomography (CT) imaging are the gold-standard techniques for the measurement of VAT. However, MRI is time-consuming, CT brings a high dose of radiation, and both are costly. Advances in dual energy X-ray absorptiometry (DXA) technology include the development of VAT assessment capabilities that have been validated using CT (6). The advantages of DXA over CT and MRI are that it provides a more accessible and rapid assessment of abdominal VAT, with good precision (7–9), at a lower cost, and with considerably lower radiation than CT and, as such, is appropriate for longitudinal investigations.

Over the last six years, DXA-derived VAT using the GE Corescan (GE Healthcare, Madison, WI) software has been associated with cardio-metabolic risk factors, such as insulin resistance, across different body mass index classifications (10–12). Such associations have also been observed using VAT mass measures derived from the Hologic DXA models and their associated software (13,14). However, in practice, the utility of DXA-VAT measurements is currently limited due to the lack of appropriate reference ranges (12,15), presenting a challenge when interpreting results and when providing feedback to patients, research participants, and athletes. The characterisation of individuals based on visceral fat levels has clinical utility for obesity specialists in a variety of fields including endocrinology, epidemiology, sports medicine and dietetics.

The purpose of this study therefore was to develop age- and sex-specific reference intervals for DXA-derived VAT mass in heterogeneous samples of general population and athletic adults in the United Kingdom.

Materials and Methods

Reference groups

The reference data groups included adults who were residing in the United Kingdom and had taken part in various research studies approved by the Leeds Beckett University ethics committee between 2007 and 2017, providing their signed informed consent prior to their DXA scans. The inclusion criterion was age 18 years or above. Included adults were deemed generally healthy, as there were no specific patient groups recruited. The exclusion criteria applied to women who were pregnant and individuals who were not able to fit within the DXA scan table boundaries, or those who had a body mass greater than 204 kg, due to the DXA table weight limit. The total reference group comprised of 2286 men and 933 women, aged 18 to 83 years. The group were sub-divided to a general population sample (n=1886, aged 18-83y, 42% women) and athletes (n=1333, aged 18-61y, 11% women). Individuals in the general population sample did not take part in any competitive sport at the time of their DXA scan. Athletes were individuals who took part in competitive sport at the time of their DXA scan, including athletes from club to world class performance levels across a variety of team and individual sports.

Procedures

Participants were asked to refrain from vigorous exercise during the preceding 12 h and, for all physical measurements, were tested in minimal clothing with shoes and jewellery removed. Body mass was measured to the nearest 0.1 kg using calibrated electronic scales (SECA, Birmingham, UK) and standing height was measured to the nearest 0.1 cm using a stadiometer (SECA, Birmingham, UK). Body mass index (BMI; kg/m^2) was subsequently calculated [weight (kg)/height$(m)^2$]. Narrow fan beam DXA (Lunar iDXA, GE Healthcare, Madison, WI) was used to evaluate total and regional fat and lean mass, and the advanced CoreScan software (EnCore version 15.0) estimated VAT mass (g). For all scans, the

correct region of interest placement and analyses were verified by the same clinical densitometrist certified by the International Society for Clinical Densitometry.

Participants were placed in the supine position on the scanning table, aligning with the central vertical axis. The arms were positioned parallel to - but not touching - the body, with a 1-cm space in between the thigh and the hand to enable the estimation of VAT. The forearms were pronated with the hands face down in accordance with the National Health and Nutrition Examination Survey protocol (16). For broader participants, the hands were placed mid-prone so that the whole body could fit within the scan boundaries. The legs were fully extended, and feet were secured with a canvas and Velcro support to avoid foot movement during the scan acquisition. Scans were conducted using standard (153 mm/sec) or thick (80 mm/sec) mode depending on body stature, and the DXA software automatically determined the mode. The regions of interest (ROI) for the total body cut-offs were manually adjusted according to the manufacturer's instructions. The ROI over the android region for the assessment of VAT mass was automated by the CoreScan software (EnCore version 15.0). The iDXA CoreScan application uses a validated model derived from DXA and CT images, which computes VAT by subtracting subcutaneous abdominal fat from total abdominal fat (6). As well as being validated against CT, iDXA VAT is highly correlated with criterion MRI measurements of VAT (17), and robust associations with cardiometabolic risk (11) and glucose intolerance (18) have been demonstrated. Daily calibration and quality control observations were recorded according to manufacturer's guidelines throughout the duration of the data collection and no equipment drifts or faults were reported during the study period. Short-term precision estimates for iDXA measurements on the DXA scanner used in this study are 0.8% CV for total fat mass and 0.5% CV for VAT mass in individuals with a BMI between 25.5 and 42.4 kg/m^2 (8).

Statistical Analysis

All analyses were conducted using Stata® software (v. 14.2; Stata Corp. College Station, Texas). We derived age-related reference intervals by modelling the mean and standard deviation (SD) for VAT (g) as a function of age (19). Data were first transformed using a Box-Cox power function and then back-transformed to provide reference intervals in the original scale. Appropriate powers for the fractional polynomials to model the mean and SD were determined from the data using the Stata® -xrigls- program (20), from a selection of -2, -1, -0.5, 0, 0.5, 1, 2, 3 (0 = log). In this program, the best model (fractional polynomial, linear, constant fits) for both mean and SD is chosen via likelihood-ratio tests. We specified maximum degrees of freedom for the best-fitting model of 4 for the mean and 3 for the SD and a significance level (alpha) of 5%. The specification of the alpha for comparison of two nested models via a likelihood ratio test is arbitrary to an extent. We chose an alpha of 0.05 as it approximates a difference of 2 for Akaike's Information Criterion for models that differ by one parameter (21), and is therefore a sensible default. Sensitivity analyses using model deviance (-2*Log-Likelihood) showed that a 5% alpha provided a good relative fit in all samples versus models derived with substantially more stringent or lenient alpha.

Outliers in the solution were defined as values that would occur only rarely (<5% of the time), using sample size-dependent model Z-score thresholds (22), and were removed prior to final analysis (one iteration). If any outliers were removed, then the Box-Cox transformation was re-determined on the remaining data prior to modelling. We estimated the 1st, 2.5th, 97.5th and 99th centiles, providing 95% and 98% reference intervals. Confidence intervals (90%) for these centiles across the age range were derived from the obtained standard errors. In this generalised least squares model, the transformed variable is assumed to be normally distributed conditional on age. The distribution of model Z scores was inspected visually to check that the model was adequately specified, with the assumption of N(0,1) in a symmetrical distribution.

We derived a rough estimate of the precision of estimation of the reference limits afforded by the sample sizes available to us, using the relative margin of error (23). The relative margin of error is defined as the ratio of the width of the confidence interval of the reference limit (e.g. 2.5th or 97.5th centile) to the width of the reference interval at any value of age, assuming a uniform distribution of the covariate. It is desirable for the width of the confidence interval for the centile limits to be a small proportion of the width of the reference interval. The width of the 90% confidence interval for the 95% reference limits (on the Box-Cox transformed data analysed in the model) was approximately 6% of the 95% reference interval width in both samples of men and 7% for the general population sample of women, representing acceptable precision. For the small sample of female athletes, the relative margin of error was approximately 17%, which is relatively imprecise.

Results

Summary data for each of the four samples are presented in Table 1. Tables 2-5 present the age- and sex-specific centiles. In the general population groups, average VAT mass increases with age up until around 65-70 years, and then begins to decline at older ages. However, caution is warranted, as the data are relatively sparse at the upper end of the age range. In athletes, on average, VAT mass increases with advancing age in both men and women across the age range. The distribution of model Z scores was acceptable in all samples, with negligible skewness and kurtosis (Table 6). Table 6 also shows the fractional polynomial powers determined from the data and used to construct the reference intervals. The derived equations, plus a worked example of how the centiles are calculated, are provided in the supplementary information (S1). Readers may use the equations to derive any centile for any age within the distribution; for example, for ages in-between those presented in the Tables. In men, 6 outliers were removed in the general population sample, with one outlier removed for athletes. In women, there were no outliers in either of the two samples.

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183 It should be noted that some practitioners might prefer to use VAT volume (cm^3) rather than
184 mass, so the reference data provided can be easily converted as 1 g = 1.06 cm^3 (GE,
185 Europe).

186

187 **Discussion**

188 In this study, we have derived the first age- and sex-specific reference intervals for iDXA-
189 derived VAT mass in UK adults, in both the general population and athletes. The derived
190 centiles show that on average men have greater VAT mass than women across the age
191 range, regardless of athletic status. Also, for both men and women, VAT mass increases
192 with advancing age across the range in athletes, and in the general population sample up to
193 around 65-70 years.

194

195 Neither of these findings are surprising, as men typically accumulate more body fat around
196 the abdomen, hence the “apple” shape phenotype that has been associated with cardio-
197 metabolic diseases (2,3,24). In addition to menopause-related hormonal changes, there is a
198 well-documented age-related shift of fat distribution from the periphery and subcutaneous
199 level to the central abdominal region contributing to higher visceral fat as we age in both
200 sexes (25). This shift is accepted as one of the key physiological changes that increases
201 disease risk over time, so the development of VAT mass reference intervals from 18 years
202 across all groups provides valuable information for disease prevention and management.

203

204 In the general population sample, average VAT mass increases with age up to around 65-70
205 years and then appears to begin to decline. Caution is warranted, however, as data become
206 more sparse at the upper end of the age range. These are, however, the first reference data
207 for DXA-derived VAT in older adults and act as a robust starting point. Future work should
208 focus on enhancing the reference data for men and women ≥65 years, as their use may be
209 of interest to those researching and diagnosing obesity-related conditions including

osteosarcopenic obesity. The current diagnostic criteria for this condition utilises obesity cut-points based on percentage of body fat (26) and there is a need for more specific criteria. Visceral fat influences inflammatory processes (1), which contribute to osteoporosis and sarcopenia (27), so these VAT reference intervals could provide a more accurate diagnosis and help identify VAT-reduction targets with patients.

It is well understood that athlete populations generally have lower levels of total body fat in comparison to their general population counterparts; however, little is known about visceral fat levels in athletes. Anecdotal evidence demonstrated very low, almost undetectable, VAT mass in some athletes, and these are the first robust reference data produced to provide a useful guide for athletes, trainers, and coaches. Although the information was available to categorise the athlete group according to individual sports or sport types that align with the Task Force Classification of Sports (28), this would have created multiple groups of a small size, especially for women. Therefore, we consider the influence of sport type to be outside the scope of the current study, but it could be a focus of future work.

When DXA can be accessed, it provides a more efficient and less-invasive tool than MRI and CT to determine VAT with high accuracy and precision across a range of ages and body sizes. These new data will provide clinicians, researchers, and practitioners with more confidence when utilising DXA for VAT assessment, by enabling the identification of more or less favourable VAT mass values for an individual. This process will allow links to be made in relation to clinical markers, and potentially help quantify disease risk, but also provide a tool for monitoring and interpreting change during and after lifestyle interventions. In the context of athletic populations, the data will allow coaches and sport scientists to provide comparisons and act as a monitoring tool.

An example of the application of the reference ranges to individuals is instructive here. Consider a new individual aged 40 years, drawn from the male general population group,

presenting with a VAT mass of 1800 g. Note from Table 3 that this value is above the 50th centile and below the 97.5th centile – the upper limit of the 95% reference interval. It is a straightforward matter to derive this individual's centile position using the equations presented in the supplementary file (S1) and the standard normal distribution, after transformation of the 1800 g value using the Box-Cox power applied to the data in this sample. This 40-year old male is at the 85th centile for VAT mass. This result could be presented as him being 85th in a queue of 100 people like him (male general population, aged 40 years) with 15 men behind, where being nearer to the front of the line is more desirable. This type of simple presentation might facilitate discussion of cardio-metabolic disease risk in the context of other clinical data and behavioural risk factors.

To date, there has only been one prior study that has published VAT reference values, using percentiles in 421 healthy Polish adults aged 20-30 years (15). The reference intervals were not age-specific, and the age-range of 10 years renders comparisons with our age-related reference data essentially irrelevant. Katzmarzyk *et al.* (12) determined DXA-derived VAT for 2317 white and African American adults using a Hologic scanner, with a focus on identifying clinical thresholds associated with the presence of cardiovascular risk factors. Although this approach has relevant and important clinical utility, the authors did not specifically identify VAT reference data. In the current study, due to wider age ranges and the derivation of equations to predict VAT mass (S1), practitioners can calculate VAT mass centiles for any age, so our study offers the opportunity for greater generalisability and utility in practice.

An interesting question is how our derived centiles compare with crude reference ranges that may be derived from published mean (SD) VAT mass data measured using a GE iDXA scanner. Sasai et al. (29), for example, presented VAT mass data in 81 men and 113 women (general population). In men, the mean (SD) VAT mass (g) was 1440 (1170), with a range of 70 to 4890 g. Note that the fact that the mean is smaller than twice the SD indicates a substantially skewed distribution (30), as is typical with visceral fat measures. We

assumed a log-normal distribution and derived the 2.5th and 97.5th centiles to produce a 95% reference range using Parameter Solver software (v3.0, University of Texas MD Anderson Cancer Center, Department of Biostatistics: http://biostatistics.mdanderson.org/SoftwareDownload/). The 95% reference range was 277 to 4512 g, in a sample with a mean (SD) age of 41.8 (14.1); range 18-67 years. Table 2 shows that our derived 95% age-related reference interval for a 40-year old man (approximating the mean age in the Sasai et al. sample) was 107 to 3869 g. The 95% reference intervals for an 18-year old and a 65-year old (approximating the sample range in that study) were 56-772 g, and 430-5960 g, respectively. The men's data from the Sasai et al. study is therefore broadly consistent with our reference intervals. Nevertheless, it is very clear from this example that the method we have applied is superior to this crude approach in that it enables us to derive age-specific reference intervals, rather than a single interval applying to a very wide age range. In as much as VAT mass is substantially age-related, we believe that deriving a single reference interval based on a sample heterogeneous for age would be inappropriate. The sample of women in Sasai et al. had a mean (SD) VAT mass of 950 (680) g and a mean (SD) age of 42.4 (12.3), ranging from 19 to 69 years. Again, assuming a log-normal distribution, the 95% reference interval is 219 to 2725 g. Table 4 shows that our derived 95% reference interval for a 40-year old was 10 to 1810 g. The 95% reference intervals for an 18-year old and a 70-year old were 0-716 g and 56-2941 g, respectively. The Sasai et al. data are consistent with our reference intervals, though it appears as though the women in their sample had somewhat higher levels of visceral fat across a similar age range. Again, however, the fact that their sample was heterogeneous for age precludes a rigorous comparison, and age-related reference intervals are clearly more informative than a single interval.

We must acknowledge several limitations. First, although we collected data from different ethnic groups it was only a very small proportion, and we could only use the data from white participants to develop robust reference intervals. Future work should look to develop

reference intervals in different ethnic groups. This research is particularly important for Asian, especially South-Asian, populations as they have a greater risk of developing type 2 diabetes, and an evidence-based mechanistic link exists between visceral fat accumulation and poor glycaemic control (31,32). There will also be a need for the US and other countries to generate their own reference intervals, but they should find those developed as part of our study useful until country-specific data is available.

Secondly, in the female general population sample, we were unable to back-transform (Box-Cox) the derived 1st centile for ages 18-25 years, and the 2.5th centile for 18-year-olds, because the values were too small, and the back transformation cannot be negative. This issue can arise because the normal distribution has an infinite lower tail of negative values, so it might be something of a compromise model when dealing with an intrinsically positive outcome variable like VAT mass, especially when combined with the generally low levels of VAT in young women. This issue is of no practical consequence, however, because we have set the values to 'essentially zero' for these centiles for those few instances.

Thirdly, precision of the centiles was assessed using confidence intervals derived from the model standard errors. This approach relies on a normal distribution, and this assumption was satisfied for all four models. Bootstrap resampling with replacement might provide even more robust confidence bands with respect to accurate coverage (33). However, bootstrap-derived confidence bands for the centiles is impossible within Stata® software. Although a user-written custom program is possible theoretically, the –xrigls- program does not store the requisite regression coefficients and fractional polynomial-related quantities defining the mean and SD curves for construction of bootstrap confidence bands. For the male general population sample only, we repeated the analysis in Medcalc® software (version 18.10.2; Ostend, Belgium; http://www.medcalc.org; 2018), which permits bootstrapping. (Medcalc® software does not allow a constant SD, so we could not re-run the analyses in the other

three samples). The derived confidence bands were not materially different to those presented in Table 3, underscoring the fact that the data are adequately normally distributed. As detailed in the Methods, precision of estimation of the reference limits was inadequate for the small female athlete sample. We urge caution in interpreting these intervals and further research is required with substantially larger samples of female athletes.

Fourthly, we used a fractional polynomial mean and SD model to derive the reference intervals. Other methods are available, including smooth crude centiles and the lambda-mu-sigma (LMS) method (34). Silverwood and Cole (34) stated that the LMS method is superior, due to its flexibility and applicability, and the production of curves that summarise the distribution of the measurement fully across the age range. However, as Wright and Royston (33) highlighted, the approach we adopted herein allows estimation of the centile rank for any individual, which is impossible with the LMS method (34). The limitation of the fractional polynomial mean and SD method is that the approach is parametric and relies on the assumption that the data at each age are drawn from a normally distributed population. We used a single Box-Cox transformation in each of the four samples to normalise the data. Although this transformation does not address kurtosis, the model Z-scores displayed negligible kurtosis (Table 6). We are confident, therefore, that the reference intervals derived herein are robust.

Finally, it is important to highlight that VAT mass differences do exist between the two main DXA devices (GE and Hologic), but VAT determined by Hologic has been reported to be highly correlated (r=0.93) and cross-calibration equations have been proposed (35). There is also a strong correlation (r=0.98) between the GE Lunar Prodigy and the GE Lunar iDXA (36) supporting the wider usability of our reference intervals. Both studies used healthy adults with a similar mean age to our current study, but it is worth noting that device comparison studies are still limited in relation to VAT. The results generated by other devices

can still utilise these GE Lunar iDXA based reference data, but it would be worthwhile developing device-specific reference data to ensure greater accuracy.

In conclusion, this is the first set of comprehensive and robustly determined age- and sex-specific reference intervals for DXA-derived VAT mass in UK adults, using the GE CoreScan software in both the general population and in athletes. These intervals can be used in both clinical and athletic environments to help clinicians, health practitioners, and coaches interpret an individual's VAT mass. Future work should further refine reference data in those over 65 years and in female athletes, in different ethnic groups especially Asian populations, and across specific sports classifications. In addition, these reference intervals can be used to create sex and age-specific targets for fat loss interventions from a stratified medicine perspective.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary information is available at the *International Journal of Obesity's* website.

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472

Tables

Table 1. Sample characteristics

Table 2. Visceral adipose tissue centiles (g) for adult men (N=1090).

Table 3. Visceral adipose tissue centiles (g) for male athletes (N=1189).

Table 4. Visceral adipose tissue centiles (g) for adult women (N=790).

Table 5. Visceral adipose tissue centiles (g) for female athletes (N=143).

Table 6. Derived powers for regression of visceral adipose tissue mass on age, with distribution of model Z-scores.

Supplementary Information

S1. Derived equations from the fractional polynomial models for the mean and SD for the prediction of visceral adipose tissue mass (VAT), plus worked example (precision given to 4 decimal places)

Table 1. Sample characteristics

Population sample	General		Athletes	
	Men (n=1096)	**Women (n=790)**	**Men (n=1190)**	**Women (n=143)**
Age (years)	40.6 (17.8)	50.0 (18.0)	24.2 (5.1)	25.8 (7.5)
Body Mass (kg)	85.2 (15.2)	67.9 (13.7)	91.5 (15.2)	64.6 (12.1)
Height (cm)	177.6 (6.8)	162.7 (8.2)	182.3 (7.4)	166.8 (6.4)
BMI (kg/m^2)[a]	26.9 (4.3) (17.8, 44.2)	25.6 (5.0) (15.0, 47.6)	27.4 (3.5) (16.2, 42.9)	23.1 (3.5) (16.7, 34.9)
VAT mass (g)[b]	570 (273 to 1651)	440 (132 to 1006)	337 (212 to 528)	77 (29 to 164)

Key: BMI – Body Mass Index, VAT – Visceral Adipose Tissue

[a]BMI is presented as mean (SD) (range)

Data presented as mean (SD) except [b]VAT mass is presented as median (interquartile range)

Table 2. Visceral adipose tissue centiles (g) for adult men (N=1090).

	Centile (90% confidence interval)				
	1st	**2.5th**	**50th**	**97.5th**	**99th**
Age					
18	43 (35 to 53)	56 (47 to 68)	222	772 (664 to 895)	963 (811 to 1139)
20	40 (34 to 48)	54 (47 to 63)	244	948 (840 to 1070)	1205 (1051 to 1380)
25	39 (34 to 44)	55 (50 to 62)	316	1487 (1363 to 1621)	1950 (1770 to 2146)
30	44 (39 to 50)	64 (57 to 72)	417	2167 (1988 to 2361)	2889 (2623 to 3179)
35	55 (47 to 63)	81 (72 to 91)	552	2976 (2709 to 3267)	3991 (3591 to 4431)
40	73 (63 to 85)	107 (95 to 122)	724	3869 (3504 to 4268)	5181 (4639 to 5781)
45	100 (87 to 116)	146 (129 to 166)	931	4765 (4315 to 5258)	6337 (5678 to 7066)
50	140 (121 to 160)	199 (176 to 225)	1161	5549 (5043 to 6101)	7296 (6570 to 8097)
55	192 (168 to 218)	267 (238 to 299)	1392	6084 (5556 to 6659)	7884 (7138 to 8702)
60	256 (225 to 291)	347 (310 to 387)	1586	6246 (5704 to 6834)	7955 (7196 to 8787)
65	327 (283 to 377)	430 (379 to 486)	1703	5960 (5377 to 6603)	7443 (6629 to 8350)
70	394 (327 to 474)	502 (428 to 587)	1704	5241 (4582 to 5987)	6403 (5502 to 7440)
75	444 (346 to 567)	546 (440 to 675)	1572	4200 (3486 to 5047)	5009 (4065 to 6154)

Age range = 18 to 83 years, but data are sparse >70 years.

The 50th centile is shown as a point estimate only, as a reference point.

Table 4. Visceral adipose tissue centiles (g) for adult women (N=790).

	Centile (90% confidence interval)				
	1st	**2.5th**	**50th**	**97.5th**	**99th**
Age					
18	0 (0 to 0)	0 (0 to 0)	61	716 (619 to 824)	983 (854 to 1126)
20	0 (0 to 0)	0 (0 to 0)	72	778 (680 to 886)	1061 (931 to 1204)
25	0 (0 to 0)	0 (0 to 0)	109	967 (865 to 1077)	1295 (1160 to 1440)
30	0 (0 to 0)	1 (0 to 2)	162	1205 (1096 to 1321)	1586 (1442 to 1741)
35	1 (0 to 1)	4 (2 to 6)	233	1489 (1365 to 1621)	1930 (1767 to 2104)
40	2 (1 to 4)	10 (6 to 14)	323	1810 (1662 to 1966)	2314 (2123 to 2518)
45	7 (4 to 10)	19 (14 to 26)	425	2148 (1974 to 2333)	2717 (2494 to 2953)
50	13 (9 to 19)	32 (24 to 42)	531	2477 (2281 to 2685)	3104 (2855 to 3368)
55	21 (15 to 28)	46 (36 to 59)	627	2760 (2554 to 2977)	3436 (3175 to 3711)
60	27 (20 to 36)	57 (46 to 71)	696	2956 (2755 to 3167)	3665 (3408 to 3935)
65	29 (22 to 38)	62 (50 to 75)	721	3027 (2830 to 3233)	3747 (3494 to 4013)
70	26 (19 to 36)	56 (44 to 72)	691	2941 (2709 to 3187)	3647 (3357 to 3955)
75	18 (10 to 30)	42 (28 to 62)	602	2686 (2367 to 3036)	3350 (2963 to 3772)
80	9 (3 to 21)	24 (11 to 46)	466	2276 (1854 to 2762)	2867 (2361 to 3447)

Age range = 18 to 80 years.

The 50th centile is shown as a point estimate only, as a reference point.

Table 3. Visceral adipose tissue centiles (g) for male athletes (N=1189).

	Centile (90% confidence interval)				
	1st	**2.5th**	**50th**	**97.5th**	**99th**
Age					
18	27 (23 to 31)	41 (35 to 47)	227	771 (719 to 825)	936 (871 to 1003)
20	36 (32 to 41)	53 (48 to 59)	273	885 (840 to 932)	1067 (1010 to 1128)
25	58 (52 to 64)	82 (75 to 89)	368	1111 (1059 to 1164)	1327 (1261 to 1396)
30	79 (71 to 88)	109 (100 to 120)	451	1301 (1236 to 1368)	1545 (1464 to 1629)
35	103 (91 to 116)	140 (126 to 156)	540	1497 (1409 to 1590)	1768 (1662 to 1880)
40	135 (114 to 158)	180 (155 to 208)	648	1730 (1585 to 1886)	2032 (1863 to 2213)

Age range = 18 to 61 years, but data are sparse >35 years.

The 50th centile is shown as a point estimate only, as a reference point.

Table 5. Visceral adipose tissue centiles (g) for female athletes (N=143).

	Centile (90% confidence interval)				
	1st	**2.5th**	**50th**	**97.5th**	**99th**
Age					
18	1 (0 to 2)	2 (1 to 3)	54	501 (381 to 651)	707 (532 to 929)
20	1 (0 to 2)	2 (1 to 4)	59	532 (413 to 680)	749 (573 to 969)
25	1 (1 to 2)	3 (2 to 5)	72	617 (492 to 769)	863 (676 to 1092)
30	2 (1 to 3)	4 (2 to 7)	88	714 (566 to 895)	991 (773 to 1259)
35	3 (1 to 5)	6 (3 to 9)	107	824 (632 to 1064)	1135 (861 to 1480)
40	4 (2 to 8)	7 (4 to 14)	129	947 (691 to 1280)	1297 (942 to 1759)

Age range = 18 to 59 years, but data are sparse >35 years.

The 50th centile is shown as a point estimate only, as a reference point.

Table 6. Derived powers for regression of visceral adipose tissue mass on age, with distribution of model Z-scores.

Sample	Powers for mean	Powers for SD	Model Z-scores*	Z-score Skewness	Z-score Kurtosis
Adult men	2, 3	0.5, 1	0.00 (1.00)	-0.2	0.22
Male athletes	-2, 3	Constant	0.00 (1.02)	-0.11	0.28
Adult women	2, 3	Constant	0.00 (0.98)	-0.02	-0.33
Female athletes	1	Constant	0.00 (0.99)	-0.05	0.05

*Data presented as mean (SD)