# Deep learning-based body composition analysis from whole-body magnetic resonance imaging to predict all-cause mortality in a large Western population

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## I SUPPLEMENTAL METHODS

### Data sources

*UKBB*

The UKBB is a large, prospective population-based study established to investigate the genetic and non-genetic determinants of diseases of middle and older age. It included over 500,000 volunteers aged 38–73 years at baseline across the United Kingdom and provides detailed clinical parameters on prevalent diseases and outcomes.1,2

In this study, we included all UKBB participants from the multimodal-imaging cohort who underwent T1-weighted 3D two-point VIBE Dixon MR imaging in axial orientation (slice thickness of 4·5 mm, voxel size of 2·23 x 2·23 mm, matrix of 224 x 168 x 44 , repetition time [TR] of 6·69 ms, echo time [TE] of 2·39 and 4·77 ms; 1·5T MAGNETOM Aera, Siemens Healthineers, Erlangen, Germany) until the date of data download, May 25, 2023.3

**Body composition analysis:** A total of 36,515 baseline MRI scans were identified. 198 individuals were excluded due to corrupt or incomplete imaging data, resulting in a final study cohort of 36,317 individuals with available whole-body MRI scans for body composition quantification.

**Survival analysis:** The association between body composition measures and all-cause mortality was investigated in a subsample of UKBB participants, for whom a complete panel of predefined clinical covariates was available. 9,768 individuals were excluded because one or more clinical covariates were missing (predominantly blood serum markers and blood pressure measures), resulting in a final study cohort of 26,549 subjects for outcome analysis (**Supplemental Figure 1**).

*NAKO*

The NAKO is an ongoing interdisciplinary cohort study investigating common diseases such as cardiovascular disease, diabetes, and cancer, with 200,000 asymptomatic participants aged 20–72 years enrolled at 18 sites in Germany.4 Over 30,000 participants underwent whole-body MRI at five imaging sites in the imaging substudy. The NAKO was approved by all local institutional review boards of the five imaging sites, and written informed consent was obtained from all participants prior to enrollment.5 Whole-body MR imaging was performed at all five sites using a dedicated T1-weighted 3D two-point VIBE Dixon sequence in axial orientation (slice thickness of 3 mm, voxel size of 1·41 x 1·41 mm, matrix of 320 x 260 x 96, TR of 4·36 ms, TE of 1·23 and 2·46 ms; 3T MAGNETOM Skyra, Siemens Healthineers, Erlangen, Germany).

For the current study, we used MRI data and clinical information from the second release that included 30,770 participants who underwent MR imaging between May 27, 2014 and September 30, 2019. We excluded participants <40 years of age (n=6635) from the NAKO to harmonize age ranges between NAKO and UKBB. An additional 410 individuals were excluded because of corrupt or incomplete imaging data, resulting in a final study cohort of 23,725 individuals with available whole-body MRI scans for body composition quantification (**Supplemental Figure 2**).

NAKO data was used 1) to define the thresholds to categorize the continuous body composition measures into groups and 2) to perform a correlation analysis between volumetric whole-body and single-slice area body composition measures at the height of each vertebral body. NAKO data was not used in the survival analysis as outcome data were not yet available.

### Development of model 1: volumetric whole-body composition segmentation

The whole-body composition segmentation model was developed to quantify (i) subcutaneous adipose tissue (SAT), (ii) visceral adipose tissue (VAT), (iii) skeletal muscle (SM), and (iv) intramuscular adipose tissue (IMAT) in cubic decimetres (dm3) from whole-body T1-weighted two-point VIBE Dixon MR imaging. The model was developed using a random sample of n=150 individuals with whole-body MRI data from the NAKO imaging sub-study.5

To ensure the most accurate discrimination and segmentation of different tissues, an experienced radiology resident (5 years of experience in MR imaging) performed manual annotations of SAT, VAT, IMAT, and SM on T1-weighted Dixon sequences using all four image contrasts (in-phase, opposed-phase, water, fat) and three imaging planes (axial, as well as coronal and sagittal multiplanar reconstructions in the nora medical imaging platform viewer; https://www.nora-imaging.org). This approach allowed for the most accurate discrimination and segmentation of tissue boundaries, which is particularly important in areas of fat-water interfaces, such as between SM and adipose tissue compartments, where chemical shift artefacts of the second kind ("India ink" or "black line" artefacts) can occur in opposed-phase contrasts, leading to overestimation or underestimation of tissue boundaries.6 These segmentations were independently validated and adjusted where necessary by a board-certified radiologist (10 years of experience in MR imaging). Approximately 10% of the manually labelled cases required minor adjustments to one or more masks, which were made in consensus with the radiology resident. SAT and SM were segmented from the upper plate of the first thoracic vertebra to the femoral insertion of the abductor brevis muscle. SM included all trunk (autochthonous and chest/abdominal wall), pelvic, and proximal thigh muscles within the deep peripheral fascia from the upper plate of the first thoracic vertebra to the femoral insertion of the adductor brevis muscle. VAT segmentation was performed within the limits of the abdominal cavity. IMAT segmentations were limited to the autochthonous spinal musculature as this is a commonly used approach for IMAT quantification.7-9

The volumetric input to the deep learning model were all axial slices of the in- and opposed-phase sequences of the whole-body T1-weighted two-point VIBE Dixon MR sequence; the output of the model were segmentation masks for SAT, VAT, SM, and IMAT that estimated the whole-body volumes (dm3) inside the boundaries defined above. Subsequently, the SM fat fraction (SMFF) was derived from the chemical shift encoding-based water-fat information of the VIBE Dixon sequence as follows:

The model was implemented as a hierarchical, patch-based stack of convolutional neural networks (CNN). The patchwork approach uses nested patches of a fixed matrix size that decrease in physical size.10 A U-Net-type architecture is utilized in each scale, with the U-Net matrix size set to 32x32x32 voxels for all scales. A scale pyramid with a depth of four is employed. These settings were chosen based on the available hardware capacity, which limited sample size and pyramid size. The pyramid size was chosen to achieve a coarsest layer field-of-view of 300x200x500mm and a final isotropic resolution of 2mm. Intermediate levels of the pyramid were exponentially interpolated. The input to the network consists of concatenated in- and out-of-phase contrasts. The architecture of the U-Net we used is similar to the default UNet configuration11, with feature dimensions (32,32,64,64,128) and max-pooling and transposed convolutions in the encoding and decoding layers, respectively. Each U-Net has n+8 output channels, with the first n=4 corresponding to the labels and used for intermediate loss computations. The total logits of n+8 outputs are passed to the next scale. The network is trained with the Adam optimizer12 with a learning rate of 0·001 and using ten million patches for training of the network with a batch size of 32. The training took approximately four days (Nvidia RTX A6000 48GB). Applying the model took 170 seconds per case using 16 CPU cores (Intel Xeon Gold 6448H 32-Core CPU, 2·40GHz, 60·00MB L3 Cache, DDR5-4800, Turbo Core max. 4·10GHz, MCC Die, 512GB SGX). No systematic tuning was performed, and all labels were trained using binary-cross entropy per channel. More details about the model architecture are reported elsewhere.10

### Independent testing of model 1: volumetric whole-body composition segmentation

First, the model was internally tested in an independent dataset of n=50 randomly chosen NAKO participants not seen during any part of model development. To evaluate model performance, the automatically generated volumetric segmentations of the model were compared to the manual segmentations of the four different body composition measures using the Dice coefficient to compare the manual to the predicted segmentation masks and Pearson's correlation coefficients to measure the strength of the linear relationship between the manual segmentation mask-derived measures and the predicted segmentation mask-derived measures.

Second, we used transfer learning to apply the model to UKBB participants and account for differences in imaging data. Fine tuning was performed using a random sample of n=130 UKBB participants, which were labelled as described above. Independent testing of the retrained UKBB model was performed on an additional random sample of n=50 subjects from the UKBB not seen during any part of model retraining. The automatically generated volumetric segmentations of the retrained model were compared to the manual segmentations of the four different body composition measures using the Dice coefficient and Pearson's correlation coefficient to evaluate model performance.

### Development of model 2: spine labelling to extract single-slice body composition area segmentations

The spine labelling model was developed to automatically detect and label every vertebral body of the thoracic (T1-T12) and lumbar spine (L1-L5). The model was trained using another random sample of n=150 individuals with whole-body MRI data from the NAKO imaging sub-study.5 An experienced radiology resident manually labelled the centre of each vertebral body (T1-L5) on T1-weighted Dixon sequences using all four image contrasts (in-phase, opposed-phase, water, fat) and three imaging planes (axial, coronal, sagittal). All annotations were independently validated and adjusted by a board-certified radiologist if necessary. The inputs to the model were the in- and out-of-phase images of the whole-body T1-weighted two-point VIBE Dixon MRI sequence; the output of the model was a dense field of template coordinates. Therefore, a unique template position was assigned to each vertebral body based on one template subject. The architecture of the network was similar to model 1 but with different parameters: the initial Field-of-view was [400,400,800] mm, and we used a final resolution of 4,4,8 mm. The CNN architecture was a classical Unet autoencoder architecture as described above, but without "U"-skip connections. The loss function was mean-squared error masked with a Gaussian weight around the vertebral bodies.

Independent testing of model 2: spine labelling to extract single-slice body composition area segmentationsFirst, Model 2 was tested on n = 50 independent NAKO participants not seen during any part of model development. The automatically generated spine labels of the model were compared to the manual labels of each vertebral body by calculating the mean distance error in the craniocaudal direction.

Second, we used transfer learning to fine tune model 2 with an additional n=360 UKBB participants. Labelling was performed as described above. The automatically generated spine labels of the retrained model 2 were compared to the manual labels of each vertebral body by calculating the mean distance error in the craniocaudal direction in a random sample of n=50 subjects from the UKBB not seen during any part of model retraining.

### Extraction of single-slice body composition area segmentations

To subsequently extract a single-slice body composition area at a certain level of a vertebral body, the output of the model was linearly up-sampled to the original resolution of the input and the closest point to the template coordinates was searched. Subsequently, a single-slice area for SAT, VAT, and SM in dm2, as well as IMAT in 10-1cm2 per vertebral body level, was calculated for each body composition measure based on the volumetric whole-body segmentation masks generated by model 1.

### Development of model 3: Correction of fat-water swap artefacts in UKBB Dixon MRI

To correct for Dixon swaps, which were particularly present in the UKBB, we trained a network that predicted the sign of the opposed-phase contrast. The ground truth was generated from n = 100 UKBB scans that did not show any Dixon swaps. The inputs to the network were the in- and opposed-phase images. Model 3 architecture was identical to Model 1, but Model 3 was trained with only one output label image indicating the algebraic sign of the opposed-phase contrast. To correct for Dixon swaps, fat and water images were computed based on the predicted sign and compared to the original (scanner-side) computed images. When differences were higher than 100 signal intensity units, the contrast was exchanged from fat to water or vice versa in the original images to correct for the former Dixon swap artefact. All corrections were performed on a slice level.

### Independent testing of model 3: Correction of fat-water swap artefacts in UKBB Dixon MRI

The quality of the automatically corrected Dixon swaps was visually assessed by an experienced radiologist in n=180 UKBB subjects with a former Dixon swap on a per-scan basis.

Covariates

*UKBB*

Date of birth, sex, and race were extracted from the self-reported UKBB baseline population characteristics. Due to the small number of non-white participants in the UKBB imaging study, race was dichotomized into white and others. Physical measurements, including BMI (weight/height2; kg/m2), were obtained at the imaging visit. Smoking status (former, current, never), prevalent diabetes, and history of cancer were self-reported via a touchscreen questionnaire at the imaging visit. Alcohol consumption was defined as "regular" ("Daily or almost daily", "Three or four times a week", "Once or twice a week") and "occasional" ("One to three times a month", "Special occasions only", "Never"). Smoking was dichotomized by subsuming former and current smokers into "ever smokers". History of Hypertension was defined as "Yes" (Available "Age high blood pressure diagnosed", history of "Medication for blood pressure", systolic blood pressure ≥ 140 mmHg and/or a diastolic blood pressure ≥ 90 mmHg), and "No" (none of the above). History of stroke and history of myocardial infarction were based on available dates of stroke ("Date of stroke") and myocardial infarction ("Date of myocardial infarction") through linkage to electronic medical records or self-report. Blood serum biomarkers, including total cholesterol (TC, mmol/L), HDL (mmol/L), LDL (mmol/L), triglycerides (mmol/L), glucose (mmol/L), and HbA1c (mmol/mol) were measured at initial assessment.

*NAKO*

Only baseline demographic data were available for the NAKO participants. This included age at MRI, sex, height (m), and weight (kg), which were assessed with standardized measuring devices at the imaging centres (all Stadiometer 274 for height and medical Body Composition Analyzer 515 for weight, both seca GmbH, Hamburg, Germany).

Data harmonization

After extracting the body composition measures from the whole-body MRI scans, we observed a small data shift between the UKBB and NAKO data for SMFF and IMAT.

*SMFF:* Swapping artefacts are typical artefacts in MR Dixon imaging due to errors in the water and fat imaging calculation, resulting in image areas erroneously labelled as "water" in the fat image and vice versa. This leads to incorrect estimates when calculating the fat fraction, which is extracted from the water and fat images as described above. In the UKBB, swapping artefacts occurred mainly as block-wise artefacts (e.g. abdomen), which are easy to detect and correct. Therefore, all swaps in the UKBB were corrected before extracting SMFF (see above). In contrast, in the NAKO, swapping artefacts affected only a small portion of some imaging slices that are difficult to detect and correct, which likely was the reason for a small right-sided distribution shift in SMFF of the NAKO data compared to the corrected UKBB data. As reliable correction of these small swapping artefacts is difficult, no correction algorithm was employed. Instead, since the SMFF distributions were approximately normal, we used a normal score transformation to convert the NAKO SMFF distribution to the same mean and variance as the UKBB SMFF.

*IMAT:* For IMAT, we observed a small right-sided distribution shift in the UKBB IMAT histograms compared to the

NAKO IMAT histograms, likely due to the lower spatial resolution of the 1·5T VIBE Dixon sequence in the UKBB. IMAT data was harmonized by transforming the log IMAT distribution in UKBB to match the NAKO.

## II SUPPLEMENTAL RESULTS

### Independent testing of model 1: volumetric whole-body composition segmentation

Internal testing was performed in 50 randomly selected individuals of the NAKO. Dice coefficients were 0·95 ± 0·02 for SAT, 0·92 ± 0·03 for VAT, 0·93 ± 0·02 for SM, and 0·88 ± 0·5 for IMAT. Pearson's correlation coefficients assessing the linear relationship between manual and automatically generated volumetric segmentation masks were r>0·99 (R2>0·98) for all body composition measures (all p values <0·0001; **Supplemental Figure 4**).

After transferring and fine-tuning model 1 on n=130 UKBB datasets, testing was performed in 50 randomly selected participants of the UKBB imaging sub-study. The Dice coefficient was 0·93 ± 0·01 for SAT, 0·90 ± 0·01 for VAT, 0·90 ± 0·03 for SM, and 0·86 ± 0·4 for IMAT. Pearson's correlation coefficients comparing the manual and automatically generated volumetric segmentation masks were r>0·97 (R2>0·94) for all body composition measures (all p values <0·0001; **Supplemental** **Figure 5**).

In addition, the quality of the automatically generated segmentations was visually assessed in n=400 (n=200 NAKO and n=200 UKBB) random subjects by an experienced radiologist. Most of the minor errors occurred when the model segmented the cranial and caudal boundaries of SAT and SM. No systematic errors with respect to age, sex, or BMI were noted across all study participants.

### Independent testing of model 2: spine labelling to extract single-slice body composition area segmentations

To assess the deep learning spine labelling model's performance, we tested it on an independent NAKO test dataset (n=50) not seen during model development by comparing automatic and manual vertebral body labels. The mean distance error of the automated labels in the craniocaudal direction was -1 ± 7 mm in the NAKO.

After transferring and fine-tuning model 2 on n=360 UKBB datasets, testing was performed in n=50 randomly selected participants of the UKBB not seen during fine-tuning. The mean distance error of the automated labels in the craniocaudal direction was 4 ± 8 mm in the UKBB testset. **Supplemental Table 5** shows the mean distance error in the craniocaudal direction and normal intervertebral distances for each vertebral body.   
In addition, the quality of the automatically generated spine labels was visually assessed in n=200 (n=100 NAKO and n=100 UKBB) random subjects by an experienced radiologist. No systematic errors with respect to age, sex, or BMI were noted across all study participants.

### Independent testing of model 3: Correction of fat-water swap artefacts in UKBB Dixon MRI

An independent UKBB test dataset (n=180) containing only subjects with a previous Dixon swap was visually evaluated to assess the performance of the deep learning Dixon swap correction model. No systematic errors were found with respect to age, sex, or BMI, and the model correctly changed the swapped fat contrast to a water contrast and vice versa when a Dixon swap artefact was present in the original images and left the correct contrasts unchanged.

## III SUPPLEMENTAL TABLES

### Supplemental Table 1: Cutoffs for body composition risk categories in the NAKO

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **Volumetric whole-body composition measure** | | | | |
| **Sex** | **Percentile** | **SAT (dm3)** | **VAT (dm3)** | **SM (dm3)** | **SMFF (%)** | **IMAT (10-1 dm3)** |
| female | Upper 10th | 27·88 | 4·54 | 11·53 | 21·27 | 2·39 |
| Lower 10th | 9·79 | 0·66 | 7·88 | 13·47 | 0·92 |
| male | Upper 10th | 21·14 | 7·72 | 17·81 | 18·64 | 2·31 |
| Lower 10th | 7·75 | 1·95 | 12·42 | 11·27 | 0·72 |
|  | | | | | | |
|  |  | **Single-slice area body composition measure at L3** | | | | |
| **Sex** | **Percentile** | **SAT (dm2)** | **VAT (dm2)** | **SM (dm2)** | **SMFF (%)** | **IMAT (10-1 dm2)** |
| female | Upper 10th | 4·05 | 2·01 | 1·33 | 33·71 | 0·92 |
| Lower 10th | 1·06 | 0·24 | 0·9 | 19·59 | 0·23 |
| male | Upper 10th | 3·14 | 3·38 | 2·03 | 29·34 | 0·69 |
| Lower 10th | 1·08 | 0·75 | 1·40 | 16·41 | 0·12 |

**Supplemental Table 1 |** Cutoffs for body composition risk categories defined as high (≥ upper 10th percentile of NAKO participants) and low (< 10th percentile of NAKO participants), which were calculated for males/females and volumetric/single-slice area body composition measures separately and subsequently applied to the UKBB.

IMAT, intramuscular adipose tissue. L, lumbar vertebra. NA, not available. NAKO, German National Cohort. SAT, subcutaneous adipose tissue. SM, skeletal muscle. SMFF, skeletal muscle fat fraction. VAT, visceral adipose tissue.

### Supplemental Table 2: Correlation between volumetric whole-body and single-slice area body composition measures – UKBB

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·621 (0·616,0·625) | NA | 0·763 (0·759,0·767) | 0·849 (0·846,0·852) | 0·380 (0·374,0·386) |
| T2 | 0·693 (0·690,0·697) | NA | 0·881 (0·879,0·883) | 0·824 (0·820,0·827) | 0·470 (0·465,0·475) |
| T3 | 0·716 (0·712,0·719) | NA | 0·896 (0·894,0·898) | 0·898 (0·896,0·900) | 0·477 (0·471,0·482) |
| T4 | 0·742 (0·739,0·745) | NA | 0·922 (0·920,0·923) | 0·908 (0·907,0·910) | 0·424 (0·419,0·430) |
| T5 | 0·753 (0·750,0·756) | NA | 0·880 (0·878,0·882) | 0·902 (0·900,0·904) | 0·343 (0·337,0·349) |
| T6 | 0·766 (0·763,0·769) | NA | 0·878 (0·876,0·880) | 0·920 (0·918,0·921) | 0·272 (0·265,0·278) |
| T7 | 0·761 (0·758,0·764) | NA | 0·913 (0·911,0·915) | 0·924 (0·923,0·926) | 0·252 (0·246,0·258) |
| T8 | 0·771 (0·769,0·774) | NA | 0·922 (0·921,0·924) | 0·932 (0·930,0·933) | 0·262 (0·256,0·268) |
| T9 | 0·774 (0·772,0·777) | NA | 0·922 (0·921,0·924) | 0·939 (0·938,0·940) | 0·293 (0·287,0·299) |
| T10 | 0·775 (0·773,0·778) | NA | 0·924 (0·923,0·926) | 0·940 (0·939,0·941) | 0·336 (0·330,0·342) |
| T11 | 0·754 (0·751,0·757) | 0·701 (0·698,0·704) | 0·932 (0·930,0·933) | 0·921 (0·920,0·923) | 0·377 (0·371,0·383) |
| T12 | 0·766 (0·763,0·768) | 0·814 (0·812,0·816) | 0·915 (0·913,0·917) | 0·927 (0·926,0·929) | 0·411 (0·405,0·417) |
| L1 | 0·789 (0·786,0·791) | 0·835 (0·833,0·837) | 0·925 (0·923,0·926) | 0·944 (0·943,0·945) | 0·453 (0·447,0·458) |
| L2 | 0·807 (0·805,0·809) | 0·880 (0·879,0·881) | 0·941 (0·940,0·942) | 0·945 (0·944,0·946) | 0·526 (0·522,0·531) |
| L3 | 0·792 (0·790,0·794) | **0·892** (0·891,0·893) | **0·944** (0·943,0·945) | 0·906 (0·904,0·907) | 0·544 (0·539,0·548) |
| L4 | 0·791 (0·788,0·793) | 0·843 (0·842,0·845) | 0·916 (0·915,0·918) | 0·934 (0·933,0·936) | **0·546** (0·541,0·550) |
| L5 | **0·820** (0·818,0·822) | 0·750 (0·747,0·753) | 0·910 (0·908,0·911) | **0·947** (0·946,0·948) | 0·222 (0·216,0·229) |

**Supplemental Table 2 |** Correlation between volumetric whole-body and single-slice area body composition measures in the UKBB for each vertebral body height. VAT is only present in the abdominal cavity (T11-L5).

All correlation coefficients are p < 0·0001. Bold indicates highest coefficient.

IMAT, intramuscular adipose tissue. L, lumbar vertebra. NA, not available. SAT, subcutaneous adipose tissue. SM, skeletal muscle. SMFF, skeletal muscle fat fraction. T, thoracic vertebra. UKBB, UK biobank. VAT, visceral adipose tissue.

### Supplemental Table 3: Correlation between volumetric whole-body and single-slice area body composition measures – NAKO

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·659 (0·655,0·664) | NA | 0·826 (0·822,0·830) | 0·863 (0·860,0·866) | 0·342 (0·334,0·349) |
| T2 | 0·701 (0·697,0·705) | NA | 0·899 (0·897,0·902) | 0·860 (0·857,0·864) | 0·466 (0·460,0·473) |
| T3 | 0·725 (0·721,0·729) | NA | 0·900 (0·898,0·903) | 0·926 (0·925,0·928) | 0·502 (0·496,0·508) |
| T4 | 0·746 (0·743,0·750) | NA | 0·922 (0·920,0·924) | 0·930 (0·928,0·932) | 0·476 (0·470,0·483) |
| T5 | 0·749 (0·745,0·752) | NA | 0·888 (0·885,0·891) | 0·918 (0·916,0·920) | 0·414 (0·407,0·421) |
| T6 | 0·756 (0·752,0·759) | NA | 0·887 (0·884,0·889) | 0·913 (0·911,0·915) | 0·330 (0·322,0·338) |
| T7 | 0·762 (0·758,0·765) | NA | 0·909 (0·906,0·911) | 0·907 (0·905,0·909) | 0·286 (0·278,0·294) |
| T8 | 0·771 (0·768,0·774) | NA | 0·914 (0·912,0·916) | 0·927 (0·925,0·928) | 0·272 (0·264,0·280) |
| T9 | 0·774 (0·771,0·777) | NA | 0·912 (0·910,0·914) | 0·939 (0·938,0·941) | 0·260 (0·252,0·268) |
| T10 | 0·777 (0·774,0·780) | NA | 0·909 (0·907,0·911) | 0·946 (0·945,0·948) | 0·307 (0·300,0·315) |
| T11 | 0·767 (0·764,0·770) | 0·583 (0·578,0·588) | 0·929 (0·928,0·931) | 0·925 (0·923,0·927) | 0·383 (0·376,0·390) |
| T12 | 0·776 (0·773,0·780) | 0·802 (0·800,0·805) | 0·909 (0·906,0·911) | 0·925 (0·924,0·927) | 0·444 (0·438,0·451) |
| L1 | 0·793 (0·790,0·796) | 0·833 (0·831,0·836) | 0·919 (0·917,0·921) | 0·936 (0·935,0·938) | 0·466 (0·459,0·472) |
| L2 | 0·813 (0·810,0·816) | 0·865 (0·863,0·867) | 0·939 (0·938,0·941) | **0·938** (0·937,0·940) | 0·521 (0·515,0·527) |
| L3 | 0·802 (0·799,0·805) | **0·890** (0·888,0·891) | **0·947** (0·946,0·949) | 0·900 (0·897,0·902) | 0·547 (0·541,0·553) |
| L4 | 0·793 (0·790,0·796) | 0·837 (0·835,0·840) | 0·923 (0·921,0·925) | 0·918 (0·916,0·920) | **0·561** (0·556,0·567) |
| L5 | **0·854** (0·852,0·856) | 0·783 (0·780,0·786) | 0·927 (0·925,0·929) | 0·934 (0·932,0·935) | 0·363 (0·356,0·371) |

**Supplemental Table 3 |** Correlation between volumetric whole-body and single-slice area body composition measures in the NAKO for each vertebral body height. VAT is only present in the abdominal cavity (T11-L5).

All correlation coefficients are p < 0·0001. Bold indicates highest coefficient.

IMAT, intramuscular adipose tissue. L, lumbar vertebra. NA, not available. NAKO, German National Cohort. SAT, subcutaneous adipose tissue. SM, skeletal muscle. SMFF, skeletal muscle fat fraction. T, thoracic vertebra. VAT, visceral adipose tissue.

### Supplemental Table 4: Correlation between volumetric whole-body and single-slice area body composition measures stratified by sex – UKBB

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Female** | | | | | |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·644 (0·638,0·649) | NA | 0·483 (0·472,0·494) | 0·830 (0·826,0·835) | 0·398 (0·390,0·406) |
| T2 | 0·712 (0·708,0·717) | NA | 0·722 (0·715,0·729) | 0·781 (0·776,0·787) | 0·492 (0·485,0·499) |
| T3 | 0·729 (0·725,0·733) | NA | 0·748 (0·742,0·755) | 0·886 (0·883,0·889) | 0·492 (0·485,0·499) |
| T4 | 0·740 (0·736,0·744) | NA | 0·771 (0·765,0·776) | 0·898 (0·895,0·901) | 0·432 (0·425,0·440) |
| T5 | 0·746 (0·742,0·750) | NA | 0·628 (0·619,0·637) | 0·883 (0·879,0·886) | 0·355 (0·346,0·363) |
| T6 | 0·749 (0·745,0·753) | NA | 0·622 (0·613,0·630) | 0·905 (0·902,0·908) | 0·290 (0·281,0·298) |
| T7 | 0·744 (0·740,0·748) | NA | 0·733 (0·726,0·739) | 0·909 (0·907,0·911) | 0·272 (0·263,0·280) |
| T8 | 0·744 (0·739,0·748) | NA | 0·762 (0·756,0·768) | 0·920 (0·917,0·922) | 0·280 (0·271,0·288) |
| T9 | 0·743 (0·739,0·747) | NA | 0·759 (0·753,0·765) | 0·928 (0·926,0·930) | 0·306 (0·297,0·314) |
| T10 | 0·741 (0·737,0·745) | NA | 0·759 (0·753,0·765) | 0·931 (0·929,0·933) | 0·341 (0·333,0·349) |
| T11 | 0·704 (0·700,0·709) | 0·656 (0·651,0·660) | 0·787 (0·782,0·792) | 0·920 (0·918,0·923) | 0·367 (0·359,0·375) |
| T12 | 0·755 (0·751,0·759) | 0·795 (0·792,0·798) | 0·756 (0·749,0·762) | 0·919 (0·917,0·921) | 0·406 (0·398,0·414) |
| L1 | 0·782 (0·779,0·786) | 0·817 (0·814,0·820) | 0·774 (0·768,0·779) | 0·936 (0·935,0·938) | 0·449 (0·441,0·456) |
| L2 | 0·805 (0·802,0·808) | 0·854 (0·851,0·856) | 0·821 (0·816,0·825) | **0·942** (0·940,0·943) | 0·537 (0·530,0·544) |
| L3 | 0·818 (0·816,0·821) | **0·874** (0·872,0·876) | **0·828** (0·823,0·832) | 0·902 (0·899,0·905) | **0·580** (0·574,0·586) |
| L4 | **0·826** (0·824,0·829) | 0·856 (0·854,0·858) | 0·776 (0·770,0·781) | 0·930 (0·928,0·932) | 0·562 (0·555,0·568) |
| L5 | 0·811 (0·808,0·814) | 0·820 (0·817,0·823) | 0·700 (0·692,0·707) | 0·934 (0·932,0·936) | 0·130 (0·120,0·140) |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Male** | | | | | |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·623 (0·616,0·629) | NA | 0·607 (0·597,0·616) | 0·821 (0·816,0·826) | 0·419 (0·411,0·427) |
| T2 | 0·671 (0·665,0·676) | NA | 0·756 (0·749,0·762) | 0·805 (0·800,0·810) | 0·523 (0·515,0·530) |
| T3 | 0·697 (0·692,0·702) | NA | 0·779 (0·774,0·785) | 0·876 (0·872,0·879) | 0·529 (0·522,0·536) |
| T4 | 0·709 (0·704,0·714) | NA | 0·798 (0·793,0·804) | 0·890 (0·887,0·893) | 0·469 (0·461,0·477) |
| T5 | 0·722 (0·717,0·726) | NA | 0·673 (0·665,0·681) | 0·896 (0·893,0·899) | 0·370 (0·361,0·379) |
| T6 | 0·759 (0·755,0·763) | NA | 0·669 (0·661,0·677) | 0·916 (0·913,0·918) | 0·282 (0·273,0·291) |
| T7 | 0·766 (0·762,0·770) | NA | 0·749 (0·742,0·755) | 0·928 (0·926,0·930) | 0·260 (0·251,0·269) |
| T8 | 0·782 (0·778,0·786) | NA | 0·767 (0·761,0·773) | 0·931 (0·929,0·933) | 0·276 (0·267,0·285) |
| T9 | 0·792 (0·789,0·796) | NA | 0·769 (0·763,0·775) | 0·931 (0·929,0·933) | 0·305 (0·296,0·314) |
| T10 | 0·800 (0·796,0·803) | NA | 0·781 (0·776,0·787) | 0·931 (0·929,0·933) | 0·346 (0·338,0·355) |
| T11 | 0·797 (0·793,0·800) | 0·609 (0·603,0·615) | 0·811 (0·806,0·816) | 0·926 (0·924,0·928) | 0·387 (0·379,0·395) |
| T12 | 0·804 (0·800,0·807) | 0·763 (0·759,0·767) | 0·782 (0·776,0·788) | 0·924 (0·921,0·926) | 0·417 (0·409,0·425) |
| L1 | 0·811 (0·807,0·814) | 0·796 (0·792,0·799) | 0·804 (0·799,0·809) | 0·941 (0·940,0·943) | 0·464 (0·456,0·472) |
| L2 | 0·801 (0·798,0·805) | 0·864 (0·862,0·866) | 0·841 (0·837,0·845) | 0·938 (0·936,0·940) | 0·534 (0·527,0·541) |
| L3 | 0·774 (0·770,0·778) | **0·868** (0·866,0·870) | **0·850** (0·846,0·854) | 0·885 (0·881,0·888) | 0·551 (0·544,0·557) |
| L4 | 0·790 (0·786,0·793) | 0·837 (0·835,0·840) | 0·801 (0·795,0·806) | 0·921 (0·919,0·923) | **0·559** (0·553,0·566) |
| L5 | **0·817** (0·813,0·820) | 0·806 (0·802,0·809) | 0·786 (0·780,0·792) | **0·946** (0·944,0·948) | 0·325 (0·316,0·334) |

**Supplemental Table 4 |** Sex-stratified correlations between volumetric whole-body and single-slice area body composition measures in the UKBB for each vertebral body height. VAT is only present in the abdominal cavity (T11-L5).

All correlation coefficients are p < 0·0001. Bold indicates highest coefficient.

IMAT, intramuscular adipose tissue. L, lumbar vertebra. NA, not available. SAT, subcutaneous adipose tissue. SM, skeletal muscle. SMFF, skeletal muscle fat fraction. T, thoracic vertebra. UKBB, UK biobank. VAT, visceral adipose tissue.

### Supplemental Table 5: Correlation between volumetric whole-body and single-slice area body composition measures stratified by BMI – UKBB

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| --- | --- | --- | --- | --- | --- |
| **BMI < 18·5** | | | | | |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·517 (0·469,0·565) | NA | 0·467 (0·387,0·540) | 0·842 (0·811,0·868) | 0·315 (0·253,0·376) |
| T2 | 0·617 (0·575,0·658) | NA | 0·657 (0·598,0·709) | 0·777 (0·735,0·813) | 0·448 (0·399,0·496) |
| T3 | 0·633 (0·595,0·672) | NA | 0·720 (0·669,0·764) | 0·862 (0·835,0·885) | 0·476 (0·428,0·523) |
| T4 | 0·662 (0·626,0·698) | NA | 0·740 (0·693,0·781) | 0·888 (0·866,0·907) | 0·437 (0·386,0·488) |
| T5 | 0·694 (0·661,0·728) | NA | 0·815 (0·779,0·845) | 0·830 (0·797,0·858) | 0·333 (0·275,0·391) |
| T6 | 0·698 (0·665,0·730) | NA | 0·799 (0·761,0·832) | 0·859 (0·831,0·882) | 0·327 (0·265,0·390) |
| T7 | 0·668 (0·633,0·702) | NA | 0·837 (0·806,0·864) | 0·909 (0·890,0·925) | 0·317 (0·256,0·378) |
| T8 | 0·676 (0·641,0·711) | NA | 0·782 (0·741,0·817) | 0·908 (0·890,0·924) | 0·332 (0·269,0·394) |
| T9 | 0·670 (0·634,0·706) | NA | 0·752 (0·707,0·792) | 0·915 (0·898,0·930) | 0·398 (0·341,0·455) |
| T10 | 0·659 (0·623,0·695) | NA | 0·719 (0·668,0·763) | 0·923 (0·907,0·936) | 0·461 (0·407,0·516) |
| T11 | 0·647 (0·613,0·681) | 0·444 (0·387,0·500) | 0·567 (0·497,0·630) | 0·901 (0·881,0·918) | 0·411 (0·355,0·467) |
| T12 | 0·672 (0·639,0·706) | 0·708 (0·674,0·742) | 0·606 (0·541,0·664) | 0·905 (0·885,0·921) | 0·382 (0·325,0·440) |
| L1 | 0·693 (0·660,0·725) | 0·752 (0·724,0·780) | 0·717 (0·666,0·761) | 0·911 (0·893,0·926) | 0·383 (0·324,0·441) |
| L2 | 0·690 (0·657,0·723) | 0·773 (0·744,0·801) | 0·843 (0·812,0·869) | **0·924** (0·909,0·937) | 0·496 (0·448,0·544) |
| L3 | 0·682 (0·646,0·717) | **0·806** (0·782,0·829) | **0·868** (0·841,0·890) | 0·909 (0·891,0·925) | **0·530** (0·481,0·578) |
| L4 | 0·697 (0·665,0·729) | 0·778 (0·750,0·805) | 0·839 (0·808,0·866) | 0·913 (0·896,0·928) | 0·506 (0·456,0·555) |
| L5 | **0·740 (0·712,0·769)** | 0·753 (0·723,0·784) | 0·683 (0·627,0·732) | 0·906 (0·887,0·922) | 0·108 (0·041,0·175) |

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| **BMI 18·5 – 24·9** | | | | | |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·477 (0·470,0·485) | NA | 0·695 (0·687,0·703) | 0·864 (0·860,0·868) | 0·334 (0·325,0·343) |
| T2 | 0·590 (0·584,0·597) | NA | 0·864 (0·860,0·868) | 0·820 (0·814,0·824) | 0·435 (0·427,0·443) |
| T3 | 0·613 (0·607,0·619) | NA | 0·890 (0·887,0·893) | 0·898 (0·895,0·901) | 0·433 (0·425,0·441) |
| T4 | 0·664 (0·659,0·670) | NA | 0·914 (0·912,0·917) | 0·909 (0·906,0·911) | 0·376 (0·367,0·384) |
| T5 | 0·690 (0·685,0·694) | NA | 0·908 (0·905,0·910) | 0·896 (0·893,0·899) | 0·300 (0·291,0·309) |
| T6 | 0·689 (0·684,0·694) | NA | 0·894 (0·891,0·897) | 0·917 (0·914,0·919) | 0·242 (0·233,0·252) |
| T7 | 0·667 (0·662,0·673) | NA | 0·917 (0·914,0·919) | 0·927 (0·925,0·929) | 0·233 (0·223,0·242) |
| T8 | 0·691 (0·686,0·696) | NA | 0·926 (0·924,0·928) | 0·929 (0·927,0·931) | 0·254 (0·245,0·263) |
| T9 | 0·699 (0·694,0·704) | NA | 0·926 (0·924,0·928) | 0·934 (0·932,0·936) | 0·303 (0·294,0·312) |
| T10 | 0·702 (0·697,0·707) | NA | 0·926 (0·923,0·928) | 0·932 (0·930,0·934) | 0·361 (0·352,0·370) |
| T11 | 0·670 (0·664,0·675) | 0·662 (0·657,0·668) | 0·925 (0·923,0·927) | 0·910 (0·907,0·912) | 0·385 (0·376,0·393) |
| T12 | 0·652 (0·647,0·658) | 0·797 (0·794,0·800) | 0·905 (0·902,0·908) | 0·917 (0·915,0·920) | 0·394 (0·386,0·403) |
| L1 | 0·683 (0·678,0·689) | 0·823 (0·820,0·826) | 0·906 (0·903,0·909) | 0·933 (0·931,0·935) | 0·427 (0·419,0·435) |
| L2 | 0·721 (0·716,0·725) | 0·857 (0·855,0·860) | 0·932 (0·930,0·934) | **0·939** (0·937,0·940) | 0·496 (0·488,0·503) |
| L3 | 0·697 (0·692,0·702) | **0·867** (0·865,0·869) | **0·938** (0·936,0·940) | 0·902 (0·899,0·905) | 0·521 (0·514,0·528) |
| L4 | 0·687 (0·682,0·692) | 0·812 (0·809,0·816) | 0·906 (0·903,0·909) | 0·931 (0·929,0·933) | **0·529** (0·522,0·536) |
| L5 | **0·768** (0·764,0·771) | 0·703 (0·698,0·708) | 0·893 (0·890,0·896) | 0·936 (0·934,0·938) | 0·234 (0·224,0·244) |

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| --- | --- | --- | --- | --- | --- |
| **BMI 25 – 29·9** | | | | | |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·467 (0·458,0·475) | NA | 0·734 (0·726,0·741) | 0·828 (0·822,0·833) | 0·432 (0·423,0·441) |
| T2 | 0·556 (0·548,0·563) | NA | 0·867 (0·863,0·871) | 0·813 (0·807,0·819) | 0·494 (0·486,0·503) |
| T3 | 0·593 (0·586,0·599) | NA | 0·882 (0·878,0·886) | 0·867 (0·863,0·871) | 0·491 (0·483,0·499) |
| T4 | 0·645 (0·639,0·650) | NA | 0·911 (0·909,0·914) | 0·886 (0·882,0·889) | 0·434 (0·425,0·443) |
| T5 | 0·654 (0·648,0·659) | NA | 0·886 (0·883,0·890) | 0·875 (0·871,0·879) | 0·348 (0·339,0·358) |
| T6 | 0·659 (0·654,0·665) | NA | 0·899 (0·896,0·902) | 0·904 (0·901,0·907) | 0·282 (0·272,0·292) |
| T7 | 0·661 (0·656,0·667) | NA | 0·924 (0·921,0·926) | 0·913 (0·910,0·915) | 0·265 (0·255,0·275) |
| T8 | 0·686 (0·681,0·691) | NA | 0·928 (0·926,0·931) | 0·919 (0·916,0·921) | 0·274 (0·263,0·284) |
| T9 | 0·701 (0·696,0·706) | NA | 0·927 (0·924,0·929) | 0·926 (0·924,0·929) | 0·310 (0·300,0·320) |
| T10 | 0·709 (0·704,0·714) | NA | 0·928 (0·926,0·931) | 0·927 (0·925,0·930) | 0·360 (0·350,0·369) |
| T11 | 0·687 (0·681,0·692) | 0·617 (0·610,0·623) | 0·927 (0·925,0·929) | 0·910 (0·907,0·913) | 0·398 (0·389,0·407) |
| T12 | 0·688 (0·683,0·694) | 0·760 (0·756,0·764) | 0·913 (0·910,0·916) | 0·918 (0·915,0·920) | 0·414 (0·405,0·423) |
| L1 | 0·719 (0·714,0·724) | 0·783 (0·779,0·787) | 0·929 (0·926,0·931) | 0·936 (0·934,0·938) | 0·462 (0·453,0·470) |
| L2 | 0·742 (0·738,0·747) | 0·841 (0·838,0·843) | **0·940** (0·938,0·942) | 0·934 (0·932,0·936) | 0·538 (0·530,0·545) |
| L3 | 0·720 (0·715,0·724) | **0·851** (0·848,0·854) | 0·938 (0·936,0·940) | 0·893 (0·890,0·897) | **0·555** (0·547,0·562) |
| L4 | 0·714 (0·709,0·719) | 0·778 (0·774,0·782) | 0·912 (0·909,0·914) | 0·924 (0·922,0·926) | 0·553 (0·546,0·560) |
| L5 | **0·770** (0·767,0·774) | 0·642 (0·636,0·649) | 0·902 (0·899,0·905) | **0·937** (0·934,0·939) | 0·235 (0·224,0·246) |

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| --- | --- | --- | --- | --- | --- |
| **BMI ≥ 30** | | | | | |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·491 (0·477,0·504) | NA | 0·781 (0·771,0·792) | 0·776 (0·765,0·787) | 0·463 (0·449,0·477) |
| T2 | 0·578 (0·567,0·589) | NA | 0·878 (0·872,0·884) | 0·793 (0·783,0·802) | 0·527 (0·515,0·539) |
| T3 | 0·619 (0·609,0·629) | NA | 0·887 (0·881,0·893) | 0·835 (0·827,0·843) | 0·548 (0·537,0·560) |
| T4 | 0·646 (0·636,0·656) | NA | 0·907 (0·903,0·912) | 0·850 (0·843,0·857) | 0·503 (0·491,0·516) |
| T5 | 0·653 (0·643,0·662) | NA | 0·866 (0·859,0·872) | 0·848 (0·840,0·855) | 0·437 (0·423,0·451) |
| T6 | 0·668 (0·658,0·677) | NA | 0·901 (0·896,0·906) | 0·867 (0·860,0·873) | 0·382 (0·367,0·397) |
| T7 | 0·677 (0·667,0·686) | NA | 0·923 (0·919,0·927) | 0·879 (0·872,0·884) | 0·352 (0·336,0·367) |
| T8 | 0·681 (0·671,0·690) | NA | 0·924 (0·920,0·927) | 0·898 (0·892,0·903) | 0·347 (0·331,0·363) |
| T9 | 0·686 (0·677,0·695) | NA | 0·919 (0·915,0·923) | 0·912 (0·907,0·916) | 0·355 (0·340,0·370) |
| T10 | 0·695 (0·686,0·704) | NA | 0·919 (0·915,0·923) | 0·918 (0·913,0·922) | 0·383 (0·368,0·398) |
| T11 | 0·688 (0·679,0·697) | 0·535 (0·523,0·546) | 0·919 (0·915,0·923) | 0·903 (0·898,0·908) | 0·428 (0·414,0·443) |
| T12 | 0·731 (0·723,0·739) | 0·698 (0·690,0·707) | 0·913 (0·908,0·917) | 0·917 (0·913,0·921) | 0·450 (0·436,0·464) |
| L1 | 0·755 (0·748,0·762) | 0·733 (0·725,0·740) | 0·931 (0·928,0·935) | **0·926** (0·922,0·930) | 0·490 (0·476,0·503) |
| L2 | **0·773** (0·766,0·779) | 0·815 (0·810,0·821) | **0·933** (0·930,0·937) | 0·917 (0·913,0·921) | **0·572** (0·560,0·583) |
| L3 | 0·763 (0·756,0·769) | **0·841** (0·836,0·845) | 0·931 (0·927,0·935) | 0·881 (0·875,0·887) | 0·569 (0·558,0·581) |
| L4 | 0·760 (0·753,0·767) | 0·784 (0·777,0·790) | 0·902 (0·897,0·907) | 0·906 (0·901,0·911) | 0·571 (0·560,0·583) |
| L5 | 0·767 (0·760,0·774) | 0·659 (0·650,0·669) | 0·904 (0·899,0·909) | 0·922 (0·918,0·926) | 0·189 (0·171,0·206) |

**Supplemental Table 5 |** BMI-stratified correlations between volumetric whole-body and single-slice area body composition measures in the UKBB for each vertebral body height. VAT is only present in the abdominal cavity (T11-L5).

All correlation coefficients are p < 0·0001. Bold indicates highest coefficient.

IMAT, intramuscular adipose tissue. L, lumbar vertebra. NA, not available. SAT, subcutaneous adipose tissue. SM, skeletal muscle. SMFF, skeletal muscle fat fraction. T, thoracic vertebra. UKBB, UK Biobank. VAT, visceral adipose tissue.

### Supplemental Table 6: Correlation between volumetric whole-body and single-slice area body composition measures stratified by sex and BMI – UKBB

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Female & BMI < 18·5**  **(n=356)** | | **Male & BMI < 18·5**  **(n=49)** | |
| **Measure** | **Vertebra** | **Correlation Coefficient** | **Vertebra** | **Correlation Coefficient** |
| SAT | L5 | 0·725 (0·693,0·757) | L3 | 0·782 (0·703,0·862) |
| VAT | L3 | 0·803 (0·781,0·826) | L1  L2 | 0·777 (0·665,0·890)  0·777 (0·653,0·901) |
| SM | L3 | 0·790 (0·747,0·826) | L3 | 0·743 (0·584,0·847) |
| SMFF | L2 | 0·925 (0·909,0·939) | L2 | 0·953 (0·918,0·974) |
| IMAT | L4 | 0·554 (0·506,0·603) | L4 | 0·609 (0·497,0·721) |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Female & BMI 18·5-24·9**  **(n=9801)** | | **Male & BMI 18·5-24·9**  **(n=6842)** | |
| **Measure** | **Vertebra** | **Correlation Coefficient** | **Vertebra** | **Correlation Coefficient** |
| SAT | L4 | 0·722 (0·716,0·728) | L1 | 0·748 (0·742,0·755) |
| VAT | L3 | 0·838 (0·834,0·841) | L2 | 0·855 (0·851,0·859) |
| SM | L3 | 0·803 (0·796,0·810) | L3 | 0·816 (0·808,0·824) |
| SMFF | L2 | 0·930 (0·927,0·933) | L2 | 0·936 (0·933,0·938) |
| IMAT | L3 | 0·563 (0·554,0·571) | L4 | 0·536 (0·525,0·547) |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Female & BMI 25-29·9**  **(n=5862)** | | **Male & BMI 25-29·9**  **(n=7957)** | |
| **Measure** | **Vertebra** | **Correlation Coefficient** | **Vertebra** | **Correlation Coefficient** |
| SAT | L3 | 0·645 (0·636,0·655) | L5 | 0·700 (0·693,0·707) |
| VAT | L3 | 0·806 (0·800,0·811) | L3 | 0·801 (0·797,0·806) |
| SM | L2 | 0·783 (0·773,0·793) | L3 | 0·815 (0·807,0·822) |
| SMFF | L2 | 0·915 (0·911,0·919) | L1 | 0·930 (0·927,0·933) |
| IMAT | L3 | 0·603 (0·593,0·614) | L4 | 0·570 (0·560,0·579) |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Female & BMI ≥ 30**  **(n=2758)** | | **Male & BMI ≥ 30**  **(n=2692)** | |
| **Measure** | **Vertebra** | **Correlation Coefficient** | **Vertebra** | **Correlation Coefficient** |
| SAT | L4 | 0·708 (0·696,0·720) | L1/L2 | 0·736 (0·724,0·747) |
| VAT | L3 | 0·785 (0·776,0·794) | L3 | 0·765 (0·755,0·774) |
| SM | L2 | 0·808 (0·794,0·820) | L3 | 0·805 (0·791,0·818) |
| SMFF | L5 | 0·903 (0·895,0·909) | L1 | 0·931 (0·926,0·936) |
| IMAT | L3 | 0·599 (0·584,0·615) | L4 | 0·593 (0·577,0·609) |

**Supplemental Table 6 |** Vertebral levels with the highest correlation coefficients between volumetric whole-body and single-slice area body composition measures in the UKBB stratified by sex & BMI.  
All correlation coefficients are p < 0·0001.

IMAT, intramuscular adipose tissue. L, lumbar vertebra. SAT, subcutaneous adipose tissue. SM, skeletal muscle. SMFF, skeletal muscle fat fraction. T, thoracic vertebra. UKBB, UK Biobank. VAT, visceral adipose tissue.

### Supplemental Table 7: Correlation between volumetric whole-body and single-slice area body composition measures stratified by sex – NAKO

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | **Female** | |  | |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·718 (0·712,0·723) | NA | 0·656 (0·645,0·666) | 0·890 (0·886,0·894) | 0·386 (0·375,0·397) |
| T2 | 0·726 (0·720,0·731) | NA | 0·762 (0·753,0·769) | 0·855 (0·850,0·860) | 0·492 (0·482,0·501) |
| T3 | 0·729 (0·723,0·734) | NA | 0·750 (0·742,0·758) | 0·928 (0·925,0·931) | 0·506 (0·497,0·516) |
| T4 | 0·740 (0·735,0·746) | NA | 0·758 (0·750,0·766) | 0·931 (0·928,0·933) | 0·480 (0·470,0·490) |
| T5 | 0·744 (0·739,0·749) | NA | 0·600 (0·588,0·612) | 0·912 (0·909,0·915) | 0·425 (0·415,0·436) |
| T6 | 0·755 (0·750,0·760) | NA | 0·615 (0·603,0·626) | 0·920 (0·917,0·923) | 0·334 (0·322,0·345) |
| T7 | 0·757 (0·752,0·762) | NA | 0·700 (0·690,0·710) | 0·925 (0·922,0·928) | 0·269 (0·258,0·281) |
| T8 | 0·758 (0·753,0·762) | NA | 0·729 (0·720,0·738) | 0·935 (0·933,0·938) | 0·245 (0·233,0·257) |
| T9 | 0·757 (0·752,0·762) | NA | 0·734 (0·725,0·742) | 0·940 (0·938,0·942) | 0·222 (0·211,0·234) |
| T10 | 0·758 (0·753,0·763) | NA | 0·722 (0·713,0·731) | 0·943 (0·941,0·945) | 0·268 (0·257,0·280) |
| T11 | 0·739 (0·734,0·745) | 0·772 (0·768,0·776) | 0·781 (0·773,0·788) | 0·934 (0·931,0·936) | 0·362 (0·351,0·373) |
| T12 | 0·792 (0·788,0·797) | 0·817 (0·813,0·820) | 0·760 (0·752,0·768) | 0·942 (0·940,0·944) | 0·423 (0·413,0·433) |
| L1 | 0·806 (0·802,0·810) | 0·842 (0·839,0·845) | 0·772 (0·764,0·779) | **0·949** (0·947,0·951) | 0·462 (0·452,0·472) |
| L2 | 0·824 (0·820,0·828) | **0·875** (0·873,0·877) | 0·807 (0·801,0·814) | 0·948 (0·946,0·950) | 0·528 (0·519,0·537) |
| L3 | 0·834 (0·831,0·838) | 0·854 (0·851,0·857) | **0·844** (0·838,0·849) | 0·913 (0·910,0·916) | **0·577** (0·569,0·585) |
| L4 | 0·835 (0·831,0·838) | 0·813 (0·809,0·816) | 0·822 (0·816,0·828) | 0·924 (0·921,0·926) | 0·578 (0·570,0·587) |
| L5 | **0·855** (0·852,0·858) | 0·298 (0·289,0·307) | 0·787 (0·780,0·794) | 0·936 (0·934,0·938) | 0·316 (0·305,0·328) |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | **Male** | |  | |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·628 (0·621,0·634) | NA | 0·652 (0·642,0·662) | 0·814 (0·808,0·819) | 0·402 (0·393,0·412) |
| T2 | 0·658 (0·652,0·665) | NA | 0·742 (0·735,0·750) | 0·857 (0·853,0·862) | 0·528 (0·520,0·536) |
| T3 | 0·702 (0·696,0·707) | NA | 0·749 (0·742,0·757) | 0·914 (0·911,0·917) | 0·541 (0·533,0·549) |
| T4 | 0·728 (0·723,0·733) | NA | 0·777 (0·770,0·784) | 0·921 (0·918,0·923) | 0·504 (0·496,0·513) |
| T5 | 0·730 (0·725,0·735) | NA | 0·678 (0·669,0·688) | 0·919 (0·916,0·922) | 0·435 (0·426,0·444) |
| T6 | 0·755 (0·751,0·760) | NA | 0·668 (0·659,0·678) | 0·928 (0·925,0·930) | 0·335 (0·325,0·346) |
| T7 | 0·769 (0·765,0·774) | NA | 0·723 (0·715,0·731) | 0·930 (0·928,0·933) | 0·286 (0·275,0·296) |
| T8 | 0·782 (0·777,0·786) | NA | 0·739 (0·731,0·747) | 0·937 (0·935,0·939) | 0·275 (0·264,0·285) |
| T9 | 0·790 (0·786,0·794) | NA | 0·736 (0·728,0·744) | 0·940 (0·938,0·942) | 0·269 (0·259,0·279) |
| T10 | 0·793 (0·789,0·797) | NA | 0·739 (0·731,0·747) | 0·942 (0·940,0·943) | 0·325 (0·315,0·335) |
| T11 | 0·798 (0·794,0·802) | 0·749 (0·744,0·753) | 0·804 (0·797,0·810) | 0·936 (0·934,0·938) | 0·405 (0·396,0·414) |
| T12 | 0·813 (0·809,0·817) | 0·783 (0·778,0·787) | 0·755 (0·748,0·763) | 0·933 (0·931,0·936) | 0·443 (0·434,0·452) |
| L1 | 0·823 (0·820,0·827) | 0·834 (0·831,0·837) | 0·778 (0·771,0·784) | **0·945** (0·943,0·947) | 0·448 (0·439,0·457) |
| L2 | 0·825 (0·822,0·829) | **0·860** (0·858,0·863) | 0·827 (0·821,0·832) | 0·936 (0·934,0·938) | 0·500 (0·492,0·509) |
| L3 | 0·811 (0·807,0·815) | 0·797 (0·793,0·801) | **0·846** (0·841,0·851) | 0·885 (0·882,0·889) | 0·517 (0·508,0·525) |
| L4 | 0·813 (0·809,0·816) | 0·777 (0·773,0·782) | 0·800 (0·793,0·806) | 0·906 (0·903,0·909) | **0·555** (0·548,0·563) |
| L5 | **0·841** (0·838,0·844) | 0·325 (0·317,0·334) | 0·785 (0·778,0·791) | 0·938 (0·936,0·940) | 0·383 (0·373,0·393) |

**Supplemental Table 7 |** Sex-stratified correlations between volumetric whole-body and single-slice area body composition measures in the NAKO for each vertebral body height. VAT is only present in the abdominal cavity (T11-L5).

All correlation coefficients are p < 0·0001. Bold indicates highest coefficient.

IMAT, intramuscular adipose tissue. NA, not available. SAT, subcutaneous adipose tissue. SM, skeletal muscle; VAT, visceral adipose tissue.

### Supplemental Table 8: Correlation between volumetric whole-body and single-slice area body composition measures stratified by BMI – NAKO

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | **BMI < 18·5** | |  | |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·446 (0·341,0·552) | 0·057 (0·029,0·084) | 0·565 (0·428,0·677) | 0·892 (0·848,0·924) | 0·370 (0·264,0·476) |
| T2 | 0·516 (0·427,0·606) | 0·125 (0·005,0·245) | 0·763 (0·675,0·829) | 0·828 (0·761,0·878) | 0·456 (0·364,0·549) |
| T3 | 0·540 (0·459,0·621) | 0·555 (0·468,0·641) | 0·806 (0·731,0·861) | 0·900 (0·859,0·929) | 0·449 (0·362,0·536) |
| T4 | 0·559 (0·480,0·638) | 0·629 (0·548,0·711) | 0·819 (0·749,0·871) | 0·916 (0·881,0·941) | 0·433 (0·336,0·530) |
| T5 | 0·602 (0·529,0·674) | 0·752 (0·702,0·801) | 0·805 (0·731,0·861) | 0·903 (0·863,0·932) | 0·404 (0·306,0·502) |
| T6 | 0·623 (0·556,0·690) | 0·772 (0·725,0·819) | 0·806 (0·732,0·862) | 0·904 (0·865,0·932) | 0·389 (0·289,0·489) |
| T7 | 0·631 (0·567,0·695) | 0·784 (0·739,0·830) | 0·839 (0·776,0·886) | 0·908 (0·869,0·935) | 0·406 (0·309,0·503) |
| T8 | 0·634 (0·566,0·702) | 0·682 (0·620,0·743) | 0·835 (0·770,0·882) | 0·922 (0·889,0·945) | 0·356 (0·251,0·461) |
| T9 | 0·608 (0·536,0·680) | 0·057 (0·029,0·084) | 0·797 (0·720,0·855) | 0·910 (0·873,0·937) | 0·431 (0·336,0·526) |
| T10 | 0·603 (0·532,0·674) | 0·125 (0·005,0·245) | 0·762 (0·674,0·828) | 0·904 (0·864,0·932) | 0·454 (0·366,0·542) |
| T11 | 0·574 (0·497,0·650) | 0·555 (0·468,0·641) | 0·796 (0·718,0·854) | 0·891 (0·846,0·923) | 0·420 (0·325,0·515) |
| T12 | 0·563 (0·481,0·645) | 0·629 (0·548,0·711) | 0·771 (0·686,0·835) | 0·863 (0·808,0·903) | 0·452 (0·368,0·535) |
| L1 | 0·587 (0·510,0·663) | 0·752 (0·702,0·801) | 0·751 (0·660,0·820) | 0·884 (0·837,0·918) | 0·433 (0·340,0·527) |
| L2 | 0·582 (0·508,0·656) | 0·772 (0·725,0·819) | 0·838 (0·775,0·885) | 0·913 (0·877,0·939) | 0·495 (0·405,0·586) |
| L3 | 0·652 (0·591,0·714) | **0·784** (0·739,0·830) | **0·869** (0·816,0·907) | 0·920 (0·886,0·944) | 0·544 (0·449,0·639) |
| L4 | 0·638 (0·569,0·708) | 0·682 (0·620,0·743) | 0·847 (0·787,0·892) | **0·926** (0·895,0·948) | **0·626** (0·550,0·702) |
| L5 | **0·736** (0·683,0·789) | 0·057 (0·029,0·084) | 0·844 (0·783,0·889) | 0·911 (0·874,0·938) | 0·147 (0·022,0·273) |

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| --- | --- | --- | --- | --- | --- |
|  | | **BMI 18·5-24·9** | |  | |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·498 (0·488,0·508) | NA | 0·791 (0·783,0·799) | 0·886 (0·881,0·890) | 0·270 (0·257,0·283) |
| T2 | 0·609 (0·600,0·617) | NA | 0·886 (0·882,0·891) | 0·869 (0·864,0·874) | 0·390 (0·378,0·401) |
| T3 | 0·634 (0·626,0·641) | NA | 0·894 (0·890,0·898) | 0·918 (0·914,0·921) | 0·427 (0·416,0·439) |
| T4 | 0·675 (0·668,0·682) | NA | 0·913 (0·909,0·916) | 0·927 (0·924,0·930) | 0·397 (0·386,0·409) |
| T5 | 0·680 (0·673,0·687) | NA | 0·916 (0·913,0·919) | 0·909 (0·905,0·912) | 0·346 (0·334,0·358) |
| T6 | 0·664 (0·657,0·671) | NA | 0·913 (0·909,0·916) | 0·913 (0·910,0·917) | 0·294 (0·282,0·307) |
| T7 | 0·655 (0·648,0·662) | NA | 0·925 (0·922,0·928) | 0·908 (0·904,0·912) | 0·272 (0·259,0·284) |
| T8 | 0·670 (0·663,0·677) | NA | 0·929 (0·926,0·932) | 0·919 (0·915,0·922) | 0·275 (0·263,0·288) |
| T9 | 0·673 (0·665,0·680) | NA | 0·930 (0·927,0·932) | 0·928 (0·925,0·931) | 0·291 (0·278,0·304) |
| T10 | 0·676 (0·669,0·683) | NA | 0·928 (0·925,0·930) | **0·933** (0·930,0·935) | 0·329 (0·317,0·342) |
| T11 | 0·652 (0·645,0·660) | 0·752 (0·746,0·757) | 0·927 (0·924,0·930) | 0·917 (0·914,0·920) | 0·373 (0·361,0·384) |
| T12 | 0·627 (0·620,0·635) | 0·812 (0·808,0·816) | 0·906 (0·902,0·910) | 0·903 (0·899,0·907) | 0·422 (0·411,0·433) |
| L1 | 0·657 (0·650,0·665) | 0·841 (0·838,0·844) | 0·907 (0·903,0·911) | 0·916 (0·912,0·919) | 0·442 (0·431,0·453) |
| L2 | 0·695 (0·689,0·702) | **0·864** (0·861,0·867) | 0·935 (0·932,0·937) | 0·923 (0·919,0·926) | 0·481 (0·471,0·491) |
| L3 | 0·691 (0·684,0·697) | 0·820 (0·816,0·824) | **0·946** (0·944,0·948) | 0·885 (0·881,0·890) | 0·540 (0·530,0·550) |
| L4 | 0·689 (0·682,0·695) | 0·747 (0·742,0·752) | 0·923 (0·920,0·926) | 0·906 (0·902,0·910) | **0·578** (0·569,0·587) |
| L5 | **0·804** (0·800,0·808) | 0·185 (0·177,0·192) | 0·928 (0·925,0·931) | 0·916 (0·912,0·919) | 0·341 (0·328,0·353) |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **BMI 25-29·9** | | | | | |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·488 (0·479,0·498) | NA | 0·786 (0·779,0·794) | 0·851 (0·845,0·856) | 0·365 (0·354,0·376) |
| T2 | 0·566 (0·558,0·574) | NA | 0·881 (0·876,0·885) | 0·848 (0·842,0·853) | 0·485 (0·476,0·495) |
| T3 | 0·595 (0·588,0·603) | NA | 0·882 (0·878,0·886) | 0·903 (0·899,0·907) | 0·510 (0·501,0·520) |
| T4 | 0·639 (0·632,0·646) | NA | 0·908 (0·904,0·911) | 0·914 (0·910,0·917) | 0·478 (0·468,0·488) |
| T5 | 0·630 (0·623,0·637) | NA | 0·900 (0·896,0·904) | 0·893 (0·889,0·897) | 0·414 (0·403,0·425) |
| T6 | 0·626 (0·618,0·633) | NA | 0·905 (0·901,0·908) | 0·898 (0·894,0·901) | 0·335 (0·323,0·347) |
| T7 | 0·645 (0·638,0·653) | NA | 0·921 (0·918,0·924) | 0·897 (0·893,0·901) | 0·305 (0·293,0·317) |
| T8 | 0·672 (0·665,0·678) | NA | 0·922 (0·919,0·925) | 0·914 (0·911,0·918) | 0·300 (0·288,0·312) |
| T9 | 0·681 (0·675,0·688) | NA | 0·918 (0·915,0·921) | 0·923 (0·920,0·926) | 0·296 (0·285,0·308) |
| T10 | 0·688 (0·681,0·694) | NA | 0·914 (0·910,0·917) | **0·929** (0·926,0·932) | 0·334 (0·323,0·346) |
| T11 | 0·672 (0·665,0·679) | 0·753 (0·748,0·758) | 0·918 (0·915,0·921) | 0·903 (0·899,0·906) | 0·392 (0·382,0·403) |
| T12 | 0·680 (0·673,0·687) | 0·790 (0·785,0·794) | 0·894 (0·890,0·898) | 0·906 (0·902,0·909) | 0·436 (0·426,0·447) |
| L1 | 0·702 (0·695,0·708) | 0·828 (0·824,0·831) | 0·910 (0·906,0·913) | 0·921 (0·918,0·924) | 0·458 (0·448,0·468) |
| L2 | 0·731 (0·725,0·737) | **0·848** (0·845,0·851) | 0·932 (0·930,0·935) | 0·927 (0·924,0·930) | 0·521 (0·511,0·530) |
| L3 | 0·716 (0·710,0·722) | 0·761 (0·756,0·766) | **0·941** (0·938,0·943) | 0·879 (0·874,0·883) | 0·540 (0·531,0·550) |
| L4 | 0·689 (0·683,0·696) | 0·695 (0·689,0·702) | 0·915 (0·912,0·918) | 0·904 (0·900,0·907) | **0·569** (0·561,0·578) |
| L5 | **0·791** (0·787,0·796) | 0·221 (0·210,0·232) | 0·914 (0·910,0·917) | 0·913 (0·910,0·917) | 0·383 (0·372,0·394) |

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| --- | --- | --- | --- | --- | --- |
|  | | **BMI ≥ 30** | |  | |
| **Vertebra** | **SAT** | **VAT** | **SM** | **SMFF** | **IMAT** |
| T1 | 0·545 (0·534,0·556) | NA | 0·832 (0·824,0·840) | 0·787 (0·776,0·797) | 0·468 (0·454,0·481) |
| T2 | 0·585 (0·574,0·595) | NA | 0·892 (0·887,0·898) | 0·832 (0·824,0·841) | 0·561 (0·549,0·572) |
| T3 | 0·614 (0·604,0·624) | NA | 0·886 (0·881,0·892) | 0·884 (0·878,0·890) | 0·567 (0·555,0·579) |
| T4 | 0·629 (0·619,0·639) | NA | 0·916 (0·911,0·920) | 0·889 (0·884,0·895) | 0·543 (0·531,0·555) |
| T5 | 0·616 (0·606,0·626) | NA | 0·884 (0·878,0·889) | 0·877 (0·871,0·883) | 0·500 (0·487,0·513) |
| T6 | 0·639 (0·630,0·649) | NA | 0·908 (0·903,0·913) | 0·877 (0·871,0·883) | 0·458 (0·444,0·472) |
| T7 | 0·669 (0·660,0·678) | NA | 0·927 (0·924,0·931) | 0·889 (0·884,0·895) | 0·436 (0·422,0·451) |
| T8 | 0·685 (0·677,0·694) | NA | 0·927 (0·923,0·931) | 0·906 (0·902,0·911) | 0·419 (0·404,0·433) |
| T9 | 0·696 (0·688,0·704) | NA | 0·916 (0·912,0·921) | 0·915 (0·910,0·919) | 0·406 (0·392,0·421) |
| T10 | 0·703 (0·695,0·711) | NA | 0·913 (0·909,0·918) | **0·922** (0·918,0·926) | 0·414 (0·400,0·429) |
| T11 | 0·702 (0·693,0·710) | 0·694 (0·685,0·703) | 0·918 (0·913,0·922) | 0·892 (0·886,0·897) | 0·457 (0·443,0·471) |
| T12 | 0·744 (0·736,0·751) | 0·720 (0·712,0·728) | 0·913 (0·909,0·918) | 0·903 (0·898,0·908) | 0·474 (0·460,0·488) |
| L1 | 0·760 (0·754,0·767) | 0·768 (0·761,0·775) | 0·930 (0·926,0·934) | 0·909 (0·904,0·914) | 0·492 (0·479,0·505) |
| L2 | 0·781 (0·775,0·787) | **0·820** (0·815,0·825) | **0·935** (0·931,0·938) | 0·906 (0·901,0·910) | 0·562 (0·550,0·574) |
| L3 | 0·746 (0·739,0·754) | 0·742 (0·734,0·749) | 0·932 (0·929,0·936) | 0·879 (0·873,0·885) | 0·560 (0·548,0·572) |
| L4 | 0·730 (0·722,0·738) | 0·663 (0·653,0·673) | 0·898 (0·892,0·903) | 0·899 (0·894,0·904) | **0·566** (0·554,0·578) |
| L5 | **0·785** (0·778,0·791) | 0·190 (0·174,0·206) | 0·916 (0·912,0·920) | 0·904 (0·899,0·909) | 0·347 (0·330,0·363) |

**Supplemental Table 8 |** BMI-stratified correlations between volumetric whole-body and single-slice area body composition measures in the NAKO for each vertebral body height. VAT is only present in the abdominal cavity (T11-L5).

All correlation coefficients are p < 0·0001. Bold indicates highest coefficient.

IMAT, intramuscular adipose tissue. L, lumbar vertebra. NA, not available. NAKO, German National Cohort. SAT, subcutaneous adipose tissue. SM, skeletal muscle. SMFF, skeletal muscle fat fraction. T, thoracic vertebra. VAT, visceral adipose tissue.

### Supplemental Table 9: Correlation between volumetric whole-body and single-slice area body composition measures stratified by sex and BMI – NAKO

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Female & BMI < 18·5**  **(n=97)** | | **Male & BMI < 18·5**  **(n=21)** | |
| **Measure** | **Vertebra** | **Correlation Coefficient** | **Vertebra** | **Correlation Coefficient** |
| SAT | L3 | 0·710 (0·656,0·763) | L3 | 0·686 (0·472,0·899) |
| VAT | L3 | 0·779 (0·724,0·834) | L3 | 0·848 (0·737,0·958) |
| SM | L3 | 0·825 (0·749,0·880) | L2 | 0·891 (0·747,0·955) |
| SMFF | T8 | 0·932 (0·900,0·954) | L3 | 0·940 (0·855,0·976) |
| IMAT | L4 | 0·653 (0·578,0·728) | L4 | 0·648 (0·419,0·876) |

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| --- | --- | --- | --- | --- |
|  | **Female & BMI 18·5-24·9**  **(n=4978)** | | **Male & BMI 18·5-24·9**  **(n=3791)** | |
| **Measure** | **Vertebra** | **Correlation Coefficient** | **Vertebra** | **Correlation Coefficient** |
| SAT | L5 | 0·764 (0·757,0·771) | L5 | 0·770 (0·762,0·778) |
| VAT | L2 | 0·823 (0·818,0·829) | L2 | 0·843 (0·838,0·848) |
| SM | L3 | 0·816 (0·807,0·825) | L3 | 0·821 (0·810,0·831) |
| SMFF | L2 | 0·934 (0·930,0·937) | L2 | 0·925 (0·920,0·929) |
| IMAT | L4 | 0·606 (0·595,0·617) | L4 | 0·549 (0·535,0·563) |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Female & BMI 25-29·9**  **(n=3289)** | | **Male & BMI 25-29·9**  **(n=6282)** | |
| **Measure** | **Vertebra** | **Correlation Coefficient** | **Vertebra** | **Correlation Coefficient** |
| SAT | L5 | 0·655 (0·642,0·667) | L5 | 0·741 (0·734,0·748) |
| VAT | L2 | 0·808 (0·801,0·815) | L2 | 0·802 (0·796,0·807) |
| SM | L3 | 0·815 (0·803,0·826) | L3 | 0·812 (0·803,0·820) |
| SMFF | L1 | 0·926 (0·921,0·931) | L1 | 0·935 (0·931,0·938) |
| IMAT | L4 | 0·587 (0·573,0·601) | L4 | 0·562 (0·551,0·573) |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Female & BMI ≥ 30**  **(n=2287)** | | **Male & BMI ≥ 30**  **(n=2980)** | |
| **Measure** | **Vertebra** | **Correlation Coefficient** | **Vertebra** | **Correlation Coefficient** |
| SAT | L5 | 0·718 (0·705,0·730) | L2 | 0·755 (0·745,0·765) |
| VAT | L2 | 0·776 (0·765,0·786) | L2 | 0·741 (0·731,0·752) |
| SM | L3 | 0·821 (0·807,0·834) | L3 | 0·790 (0·776,0·803) |
| SMFF | T12/L1 | 0·913 (0·906,0·919) | L5 | 0·912 (0·906,0·918) |
| IMAT | L3 | 0·592 (0·575,0·608) | L4 | 0·568 (0·553,0·584) |

**Supplemental Table 9 |** Vertebral levels with the highest correlation coefficients between volumetric whole-body and single-slice area body composition measures in the UKBB stratified by sex & BMI.  
All correlation coefficients are p < 0·0001.

IMAT, intramuscular adipose tissue. L, lumbar vertebra. SAT, subcutaneous adipose tissue. SM, skeletal muscle. SMFF, skeletal muscle fat fraction. T, thoracic vertebra. UKBB, UK Biobank. VAT, visceral adipose tissue.

### Supplemental Table 10: Mean Distance Error per Vertebral Body

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **NAKO**  **Testset** | | **UKBB**  **Testset** | |  |  | **Intervertebral**  **distances for reference** |  |
| **Vertebra** | **Mean Distance Error (mm)** | **SD**  **(mm)** | **Mean Distance Error (mm)** | **SD (mm)** |  | **Vertebral bodies** | **Mean Intervertebral Distance (mm)** | **Standard deviation (mm)** |
| T1 | -0·4 | 8·1 | 3·2 | 5·7 |  | T1-T2 | 16·1 | 2·1 |
| T2 | -0·2 | 8·2 | 3·9 | 5·7 |  | T2-T3 | 17·6 | 2·2 |
| T3 | -1·5 | 8·3 | 4·4 | 5·9 |  | T3-T4 | 19·0 | 1·9 |
| T4 | -2·1 | 7·6 | 4·5 | 6·7 |  | T4-T5 | 20·7 | 1·6 |
| T5 | -1·1 | 7·6 | 4·0 | 7·0 |  | T5-T6 | 22·1 | 1·8 |
| T6 | -1·9 | 7·6 | 3·0 | 8·0 |  | T6-T7 | 21·9 | 1·8 |
| T7 | -1·0 | 7·7 | 5·3 | 8·2 |  | T7-T8 | 23·6 | 1·8 |
| T8 | -2·6 | 7·6 | 5·2 | 8·7 |  | T8-T9 | 24·1 | 2·1 |
| T9 | -0·8 | 7·6 | 6·0 | 10·0 |  | T9-T10 | 27·0 | 2·2 |
| T10 | -1·0 | 7·0 | 4·0 | 9·0 |  | T10-T11 | 26·4 | 2·3 |
| T11 | -0·9 | 7·5 | 5·7 | 9·1 |  | T11-T12 | 31·1 | 2·4 |
| T12 | -2·2 | 6·5 | 2·5 | 9·8 |  | T12-L1 | 30·3 | 2·7 |
| L1 | -1·4 | 6·3 | 4·9 | 10·4 |  | L1-L2 | 34·1 | 2·6 |
| L2 | 0·3 | 5·2 | 3·2 | 9·3 |  | L2-L3 | 34·8 | 2·5 |
| L3 | 0·3 | 5·6 | 3·2 | 9·8 |  | L3-L4 | 35·4 | 2·7 |
| L4 | 0·7 | 6·0 | 4·1 | 9·4 |  | L4-L5 | 36·1 | 3·0 |
| L5 | 1·1 | 5·3 | 1·7 | 9·0 |  | NA | NA | NA |

**Supplemental Table 10 |** Mean distance error in the craniocaudal direction of the automatic 3D deep learning spine labelling model for each vertebra of the thoracic and lumbar spine (centre of the vertebral body). Mean and standard deviation are shown in millimetres. Mean intervertebral distances of the manually labelled UKBB training dataset, defined as the Euclidean distance in millimetres between the labels at the centre of each vertebral body.

## IV SUPPLEMENTAL FIGURES

### Supplemental Figure 1: Participant flowchart – UKBB



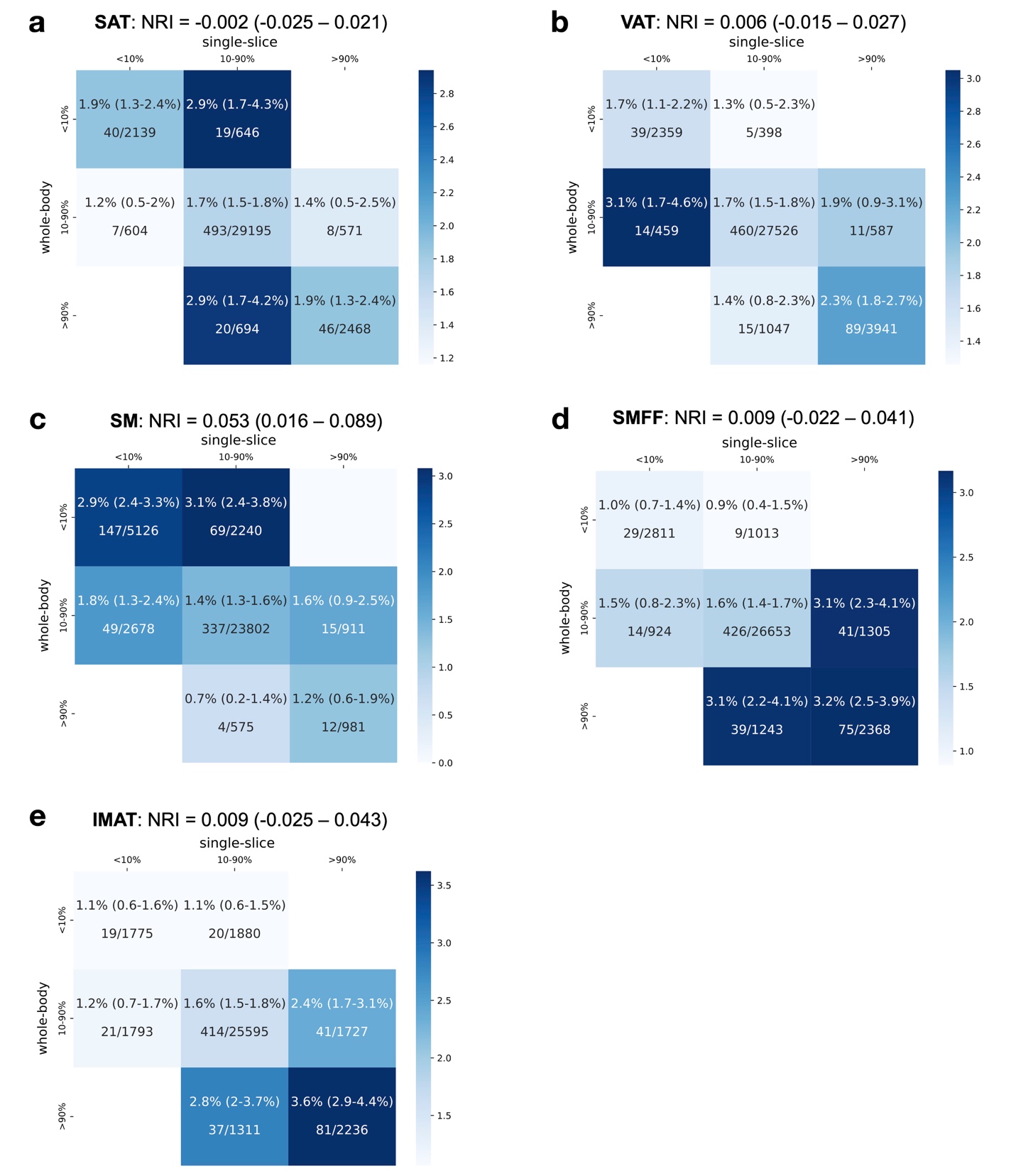
Body composition defined as subcutaneous adipose tissue, visceral adipose tissue, skeletal muscle, and intramuscular adipose tissue. HbA1c, Hemoglobin A1c. HDL, high-density lipoprotein. LDL, low-density lipoprotein. MRI, magnetic resonance imaging. NAKO, German National Cohort.

### Supplemental Figure 2: Participant flowchart – NAKO



Body composition defined as subcutaneous adipose tissue, visceral adipose tissue, skeletal muscle, and intramuscular adipose tissue. MRI, magnetic resonance imaging. NAKO, German National Cohort.

### Supplemental Figure 3: Confusion Matrices for Reclassification analysis of stratified single-slice area and volumetric whole-body composition measures

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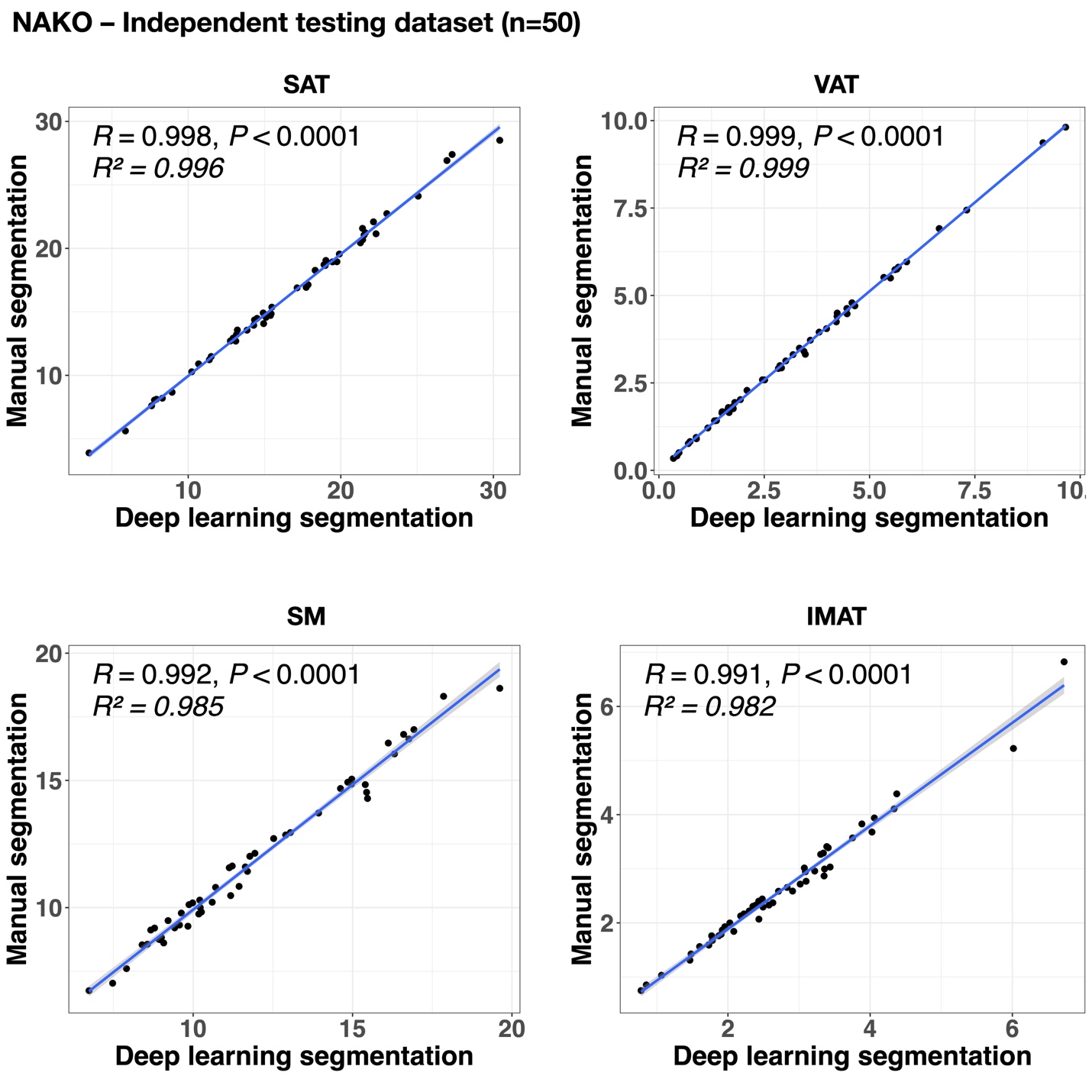
**Supplemental Figure 3 |** Confusion matrices for reclassification analysis of stratified body composition measures based on cutoff values derived from the NAKO (low: <10th percentile, middle: 10-90th percentile, and high: >10th percentile) show event rates and net reclassification indices of the primary endpoint all-cause mortality **(A-E)** for categories of SAT **(a)**, VAT **(b)**, SM **(c)**, SMFF **(d)**, and IMAT **(e)**.

Single-slice categories are shown as columns and volumetric measures as rows. Cells show event rates with 95% CI and event count/count per cell.

95% CI was estimated by using "n = count per cell" nonparametric bootstrap samples.

IMAT, intramuscular adipose tissue. SAT, subcutaneous adipose tissue. SM, skeletal muscle. SMFF, skeletal muscle fat fraction. VAT, visceral adipose tissue.

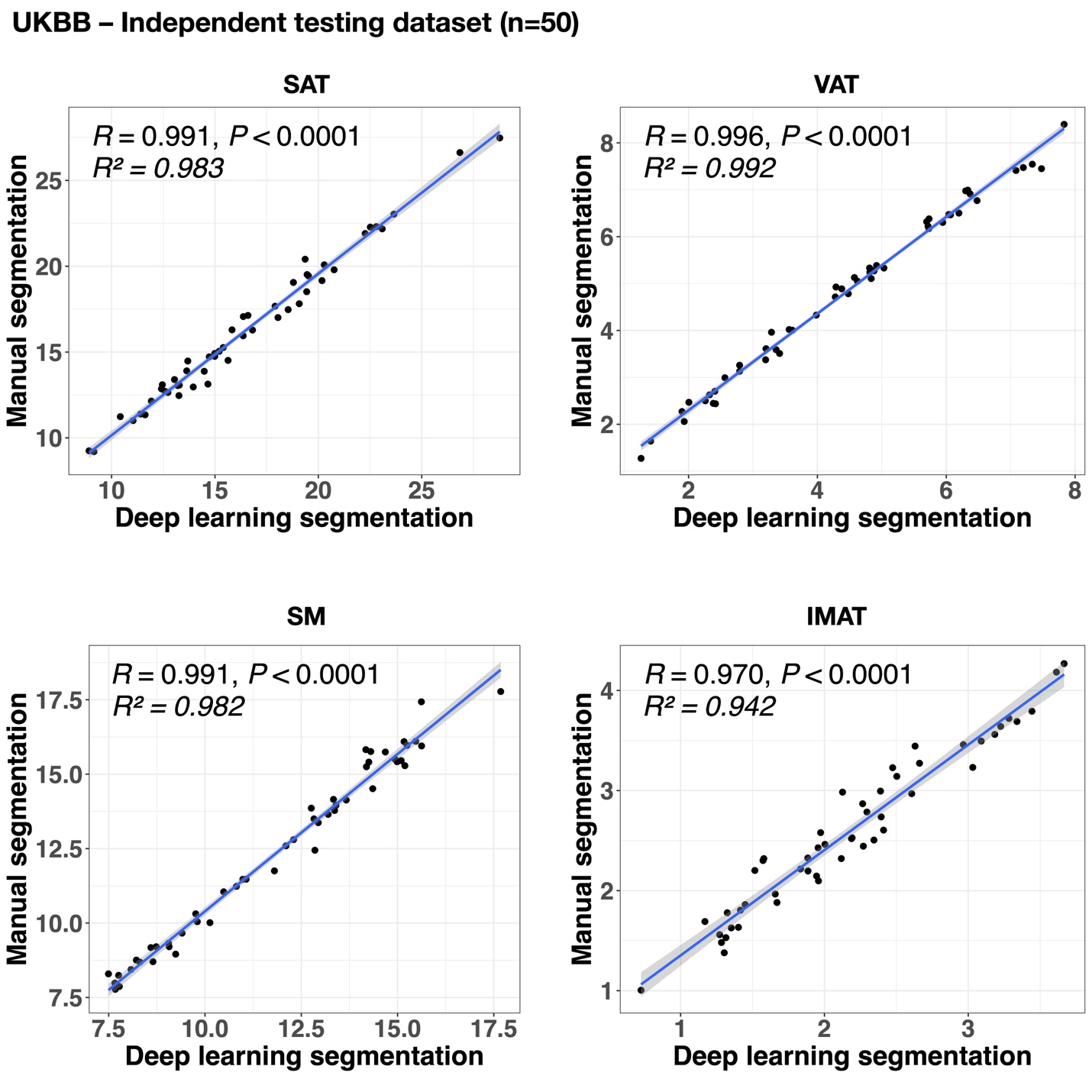
### Supplemental Figure 4: Correlation between manual and deep learning-based volumetric body composition segmentations – NAKO

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**Supplemental Figure 4 |** Correlation between manual and deep learning-based volumetric body composition segmentations in the independent internal testing dataset (n=50).

DL, deep learning. IMAT, intramuscular adipose tissue. NAKO, German National Cohort. SAT, subcutaneous adipose tissue. SM, skeletal muscle. VAT, visceral adipose tissue.

### Supplemental Figure 5: Correlation between manual and deep learning-based volumetric body composition segmentations – UKBB

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**Supplemental Figure 5 |** Correlation between manual and deep learning-based volumetric body composition segmentations in the independent external testing dataset (n=50).

DL, deep learning. IMAT, intramuscular adipose tissue. SAT, subcutaneous adipose tissue. SM, skeletal muscle. UKBB, UK biobank. VAT, visceral adipose tissue.

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