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Comparing DXA and MRI body composition measurements in cross-sectional and longitudinal cohorts

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Abstract

Background Detailed body composition assessment, through measurement of adipose tissue and muscle distribution, is essential for understanding population health trends, guiding targeted interventions, evaluating lifestyle effects, and monitoring age-related changes such as sarcopenia. Dual X-ray absorptiometry (DXA) provides estimates of fat and lean mass from low-dose X-ray images, while magnetic resonance imaging (MRI) offers three-dimensional measurements of adipose tissue and muscle distribution. Both methods have their strengths and weaknesses, but comparison between them at scale is missing.

Methods We assessed the accuracy of DXA compared to MRI for evaluating body composition. Using data from 32,961 participants in the UK Biobank, including 1,928 re-scanned participants after about two and a half years, we examined cross-sectional and longitudinal agreements in DXA and MRI measurements within android and gynoid regions. MRI scans were acquired using a Siemens 1.5 T MRI scanner, and DXA scans on a GE iDXA.

Results Our results show that DXA is able to capture fat measurements, including visceral adipose tissue and fat mass, but overestimates lean mass compared to MRI, particularly in android regions for men (4.10 kg measured by DXA vs. 1.74 kg by MRI) and women (2.92 vs. 1.10 kg). Longitudinal MRI data reveal a 4–5% muscle and lean mass decrease, undetected by DXA, which shows lean mass increases in women at the follow-up visit.

Conclusions Although DXA is practical for population-level fat assessments, it may not be as precise for lean mass assessments, especially in longitudinal studies. If economically and practically feasible, MRI remains the preferred method for detailed and precise longitudinal body composition analysis.

Plain language summary

This study looked at different ways to measure fat and muscle, which are important for understanding health, ageing, and the effects of lifestyle. Two common whole body imaging approaches are DXA, which takes 2D images and is faster, simpler, cheaper, and automated, and 3D MRI, which provides more detailed images but is slower, more expensive, and requires expert analysis. We compared these two methods in over 32,000 people in the UK population, with some scanned again after about two and a half years. We found that both methods measured body fat similarly, but DXA reported higher muscle values than MRI and may miss changes in muscle over time. This suggests that DXA may be useful for large-scale fat measurements, while MRI may be better for detailed muscle assessments and tracking changes over time.

Detailed body composition assessment, including the measurement of adipose tissue and muscle content and distribution, provides a valuable role for understanding trends in health and disease prevalence in large-scale population studies. They allow the development of targeted interventions to promote healthy ageing and mitigate the impact of conditions associated with an adverse body composition^{1,2}. Additionally, these measurements are crucial for assessing the effects of lifestyle factors, such as diet and exercise, on disease mitigation and overall well-being. Longitudinal body composition monitoring is particularly significant in ageing populations since fat distribution and muscle mass changes are associated with sarcopenia and reduced functional capacity³.

Many methodologies have been developed to measure body composition, from indirect and accessible techniques such as body mass index

(BMI), waist-to-hip ratio (WHR) or skinfold anthropometry, to more direct but more expensive and time-consuming imaging-based methods including dual X-ray absorptiometry (DXA), computed tomography (CT) and magnetic resonance imaging (MRI) which have the advantage of assessing the distribution of adipose tissue and lean mass (or muscle).

DXA for body composition assessments were developed around the same time as bone mineral density measurements, in the late 1980s⁴. The technology was later enhanced to automatically derivation of total adipose tissue and lean mass, including measurements from specific anatomical areas, such as the android and gynoid regions^{5,6}. Despite the planar nature of the acquired images, DXA provides estimates for the volume or mass of the body in three dimensions, offering a more comprehensive understanding of body composition compared with indirect methods. DXA is characterised

by rapid processing, low levels of ionising radiation and relatively low cost, making it widely used for individuals and large-scale population studies. However, DXA has limitations, unlike CT and MRI, it cannot directly measure specific individual adipose tissue depots. DXA also provides an estimate of “lean tissue”, but it is important to note that its lean tissue measurement includes other non-fat tissues besides muscle. Therefore, beyond appendicular measures, DXA may not offer specificity for muscle tissue. Despite these limitations, DXA remains a widely used tool in body composition assessments, offering a balance of accuracy and practicality for various clinical and research applications⁷.

In contrast, MRI is widely regarded as the most precise for assessing body composition⁸. Its non-invasive and non-ionising three-dimensional approach allows volumetric assessment of organs, adipose tissue, and muscles, from the largest tissues down to the smallest organ substructures. While MRI provides substantial detail and accuracy, its widespread use has been limited by cost, accessibility, and the time and expertise required for image acquisition and quantitative analysis. A trade-off between DXA and MRI depends on the specific research or clinical goals, balancing factors, such as precision, cost-effectiveness, and practicality in the given context.

Although DXA is widely accepted for assessing body composition⁹, and most studies demonstrate strong and significant correlations between MRI and DXA measurements^{10,11}, discrepancies between the two methods have frequently been noted. DXA is reported to overestimate subcutaneous adipose tissue (SAT)¹² and underestimate visceral adipose tissue (VAT) compared to MRI, especially in individuals with low levels of VAT¹². Interestingly, Neeland et al. noted that in addition to underestimating VAT at low VAT levels, DXA also modestly overestimated VAT at higher VAT levels. Similarly, although good correlations have been reported between muscle mass measurements by DXA vs MRI and CT^{12–14}, the agreement between measurements is poor, with DXA overestimating lean or muscle tissue^{14–16}. A potential reason for the lack of agreement may relate to the few direct comparisons using the DXA manufacturer’s predefined regions of interest against MRI equivalents. Moreover, several studies have demonstrated the high reliability and reproducibility of MRI in assessing regional body composition, including muscle and adipose tissue depots, across different populations and ages, further supporting its role as a reference standard in both cross-sectional and longitudinal research^{8,17,18}.

Previous studies comparing DXA and MRI for assessing longitudinal body composition have reported inconsistent findings, often due to small sample sizes or differing anatomical definitions. More precisely, while some adult studies reported comparable age-related muscle loss using DXA and MRI¹⁵, others found that DXA underestimated changes in VAT¹⁹ or is only sensitive enough to measure large changes in lean mass²⁰. In children, findings also vary, some showing agreement between methods²¹, while another found that DXA overestimated fat loss and muscle gain during a weight-loss intervention²². However, these studies were generally limited by sample size ($N \leq 100$) and focused on whole-body assessments.

To overcome these discrepancies, approaches including deriving equations to convert DXA values to MRI equivalents²³, or constructing linear regression models²⁴ have been proposed. Whether these strategies would enhance agreement between methods in longitudinal studies remains uncertain. Thus, a more comprehensive study comparing DXA and MRI, using anatomically equivalent anatomical regions and a larger cohort of subjects, is clearly needed.

This study aimed to leverage the extensive UK Biobank data to evaluate the agreement between DXA and MRI measurements of adipose tissue, lean mass, and muscle mass, using comparable DXA-defined android and gynoid regions in the MRI analyses. Additionally, the longitudinal data from this large cohort allowed us to assess the effectiveness of DXA, relative to MRI, in tracking changes in body composition over time.

The study shows that DXA is practical for population-level fat assessments, but may not be as precise for lean mass, especially in longitudinal measures. MRI remains the preferred method for detailed and precise longitudinal body composition analysis, however it comes with

higher cost and expertise requirements, and design of future body composition studies will need to evaluate the trade-off between the two.

Methods

Inclusions and ethics

Participant data from the UK Biobank cohort was obtained through UK Biobank Access Application number 44584. The UK Biobank has approval from the North West Multi-Centre Research Ethics Committee (REC reference 11/NW/0382), with informed consent obtained from all participants. This means that researchers can operate under this approval with no need for further ethical approval, other than exceptions such as re-contact applications. Researchers may apply to use the UKBB data resource by submitting a health-related research proposal in the public interest. Additional information may be found on the UK Biobank researchers and resource catalogue pages (<http://www.ukbiobank.ac.uk>). All methods were performed in accordance with the relevant guidelines and regulations as presented by the appropriate authorities, including the Declaration of Helsinki.

Image Acquisitions

MRI scans were acquired using a Siemens Aera 1.5 T scanner (Syngo MR D13) (Siemens, Erlangen, Germany), with full details of the UK Biobank abdominal MRI protocol reported previously²⁵. Our analysis used the neck-to-knee chemical-shift encoded MRI, commonly known as Dixon MRI. All data were processed and segmented using automated methods²⁶, with the outputs arising from this work already returned and available from the UK Biobank (Category 158).

DXA scans were acquired using a GE iDXA (GE-Lunar, Madison, WI). Full details of the UK Biobank DXA protocol have been previously reported²⁵. Fields available from the UK Biobank DXA scanner outputs include: category 124, “Body composition by DXA” (<https://biobank.ndph.ox.ac.uk/showcase/label.cgi?id=124>), specifically: *Android fat mass* (field 23245), *Android lean mass* (23246), *Android tissue fat percentage* (23247), *VAT volume* (23289), *Gynoid fat mass* (23262), *Gynoid lean mass* (23263), and *Gynoid tissue fat percentage* (23264). The only DXA reported volume (in litres) is for VAT, all other measurements are provided as a percentage or mass (kg).

Study Design and Cohort

DXA and MRI scans were acquired from every participant on the same day with no more than 2–4 hours between scans. Longitudinal data were acquired from a subcohort ($n = 3088$) after an average time interval of 2.3 ± 0.1 years, utilising the same scanners and protocols for each imaging modality.

Dixon MRI data for 41,707 participants that was acquired at the baseline imaging visit between 2014 and 2020 with data comprising imaging, health-related diagnoses and biological measurements were available. Participants with missing body composition measurements by DXA were excluded from the study. More specifically, android region measurements for 10,815 participants were missing VAT volume measured by DXA from the baseline imaging visit and for 1011 participants from the follow-up imaging visit. For the gynoid region, 10,674 participants were missing lean and fat mass measured by DXA from the baseline imaging visit and 978 participants from the follow-up imaging visit. Out of 3091 UK Biobank participants who underwent a follow-up imaging visit²⁷, 2906 participants had complete imaging data at both visits and were included in the study. Overall, after these exclusions, a dataset of 32,787 (30,892 from baseline imaging visit and 1895 from follow-up imaging visit) and 32,961 (31,033 from baseline imaging visit and 1928 from follow-up imaging visit) participants with android and gynoid measurements, respectively, were included in the final analysis. A detailed flow diagram is provided in Supplementary Fig. S1.

Data Analysis

To generate a direct comparison between DXA and MRI measurements, we reproduced in Python, on the MRI scans, the DXA regions as defined in the

software user manual (X-ray bone densitometer with enCORE v17 software user manual <https://www.gehealthcare.com/support/manuals> Imaging modality DXA v1.0 https://biobank.ndph.ox.ac.uk/ukb/ukb/docs/DXA_explan_doc.pdf), which states that “the android region of interest (ROI) has its lower boundary at the ‘pelvis cut’ and its upper boundary to lie at 20% of the distance between the pelvis and the ‘neck cut’. The gynoid ROI is to be twice the height of the android ROI, and the upper boundary to be below the pelvis cut line, 1.5 times the height of the android ROI”. Therefore, we defined the android and gynoid regions in the MRI utilising the same anatomical landmarks (Fig. 1), with the segmented pelvic bones used as the “pelvis cut” and the top of the MRI acquisition as the “neck cut”²⁶. The resulting android and gynoid ROI masks are cuboids that were then used to partition relevant tissues from MRI.

Given the ability of MRI to differentiate between various tissues within any anatomical area of interest, we categorised “lean tissue” in the DXA-android region to include all non-fat tissues, such as muscle, kidney, and liver, as assessed by MRI. In the gynoid region, lean tissue was defined as all non-adipose and non-bone marrow tissues. To gain further insight, we conducted a detailed comparison between the “lean tissue” identified by DXA and the specific muscle volume measured by MRI. This comparison aimed to highlight any discrepancies between the broader classification of lean tissue in DXA and the more precise muscle measurements provided by MRI, helping us better understand the gradations between these two modalities in body composition assessment.

While DXA estimates lean and fat mass in kilograms by inferring tissue composition from X-ray attenuation patterns, using proprietary three-compartment body-modelling algorithms (including fat, lean mass and bone mineral content), it does not directly measure tissue volume. In contrast, MRI directly quantifies tissue volumes through voxel-based image segmentation. To enable comparison, we converted MRI-derived volumes to mass using assumed tissue densities. Adipose tissue volume measured by MRI was converted to mass using a fat density of 0.92 g/ml^{28,29}. Given the lack of consensus in the literature on the density of muscle versus lean mass, we applied a uniform density of 1.06 g/ml for both^{30–32}, 1.04 g/ml for kidney^{33,34}, and 1.05 g/ml for liver^{35,36}. Furthermore, we also took into account the fact that adipose tissue includes cellular, structural and vascular components in addition to triglycerides. There is a lack of consensus regarding the true percentage, with literature values ranging from 50–94%. In this paper, we applied a correction assuming 80% of adipose tissue is triglyceride, to be consistent with previous MRI studies by ourselves³⁷ and others^{38–40}. Fat percentage was then defined as the ratio of fat mass to total tissue mass (fat + lean) within the defined region.

Statistical Analysis & Reproducibility

All statistical analyses were conducted using the R software environment version 4.5.0 for statistical computing and graphics⁴¹. Descriptive characteristics are presented as means and standard deviations (SD). Normality of distributions was assessed, and as the data were not normally distributed, non-parametric tests were used. Specifically, the Wilcoxon rank-sum test, using the function *wilcox.test* from *stats* library, was applied to compare independent groups, and the Wilcoxon signed-rank test was used for paired observations. A linear regression model, using the function *lm* from *stats* library, was fitted to examine the relationship between DXA and MRI measures. Regression coefficients (slope, intercept) and coefficient of determination (R^2) were reported to quantify the strength of association. Agreement between DXA and MRI measures was further assessed using Bland–Altman analysis. For each participant, the difference between the two methods (DXA – MRI) and the mean of the two methods was calculated. Bland–Altman plots were generated by plotting the differences against the means, bias and 95% limits of agreement (LoA)⁴² using the *ggplot* function from the *ggplot2* library.

To examine whether performance varied across subgroups, we conducted stratified analyses by age group, BMI, waist circumference (WC; android region only), and WHR. Stratification cut-offs were applied in accordance with prior work⁴³: BMI < 20 kg/m² (low), 20–25 kg/m² (normal), 25–30 kg/m² (overweight), > 30 kg/m² (high); WC < 102 cm (men) or < 90 cm (women); WHR ≤ 0.9 (men) or ≤ 0.85 (women).

Multiple testing correction was applied by Bonferroni adjustment for 184 hypothesis tests, yielding a significance threshold of $0.05/184 = 0.00027$.

Sample sizes for each analysis are reported in Tables 2, 3 and S1–S5. At baseline, $N = 30,892$ participants had android region DXA measures, and $N = 31,033$ had gynoid region measures. At follow-up, $N = 1895$ and $N = 1928$ participants had android and gynoid region measures, respectively. While no replicates were included, the large sample size ensures sufficient statistical power and robustness of the results.

Results

Cohort characteristics

Baseline characteristics and summary statistics for the whole cohort are provided in Table 1. Among the 31,033 participants who attended the baseline imaging visit, 96.2% were White, and 47.5% were male. The participants had an average age of 64.1 ± 7.8 years and BMI of 26.5 ± 4.4 kg/m².

Baseline body composition comparisons

Table 2 provides measurements obtained from DXA and MRI in the android and gynoid regions at the baseline imaging visit. These

Fig. 1 | DXA and MRI scans with android and gynoid regions displayed. **a** High-energy DXA with manually placed lines following the manufacturer’s definitions. Blue dashed lines are the neck and pelvic cuts. The android region spans from the first red line to the pelvic cut, and the gynoid region spans the area between the bottom two red lines. **b** Low-energy DXA with the same cuts and areas. **c** MRI of the same participant, with android and gynoid regions overlaid. **d** 3D view of the MRI-based segmentations, with structures inside non-DXA regions greyed out. Blue = subcutaneous adipose tissue (SAT). Yellow = visceral adipose tissue (VAT). Red = skeletal muscle tissue. Reproduced by kind permission of UK Biobank ©.

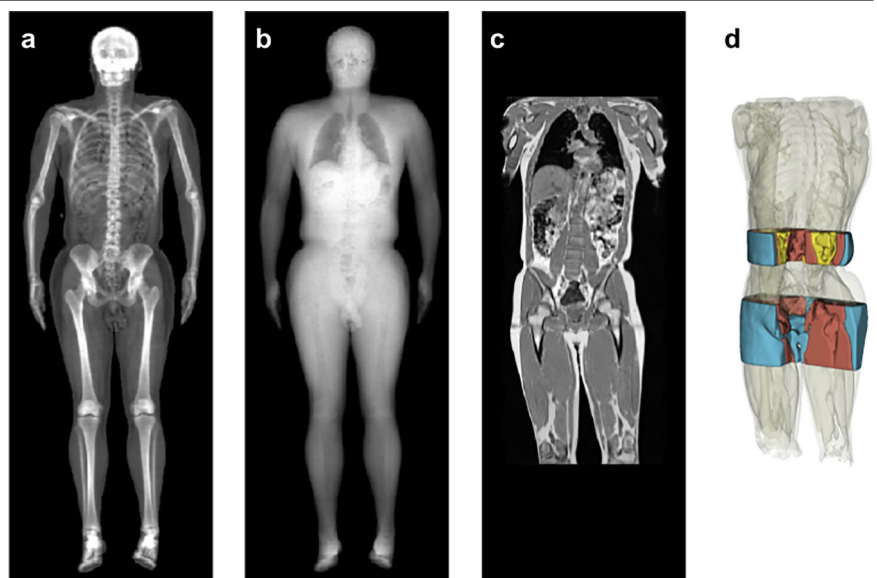


Table 1 | Demographics of the full cohort, separated by sex

	Baseline imaging visit			Follow-up imaging visit		
	Full Cohort (N = 31,033)	Men (N = 14,743)	Women (N = 15,711)	Full Cohort (N = 1928)	Men (N = 993)	Women (N = 935)
White (n)	29,858	14,419	15,306	1875	961	881
Age (yrs.)	64.17 ± 7.75	64.88 ± 7.84	63.52 ± 7.61	65.21 ± 7.22	65.68 ± 7.20	64.80 ± 7.17
Weight (kg)	76.00 ± 15.09	83.48 ± 13.13	68.71 ± 12.73	75.57 ± 14.69	82.54 ± 12.91	67.44 ± 11.90
Height (m)	169.23 ± 9.29	176.12 ± 6.66	162.75 ± 6.26	169.82 ± 9.46	176.50 ± 6.80	162.68 ± 6.13
BMI (kg/m²)	26.45 ± 4.35	26.89 ± 3.82	25.94 ± 4.61	26.12 ± 4.21	26.48 ± 3.76	25.48 ± 4.31
WC (cm)	87.65 ± 12.62	93.61 ± 10.46	81.85 ± 11.51	87.93 ± 12.08	93.15 ± 10.29	81.81 ± 10.78
HC (cm)	100.37 ± 8.67	100.25 ± 7.17	100.33 ± 9.63	99.57 ± 8.17	99.39 ± 7.00	99.23 ± 8.69
WHR	0.87 ± 0.09	0.93 ± 0.06	0.81 ± 0.07	0.88 ± 0.09	0.94 ± 0.06	0.82 ± 0.07
Systolic blood pressure (mmHg)	138.35 ± 18.57	141.51 ± 17.35	135.34 ± 19.17	139.93 ± 17.99	142.58 ± 16.87	136.99 ± 18.56
Diastolic blood pressure (mmHg)	78.57 ± 10.03	80.41 ± 9.80	76.80 ± 9.93	78.85 ± 9.78	80.71 ± 9.74	76.85 ± 9.46
Dominant hand grip strength (kg)	31.13 ± 10.63	38.73 ± 8.99	23.94 ± 6.07	28.40 ± 10.58	35.21 ± 9.24	21.08 ± 6.12

Values are reported as mean ± standard deviation for continuous variables and counts (N) for categorical variables. BMI: body mass index; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio.

measurements include muscle mass, lean mass, fat tissue mass, and body fat percentage, separated by sex. The VAT volume was further assessed in the android region. Supplementary Figs. S2–S8, show the relationship between MRI and DXA measures for all participants at the baseline imaging visit.

In the android region, the slope for lean mass was 1.23 (95% CI [1.21, 1.25]) in men and 1.36 (95% CI [1.34, 1.38]) in women, indicating an overestimation of DXA compared to MRI by approximately 1.95 kg (relative difference = 135.6%) in men and 1.43 kg (165.5%) in women (Table 2). Similarly, in the gynoid region, DXA overestimates MRI lean mass by 2.22 kg (10.3%) in men and 1.84 kg (14.6%) in women ($p < 0.00027$). Despite the slopes in the regression equations from Table 2 indicating differences in proportionality between android and gynoid, larger the intercept for both ROIs in men and women means that for biologically relevant ranges of lean mass, the DXA measures generally exceed those from MRI in both ROIs as can be observed in Figures S2 and S6. For differences across age groups, the variance in DXA fat mass measures explained by the MRI fat mass measures (R^2 value) was 0.95 in men and 0.96 in women ($p < 0.00027$). Similar results were found for gynoid fat mass measurements. VAT also showed a good fit with R^2 of 0.9 in both men and women ($p < 0.00027$). Similar results were observed in the follow-up imaging visit (Supplementary Data A). Bland-Altman analysis on the android region also showed a bias of 2.35 kg in men and 1.82 kg in women (95% LoA 1.59 to 3.11 kg in men; 1.22 to 2.42 kg in women) for lean mass, −0.16 kg in men and −0.17 in women (95% LoA −0.69 to 0.38 kg in men; −0.62 to 0.28 kg in women) for fat mass and −0.26 L in both men and women (95% LoA −0.90 to 0.39 L in men; −0.67 to 0.16 L in women) for VAT (Supplementary Fig. S9). While on the gynoid region the bias was 0.80 kg in men and 0.78 in women (95% LoA −0.37 to 1.97 kg in men; −0.09 to 1.66 kg in women) for lean mass and −0.16 kg in men and −0.03 in women (95% LoA −0.72 to 0.39 kg in men; −0.88 to 0.83 kg in women) for fat mass (Supplementary Fig. S10). Notably, the relationship between MRI and DXA measures of fat percentage showed evidence of nonlinearity, suggesting systematic deviations, particularly at the extremes of body composition. This may reflect the inherent differences in measurement principles. For example, DXA estimates fat percentage indirectly via X-ray attenuation and uses proprietary three-compartment modelling, whereas MRI provides direct volumetric quantification of adipose and lean tissues. Moreover, fat percentage is a ratio metric (fat mass divided by total mass), which can amplify the impact of small errors in either component. These methodological contrasts likely contribute to the nonlinear behaviour observed across the full range of fat distribution.

Subgroup analyses: Age, BMI, Waist circumference, and WHR

A sub-analysis comparing DXA and MRI measurements across age, BMI, WC and WHR groups is presented in Supplementary Data B–E. Among participants with low BMI ($< 20 \text{ kg/m}^2$), MRI-derived lean mass in the android region explained only a small proportion of the variance in DXA measurements with $R^2 = 0.26$, $p < 0.00027$ in men and $R^2 = 0.32$, $p < 0.00027$ in women an overestimation of DXA compared to MRI by approximately 2.53 kg (relative difference = 135.6%) in men and 1.50 kg (165.5%) in women, although R^2 improved with increasing BMI. Similarly, in VAT, the variance explained by MRI was also relatively low in the low BMI group ($R^2 = 0.66$ in men; $R^2 = 0.51$ in women; $p < 0.00027$). However, R^2 values for android lean mass and VAT remained comparable across different WC and WHR groups relative to the overall population shown in Table 2, suggesting that the reduced agreement in the low BMI group may be influenced by its smaller sample size. The highest R^2 values for android lean mass were observed in the youngest age group (40–49 years), with $R^2 = 0.61$ ($p < 0.00027$) in men and $R^2 = 0.57$ ($p < 0.00027$) in women, though this group also had a low sample size.

Longitudinal body composition comparisons

Table 3 provides a comparison of the longitudinal observations for MRI and DXA measurements, captured approximately 2.3 ± 0.1 years apart between the baseline and follow-up imaging visits. We observed a reduction in muscle and lean mass as measured by MRI in both android and gynoid regions for both sexes, with changes ranging from −4.5% to −3.9% in the android region and −5.2% to −4.1% in the gynoid region ($p < 0.00027$). For example, in men, the average follow-up MRI lean mass in the android region was $1.76 \pm 0.30 \text{ kg}$, compared to $1.85 \pm 0.31 \text{ kg}$ at baseline, while in women, the average follow-up MRI android lean mass was $1.09 \pm 0.23 \text{ kg}$, compared to $1.14 \pm 0.19 \text{ kg}$ at baseline. In contrast, DXA lean mass in women showed a significant increase of 2.6% ($p < 0.00027$), with an average follow-up value of $2.90 \pm 0.35 \text{ kg}$ compared to $2.83 \pm 0.36 \text{ kg}$ at baseline. This could be due to differences in anatomy captured within the android region caused by variations in breath-hold during imaging. Supplementary Fig. S11 shows an example of lean mass as measured by MRI in the android region including abdominal organs and muscle, at baseline and follow-up imaging for one participant, illustrating a 12.4% decrease in lean tissue when all organs are included, but only a 1% decrease when the liver and kidneys are omitted. No further significant changes were detected in lean mass measurements from DXA. We found no significant changes in any other tissue measurements from MRI or DXA.

Table 2 | Body composition measured via DXA and MRI at the baseline imaging visit separated by sex within the android and gynoid regions

Android Region	Men (N = 14,996)				Women (N = 15,896)							
	MRI	DXA	R ²	Regression equation	%95 CI - Slope	%95 CI - Intercept	MRI	DXA	R ²	Regression equation	%95 CI - Slope	%95 CI - Intercept
Muscle mass (kg)	1.60 ± 0.28	-	-	-	-	-	0.98 ± 0.17	-	-	-	-	-
Lean mass (kg)	1.74 ± 0.31	4.10 ± 0.54**	0.493	y = 1.23x + 1.95	[1.21, 1.25]	[1.92, 1.99]	1.10 ± 0.20	2.92 ± 0.40**	0.456	y = 1.36x + 1.43	[1.34, 1.38]	[1.4, 1.45]
Fat mass (kg)	2.78 ± 1.11	2.62 ± 1.20**	0.951	y = 1.06x - 0.32	[1.05, 1.06]	[-0.33, -0.3]	2.32 ± 1.06	2.15 ± 1.12**	0.959	y = 1.03x - 0.25	[1.03, 1.04]	[-0.26, -0.24]
Fat percentage (%)	52.64 ± 11.17	37.33 ± 10.25	not linear	not linear	not linear	not linear	55.89 ± 12.56	40.03 ± 11.56	not linear	not linear	not linear	not linear
Visceral adipose tissue volume (l)	2.03 ± 0.98	1.77 ± 1.04**	0.9	y = 1.01x - 0.27	[1, 1.01]	[-0.28, -0.26]	0.92 ± 0.57	0.79 ± 0.62**	0.891	y = 1.03x - 0.15	[0.96, 0.97]	[-0.23, -0.22]
Gynoid Region	Men (N = 15,037)				Women (N = 15,996)							
	MRI	DXA	R ²	Regression equation	%95 CI - Slope	%95 CI - Intercept	MRI	DXA	R ²	Regression equation	%95 CI - Slope	%95 CI - Intercept
Muscle mass (kg)	6.02 ± 1.00	-	-	-	-	-	4.02 ± 0.66	-	-	-	-	-
Lean mass (kg)	7.78 ± 1.17	8.58 ± 1.11**	0.749	y = 0.82x + 2.22	[0.81, 0.82]	[2.17, 2.28]	5.33 ± 0.84	6.11 ± 0.79**	0.726	y = 0.8x + 1.84	[0.8, 0.81]	[1.79, 1.88]
Fat mass (kg)	3.68 ± 1.14	3.52 ± 1.23**	0.949	y = 1.05x - 0.33	[1.04, 1.05]	[-0.35, -0.32]	4.62 ± 1.34	4.59 ± 1.52**	0.925	y = 1.09x - 0.46	[1.09, 1.1]	[-0.48, -0.44]
Fat percentage (%)	38.44 ± 7.06	28.50 ± 6.06	not linear	not linear	not linear	not linear	53.78 ± 6.67	41.99 ± 6.63	not linear	not linear	not linear	not linear

N_{Android} = 30,892, N_{Gynoid} = 31,033. Average values are shown ± standard deviation. Regression analyses were conducted using linear regression models between DXA and MRI measures. Significance refers to the two-sided Wilcoxon signed-rank test, where the null hypothesis is that the medians between DXA and MRI imaging visits are equal. An asterisk (*) indicates statistical significance after multiple testing correction by Bonferroni correction (p = 0.00027). After Bonferroni correction, all linear regression coefficients were statistically significant. Regression equations are shown as y = slope x x + intercept (DXA = y, MRI = x), with R² indicating the explained variance. 95% confidence intervals (CI) are provided for slope and intercept.

Table 3 | Longitudinal measures of body composition from DXA and MRI separated by sex within the android and gynoid regions

Android Region	MRI				DXA			
	Baseline	Follow-up	Difference	% Difference	Baseline	Follow-up	Difference	% Difference
Imaging Visit	Men (N = 749)							
Muscle mass (kg)	1.69 ± 0.28	1.61 ± 0.28**	−0.08 ± 0.15	−4.40 ± 8.54	-	-	-	-
Lean mass (kg)	1.85 ± 0.31	1.76 ± 0.30**	−0.09 ± 0.19	−4.35 ± 10.15	4.05 ± 0.52	4.11 ± 0.53*	0.06 ± 0.21	1.64 ± 5.12
Fat mass (kg)	2.76 ± 1.16	2.70 ± 1.14	−0.06 ± 0.49	−0.87 ± 18.43	2.51 ± 1.23	2.57 ± 1.26	0.06 ± 0.50	4.51 ± 21.07
Fat percentage (%)	51.19 ± 11.36	51.64 ± 11.49	0.45 ± 4.92	1.49 ± 11.27	36.40 ± 10.40	36.60 ± 10.54	0.20 ± 4.56	1.47 ± 14.30
Visceral adipose tissue volume (l)	1.98 ± 1.00	1.96 ± 0.99	−0.02 ± 0.42	1.55 ± 23.09	1.63 ± 1.06	1.72 ± 1.09	0.09 ± 0.41	11.11 ± 30.28
Women (N = 665)								
Muscle mass (kg)	1.02 ± 0.17	0.97 ± 0.16**	−0.05 ± 0.09	−4.51 ± 8.46	-	-	-	-
Lean mass (kg)	1.14 ± 0.19	1.09 ± 0.23**	−0.05 ± 0.18	−3.86 ± 14.15	2.83 ± 0.36	2.90 ± 0.35**	0.07 ± 0.16	2.59 ± 5.63
Fat mass (kg)	2.23 ± 0.96	2.20 ± 0.97	−0.03 ± 0.38	−0.05 ± 18.27	1.97 ± 0.98	2.05 ± 1.03	0.09 ± 0.38	5.90 ± 19.98
Fat percentage (%)	54.35 ± 12.53	54.98 ± 12.70	0.63 ± 4.51	1.60 ± 10.13	38.79 ± 11.20	39.15 ± 11.47	0.36 ± 4.33	1.63 ± 13.01
Visceral adipose tissue volume (l)	1.00 ± 0.55	1.01 ± 0.57	0.01 ± 0.21	3.16 ± 25.51	0.69 ± 0.55	0.75 ± 0.59	0.06 ± 0.21	47.38 ± 288.6
Gynoid Region	MRI				DXA			
	Baseline	Follow-up	Difference	% Difference	Baseline	Follow-up	Difference	% Difference
Imaging Visit	Men (N = 750)							
Muscle mass (kg)	6.38 ± 0.98	6.05 ± 0.97**	−0.33 ± 0.59	−4.81 ± 9.14	-	-	-	-
Lean mass (kg)	8.15 ± 1.15	7.79 ± 1.13**	−0.36 ± 0.68	−4.09 ± 8.36	8.60 ± 1.07	8.56 ± 1.08	−0.04 ± 0.30	−0.42 ± 3.45
Fat mass (kg)	3.70 ± 1.19	3.63 ± 1.16	−0.07 ± 0.43	−1.28 ± 11.37	3.46 ± 1.24	3.48 ± 1.24	0.02 ± 0.44	1.43 ± 12.35
Fat percentage (%)	37.40 ± 7.08	37.93 ± 7.07	0.53 ± 2.56	1.72 ± 7.40	28.07 ± 6.00	28.30 ± 6.03	0.23 ± 2.40	1.21 ± 8.82
Women (N = 689)								
Muscle mass (kg)	4.20 ± 0.65	3.97 ± 0.61**	−0.24 ± 0.38	−5.19 ± 8.75	6.08 ± 0.72	6.02 ± 0.74	−0.05 ± 0.33	−0.78 ± 5.17
Lean mass (kg)	5.51 ± 0.79	5.26 ± 0.84**	−0.25 ± 0.57	−4.24 ± 9.75	6.08 ± 0.72	6.02 ± 0.74	−0.05 ± 0.33	−0.78 ± 5.17
Fat mass (kg)	4.64 ± 1.24	4.49 ± 1.26*	−0.15 ± 0.53	−2.90 ± 11.09	4.42 ± 1.37	4.48 ± 1.47	0.06 ± 0.58	1.75 ± 12.17
Fat percentage (%)	53.15 ± 6.54	53.41 ± 6.70	0.25 ± 2.50	0.56 ± 4.86	41.29 ± 6.43	41.68 ± 6.78	0.39 ± 3.22	1.17 ± 7.62

Average values are shown ± standard deviation. Significance refers to the two-sided Wilcoxon signed-rank test, where the null hypothesis is that the medians between baseline and follow-up imaging visits are equal. An asterisk (*) indicates statistical significance for p-value < 0.05, ** indicates statistical significance after multiple testing correction by Bonferroni correction (p = 0.00027).

Discussion

In this study, we compared MRI measurements of muscle, lean and fat mass, and body fat percentage in the android and gynoid regions areas, typically assessed in DXA scans, to DXA measurements estimates in these regions. We assessed the linear relationship between the MRI and DXA-derived body composition measurements in the android and gynoid regions, and we assessed the longitudinal changes in body composition measures by DXA and MRI during follow-up imaging visits. Our primary aim was to evaluate the agreement between MRI and DXA measurements in anatomically equivalent regions and to determine their precision in detecting longitudinal changes.

Android and gynoid regions are constructs specifically defined in DXA scans. Our study replicated these constructs in our MRI measurements to allow a direct comparison between these two imaging methods. DXA showed a good agreement against MRI for adipose tissue measures, with a strong correlation between MRI and DXA fat mass measures, aligning with previous literature⁴⁴. However, in our cross-sectional analysis we found that DXA overestimated lean mass when compared to MRI in both android and gynoid regions. Although previous studies comparing MRI-derived muscle against DXA-derived lean mass, found a strong correlation between the two^{20,45,46}, others comparing CT and DXA, have reported that DXA overestimates muscle, with larger differences in subjects with higher body weights, suggesting DXA may be less accurate in that population⁹.

Moreover, our sub-analysis revealed minimal variability in DXA–MRI agreement across age groups, WC, and WHR (Supplementary Data B). However, agreement for android lean mass and VAT was notably poor among individuals with low BMI (< 20 kg/m²), likely influenced by the small sample size in this subgroup. In contrast, agreement improved with increasing BMI. The agreement across WC and WHR groups closely

mirrored those observed in the overall cohort. Notably, DXA showed good agreement with MRI for android lean mass in the youngest age group (40–49 years), although this may again reflect the limited sample size. Prior studies have similarly reported that DXA underperforms in estimating VAT among individuals with low BMI, with slightly reduced accuracy in those with high WC, highlighting the importance of considering BMI and WC when interpreting DXA-derived VAT in clinical settings⁴³.

There are a number of factors, both technical and physiological, which may account for the discrepancies between DXA and MRI. Previous studies have suggested that the 2D projection which DXA uses can result in beam hardening artefacts or overlapping tissues and less accurate localisation, particularly in anatomically complex regions such as the abdomen^{47,48}. Similarly, DXA's lower sensitivity and resolution may make it less effective at defining small volumes of VAT in lean individuals^{49,50}. Furthermore, myosteatosis or muscle fat infiltration, which could be misclassified as lean mass by DXA may lead to inaccurate estimations of muscle mass^{51,52}. Finally, the reliance on algorithms for the derivation of lean and fat mass in DXA has been reported to introduce inaccuracy in subjects with unusual fat distributions, at extremes of the BMI range⁵³. Although the UK Biobank has a robust procedure in place for its MRI and DXA scanning, previous studies have suggested that factors from patient position and DXA calibration can result in measurement differences⁵¹.

The measurement discrepancies between DXA and MRI have important clinical and research implications. In clinical settings, overestimation of lean mass by DXA may lead to underdiagnosis of sarcopenia or masked muscle loss, particularly in older adults or those with subtle muscle atrophy¹⁴. This could delay intervention and misinform clinical decisions around frailty or metabolic health. Similarly, DXA's underestimation of VAT (compared to MRI) in lean individuals may

underestimate cardiometabolic risk in this subgroup. In research settings, DXA-derived measurements are widely used in epidemiological studies, including those exploring associations with morbidity, mortality, or intervention outcomes⁵⁴. Systematic biases in DXA measurements may introduce measurement error, reduce statistical power, or bias effect estimates, especially in longitudinal designs or subgroup analyses. Therefore, our findings suggest that caution is needed when interpreting DXA-derived lean and fat mass data, particularly in specific subgroups or when subtle changes are anticipated.

It is also important to consider that hydration status can influence DXA-derived body composition estimates, particularly fat-free mass, due to the sensitivity of soft tissue measurements to changes in body water. Although hydration control was not feasible in this large-scale population study, the UK Biobank implemented rigorous imaging protocols, including standardised scanning procedures and comprehensive operator training, to minimise variability. Nevertheless, prior research suggests that hydration-related differences have limited impact on the correlation between DXA and CT measurements. For example, Bredella et al. found that hydration-adjusted comparisons (by controlling for body water) of abdominal and thigh fat and muscle between DXA and CT maintained consistent correlation coefficients across normal-weight and obese participants⁹.

Longitudinal assessment of body composition is vitally important, particularly in ageing, where a decline in skeletal muscle mass, and loss of muscle strength⁵⁵ are characteristics of sarcopenia and progression toward frailty⁵⁶. We found that over the relatively short period of 2.5 years, both muscle and lean mass, as measured by MRI, decreased by 4% to 5% in both android and gynoid regions. This decrease likely reflects both true muscle atrophy and increased intramuscular fat infiltration, which are well-established hallmarks of the ageing muscle phenotype⁵⁷. Mechanistically, these changes are driven by multiple factors including reduced physical activity, anabolic resistance, mitochondrial dysfunction, and chronic low-grade inflammation, all of which contribute to muscle degradation and fat infiltration in ageing individuals⁵⁸. The apparent lack of change observed by DXA may reflect its inability to differentiate between these compartments. Previous longitudinal studies in older adults have reported that MRI and DXA detected a similar percentage loss of thigh muscle mass over a five-year period¹⁵, with similar agreement reported for changes in leg skeletal muscle mass following two years exercise training⁴⁶. However, several interventional studies have suggested that compared with MRI and other methods, DXA is unable to accurately detect longitudinal changes in lean muscle^{20,59}, also reflected in the current longitudinal study.

Unexpectedly, our study found a significant increase in DXA-measured lean mass in the android region among women at follow-up. The reason for this increase, or why it was observed only in women, remains unclear. Prior research has shown that DXA measurements of lean soft tissue mass in the trunk can differ from MRI measurements of muscle in the same region⁴⁶. This difference may result from DXA's limited capacity to distinguish muscle from other lean tissues with differing proteins, water, non-fat lipids, carbohydrates, and soft tissue minerals composition⁷. Additionally, changes in fluid retention could further complicate these measurements, potentially contributing to the inconsistencies observed.

Our study was not without limitations, particularly regarding the variability in the neck placement for the MRI scan, which is essential for our android ROI height definition. However, the impact of this variation is mitigated somewhat since the android ROI height is set only to be one-fifth of the distance between the neck and the pelvic cut. For longitudinal datasets, we fixed the height of the ROIs to match baseline images in order to remove any variability from neck positioning. Furthermore, although DXA appendicular lean mass is a more commonly used measure of muscle⁶⁰, we are unable to directly compare these measures in our study since the UK Biobank neck-to-knee MRI acquisition does not include the arms and lower legs. Moreover, as the UK Biobank study includes a predominantly White population, future work is needed to further investigate imbalanced population data. Finally, the interval between baseline and follow-up

measurements in the longitudinal aspect of this study was only two and a half years, and the changes detected by MRI although consistent were modest²⁷. Longer intervals between scans or interventions designed to produce significant weight change may result in more significant changes in lean mass which may be more reliably detected by DXA. The current study only compared measures from Siemens 1.5 T MRI acquisitions to GE iDXA scanner output. DXA systems from different manufacturers can differ in both their measurement algorithms and their ROI definitions which needs to be taken into consideration. While the magnitude and pattern of differences may vary across manufacturers, it is reasonable to expect that comparing MRI and DXA, regardless of manufacturer, will reveal some level of systematic difference. The extent and direction of such differences, however, will depend on the specific systems used.

Conclusion

Our findings in this large-scale study underscore the limitations and strengths of DXA for body composition analysis. While DXA provides cross-sectional measurements for both fat and VAT, it overestimates lean mass and has limitations for the assessment of longitudinal changes; an essential consideration for studies into ageing. The more detailed body composition assessments from MRI are therefore more appropriate for understanding health in longitudinal population studies. However, further research is needed to address the factors contributing to the discrepancies in DXA's longitudinal accuracy, particularly in diverse populations. Future work should also explore the impact of longer follow-up periods and intervention studies to better assess the ability of DXA to detect significant changes in body composition over time, as well as covering different manufacturers beyond GE iDXA as used in this study.

Supplementary Data

A) Body composition measured via DXA and MRI at the follow-up imaging visit separated by sex within android and gynoid regions. $N_{\text{Android}} = 1895$. $N_{\text{Gynoid}} = 1928$. Android muscle mass was not available from DXA measures, so the regression was done between DXA lean mass and MRI muscle mass. Regression analyses were conducted using linear regression models between DXA and MRI measures. All tests were two-sided, and Bonferroni correction was applied for multiple comparisons. An asterisk (*) indicates statistical significance for $p\text{-value} < 0.05$, ** indicates statistical significance after multiple testing correction by Bonferroni correction ($p = 0.00027$). After Bonferroni correction, all linear regression coefficients were statistically significant. Regression equations are shown as $y = \text{slope} \times x + \text{intercept}$ (DXA = y , MRI = x), with R^2 indicating the explained variance. 95% confidence intervals (CI) are provided for slope and intercept. B) Body composition measured via DXA and MRI at the baseline imaging visit separated by sex and age group within the android and gynoid regions. Regression analyses were conducted using linear regression models between DXA and MRI measures. All tests were two-sided, and Bonferroni correction was applied for multiple comparisons. An asterisk (*) indicates statistical significance for $p\text{-value} < 0.05$, ** indicates statistical significance after multiple testing correction by Bonferroni correction ($p = 0.00027$). After Bonferroni correction, all linear regression coefficients were statistically significant. Regression equations are shown as $y = \text{slope} \times x + \text{intercept}$ (DXA = y , MRI = x), with R^2 indicating the explained variance. 95% confidence intervals (CI) are provided for slope and intercept. C) Body composition measured via DXA and MRI at the baseline imaging visit separated by sex and BMI group within the android and gynoid regions. Regression analyses were conducted using linear regression models between DXA and MRI measures. All tests were two-sided, and Bonferroni correction was applied for multiple comparisons. An asterisk (*) indicates statistical significance for $p\text{-value} < 0.05$, ** indicates statistical significance after multiple testing correction by Bonferroni correction ($p = 0.00027$). After Bonferroni correction, all linear regression coefficients were statistically significant. Regression equations are shown as $y = \text{slope} \times x + \text{intercept}$ (DXA = y , MRI = x), with R^2 indicating the explained variance. 95% confidence intervals (CI) are provided for slope and intercept.

D) Body composition measured via DXA and MRI at the baseline imaging visit separated by sex and WC group (normal for men with WC < 102 cm, and women WC < 90 cm) within the android regions. Regression analyses were conducted using linear regression models between DXA and MRI measures. All tests were two-sided, and Bonferroni correction was applied for multiple comparisons. An asterisk (*) indicates statistical significance for p -value < 0.05, ** indicates statistical significance after multiple testing correction by Bonferroni correction ($p = 0.00027$). After Bonferroni correction, all linear regression coefficients were statistically significant. Regression equations are shown as $y = \text{slope} \times x + \text{intercept}$ (MRI = y , MRI = x), with R^2 indicating the explained variance. 95% confidence intervals (CI) are provided for slope and intercept. E) Body composition measured via DXA and MRI at the baseline imaging visit separated by sex and WHR group (normal for men with WHR < 0.9, and women WHR < 0.85) within the android and gynoid regions. Regression analyses were conducted using linear regression models between DXA and MRI measures. All tests were two-sided, and Bonferroni correction was applied for multiple comparisons. An asterisk (*) indicates statistical significance for p -value < 0.05, ** indicates statistical significance after multiple testing correction by Bonferroni correction ($p = 0.00027$). After Bonferroni correction, all linear regression coefficients were statistically significant. Regression equations are shown as $y = \text{slope} \times x + \text{intercept}$ (DXA = y , MRI = x), with R^2 indicating the explained variance. 95% confidence intervals (CI) are provided for slope and intercept.

Data availability

Our research was conducted using UK Biobank data. Under the standard UK Biobank data sharing agreement, we (and other researchers) cannot directly share raw data obtained or derived from the UK Biobank. However, under this agreement, all of the data generated, and methodologies used in this paper are returned by us to the UK Biobank, where they will be fully available. Access is obtained directly from the UK Biobank to all bona fide researchers upon submitting a health-related research proposal to the UK Biobank <https://www.ukbiobank.ac.uk>.

Code availability

Code to generate the segmentations is based on github.com/calico/ukbb-mri-sseg²⁶. Python code to generate the android and gynoid ROIs is available in Supplementary Data 2.

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Author contributions

J.D.B., E.L.T., M.T., and N.B. conceived the study. All authors designed the study. M.T., B.W., and N.B. implemented the methods. N.B. performed the data analysis and M.T. performed the statistical analysis. All authors draughted the manuscript. All authors read and approved the manuscript.

Competing interests

All authors declare no competing interest.

Additional information

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