Central but not peripheral fat mass percentage is associated with blood pressure components in the elderly

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Abstract

Background: the human body composition changes with advances in age. Particularly, the central fat amount increases. Because the central fat mass is a cardiovascular risk factor, we investigated whether in an elderly population, fat mass (measured at different bodily locations) is associated with peripheral and central blood pressure components.

Methods: cross-sectional design. Using dual-energy X-ray absorptiometry (DEXA), fat mass was measured within a geriatric outpatient clinic population. Blood pressure was measured with an oscillometric device, and aortic blood pressure and augmentation index (AIx) were obtained by radial artery tonometry, using the SphygmoCor system. Multivariate adjustment for confounders was performed using linear regression analyses.

Results: totally, 216 subjects were included (age 77.3 years ± 6.1, 34.7% male). The truncal fat mass percentage, but not the peripheral fat mass percentage, was positively associated with the peripheral systolic blood pressure (SBP) [beta 0.07 (95% CI: 0.02 to 0.11)] and the peripheral pulse pressure (PP) [beta 0.07 (95% CI: 0.02 to 0.11)], but negatively with the peripheral diastolic blood pressure (DBP) [beta −0.16 (95% CI −0.27 to −0.04)]. The truncal fat mass percentage was similarly associated with estimated aortic blood pressure components, but no association was found between the truncal fat mass percentage and the AIx.

Conclusion: in older persons, the truncal fat mass percentage as a reflection of the central fat mass percentage, but not the peripheral fat mass percentage is associated with peripheral and aortic blood pressure components.

Keywords: fat mass, blood pressure components, aortic augmentation index, elderly

Introduction

Truncal obesity (particularly, visceral obesity) is independently associated with cardiovascular disease and mortality [1–3]. With ageing, the human body composition changes significantly [4]. In individuals aged less than 60 years, the total fat mass increases, resulting in a proportional decrease in fat-free mass. In individuals aged above 70 years, while total fat mass tends to decline, there is a proportional increase in abdominal adiposity and fat deposition in skeletal and cardiac muscles [4, 5]. As demonstrated in numerous studies, fat mass, especially in the visceral region, is associated with increased large artery stiffening [5–8]. Notably, large artery stiffening is a major determinant for the age-related rise in systolic blood pressure (SBP) and is associated with cardiovascular mortality [9–11].

Many methods are available for the assessment of body composition [12]. They can be divided into direct and indirect techniques. Direct techniques include underwater weight densitometry, neutron activation, computed tomography and magnetic resonance imaging [12]. These techniques give an accurate estimate of body composition and adipose tissue distribution, but are not user-friendly and are not routinely used in clinical practice. Indirect techniques such as
anthropometric measurements, ultrasound and bioelectric impedance are easier to use, but are less accurate. Nowadays, a popular measurement for body composition is dual-energy X-ray absorptiometry (DEXA) [13, 14]. This method has been reported to be accurate compared with the more traditional techniques described above [15–17]. Recently, DEXA is used often for the estimation of central fat, using the standard trunk region as a standard reference point. This region has been shown to be strongly associated with visceral fat [13, 18, 19].

The purpose of this study was to investigate possible associations between absolute and relative fat mass distribution, measured with DEXA at different body areas and blood pressure components in an elderly outpatient clinic population.

Methods

Study participants

The present study was conducted within the framework of a prospective cohort study in elderly subjects. A detailed description of this study cohort has been reported in a previous study [20]. To summarise that study, all new consecutive referrals to the geriatric outpatient clinic and the diagnostic day center of the Erasmus MC were included in a prospective cohort study investigating the effect of withdrawal of fall-risk-increasing drugs on fall-incidence. Subjects were considered to be eligible if they were aged 65 years or older, were able to walk 10 m without a walking aid and had a Mini-Mental State Examination score of at least 21 points out of 30 points. The medical ethics committee of the Erasmus MC approved the study protocol and written informed consent was obtained from all patients. Patient recruitment started in April 2003 and ended in November 2004. During the study period, data were collected from 217 participants. During the baseline examination, information on cardiovascular risk factors, blood pressure data and augmentation index (AIx) were collected and a DEXA scan was performed.

Blood pressure and heart rate measurements

Blood pressure was measured after 10 min of supine rest. Systolic and diastolic blood pressure levels (SBP and DBP) and mean arterial pressure (MAP) were measured on the left arm using an automatic oscillometric device with appropriate size cuffs. Pulse pressure (PP) was calculated as SBP – DBP. Pulse pressure amplification (PPA) was defined as the ratio between the peripheral PP and the central PP. The heart rate was measured with use of the automatic oscillometric blood pressure device.

Aortic augmentation index

The aortic AIx was derived from radial artery waveform measurements using the SphygmoCor device, version 7.01, and a general transfer function (AtCor Medical, Sydney, Australia). The accuracy and reliability of this method have been validated before [21, 22]. Aortic SBP and DBP and PP as well as augmentation pressure (AP), i.e. the portion of the aortic systolic pressure due to the early reflected wave, were computed. The AIx was calculated as AP divided by aortic PP times 100.

Measurements of body composition

Total body, hip and spine tissue masses were measured using a DEXA scan (Lunar, GE Healthcare, Waukesha, WI, USA). The analysis for determining body composition was performed using MatLab (version 7.1 MathWorks, Inc., MA, USA). The software calculates the parameters in a semi-automatic way. The tissue mass and percentages of fat, lean (fat-free) and bone mineral content at different locations were automatically computed with the MatLab software. In addition to the total body fat mass, the limbs (peripheral fat) and the trunk (central fat) fat mass were computed. The central fat mass percentage was calculated from the regional truncal fat divided by the total truncal tissue mass. In the same way, the peripheral fat percentage was calculated from the total tissue mass of the limbs. In addition, the central fat mass was also calculated as a percentage of total body fat mass.

Cardiovascular risk factors

Cardiovascular risk factors were obtained at the first visit during the baseline assessment. Height and weight were measured and the body mass index (BMI) was calculated as: weight divided by height$^2$ and expressed as kilogram per metre square. Smoking status was classified as current, past or never. Serum total cholesterol, low-density lipoprotein (LDL) cholesterol and high-density lipoprotein (HDL) cholesterol values were determined by an automatic enzymatic procedure (Boehringer Mannheim System). Diabetes mellitus was defined as a medical history of diabetes mellitus or the use of anti-diabetic medication. Hypertension was defined as a medical history of hypertension or an SBP >140 mmHg and/or a DBP >90 mmHg, according to the guidelines of the WHO. Hypercholesterolaemia was defined as a total cholesterol >6.6 mmol/l. Hypertriglyceridaemia was defined as >2.0 mmol/l.

Cardiovascular and anti-diabetic medication

Use of cardiovascular medication and anti-diabetic medication was defined using the World Health Organization’s Anatomical Therapeutic Chemical (ATC) classifications. The cardiovascular medication was divided subgroups per ATC classification the statistical analysis. Subgroups of cardiovascular medication used were anti-arrhythmics, diuretics, nitrates, beta-blockers, ACE-inhibitors, AT II antagonists, calcium channel blockers and alpha-blockers.
Statistical analysis

Associations between blood pressure components and different variables of fat mass were calculated. Variables of fat mass used in the statistical analysis included fat mass amount in the peripheral region and the truncal region and regional fat percentages. Besides, the truncal fat mass percentage was not only calculated as a percentage of total trunk mass, but also as a percentage of the total body fat mass. Next, the BMI was used in as a variable of body composition in the statistical analysis.

The association between fat mass amount, fat mass percentages and blood pressure components was investigated in multiple steps. The differences in means between men and women were tested using Student’s t-test for continuous variables. An univariate analysis with Pearson correlation coefficients for the continuous variables was performed and Spearman correlation coefficients for categorical variables. Next, the contribution of each variable was evaluated in a multivariate linear regression analysis, addressing the following potential confounders: age, gender, MAP, heart rate, BMI, total cholesterol, HDL cholesterol, LDL cholesterol, diabetes mellitus, smoking status, and use of anti-diabetic and type of cardiovascular medication. Ultimately, only those variables that contributed to a ≥10% change of the beta coefficient were included in the final model. Data are presented as mean ± SD for normally distributed data. Statistical analyses were carried out using the SPSS version 17.0 software package (SPSS, Inc., Chicago, Illinois, USA). A P-value < 0.05 was considered as statistically significant.

Results

In total, 216 participants were included in the analyses. Owing to missing values one participant had to be excluded. The baseline characteristics are given in Table 1. The mean age was 77.3 ± 6.1 years and 34.7% of the participants were male. The average BMI was 26.5 ± 4.3 kg/m². The mean peripheral SBP and DBP levels were 161.2 ± 30.6 and 86.2 ± 15.0 mmHg, respectively. At the time of measurement, 76.4% of our participants had hypertension and 45.8% used anti-hypertensive medication.

In the univariate model, significant correlations were found between regional truncal fat percentages and aortic SBP (r = 0.14), aortic and peripheral PP (r = 0.22 and r = 0.12) and AIx (r = 0.13), but blood pressure components were not associated with the total body fat mass, truncal fat mass or peripheral fat mass (g) or with regional peripheral fat percentage. The relation between truncal fat mass percentage and blood pressure components is shown in Figure 1. No significant associations were demonstrated using the truncal fat mass as a percentage of total body fat mass and blood pressure components in the univariate analysis.

The final multivariate linear regression model included age, gender, MAP, heart rate and BMI. Other covariates, such as diabetes, cholesterol, smoking and use of cardiovascular and anti-diabetic medication, which did not significantly change the results were therefore left out of the final model. In this multivariate model, the positive association between the regional truncal fat mass percentage and the peripheral SBP [beta 0.07 (95% CI: 0.02 to 0.11)] and the peripheral PP [beta 0.08 (95% CI: 0.02 to 0.14)] remained significant, whereas a negative association was present with the peripheral DBP [beta −0.16 (95% CI: −0.27 to −0.04)]. Absolute total body, truncal or peripheral fat mass (g) and blood pressure components were unrelated in the multivariate regression analysis (Table 2). Aortic SBP [beta 0.10 (95% CI: 0.03 to 0.17)], aortic PP [beta 0.08 (95% CI: 0.03 to 0.13)] and aortic DBP [beta −0.16 (95% CI: −0.28 to −0.05)] remained associated with the regional truncal fat mass percentage in the multivariate linear regression analysis (Table 2). AP was significantly associated with the truncal fat mass after adjustment for the BMI [beta 0.17 (95% CI: 0.03 to 0.26)]. The AIx showed no relation with either truncal or peripheral fat mass percentages after

<table>
<thead>
<tr>
<th>Table 1. Characteristics of the study population (n = 216)</th>
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<tbody>
<tr>
<td>Characteristics</td>
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<tr>
<td>Age (years)</td>
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<tr>
<td>Male gender (%)</td>
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<tr>
<td>BMI (kg/m²)</td>
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<tr>
<td>Total fat mass (g)</td>
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<tr>
<td>Truncal (central) fat mass (g)</td>
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<tr>
<td>Peripheral fat mass (g)</td>
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<td>Fat % of total body mass</td>
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<tr>
<td>Fat % of truncal (central) region</td>
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<tr>
<td>Fat % of peripheral region</td>
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<tr>
<td>SBP peripheral (mmHg)</td>
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<tr>
<td>DBP peripheral (mmHg)</td>
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<tr>
<td>Total cholesterol (mmol/l)</td>
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<tr>
<td>HDL cholesterol (mmol/l)</td>
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<tr>
<td>Triglycerides (mmol/l)</td>
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</table>

Values are expressed as mean ± SD, except for age that is expressed as a mean (range), BMI (range), male gender, medical history and the presence of disease and the use of cardiovascular medication (number and percentage). BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; PP, pulse pressure; PPA, pulse pressure amplification, AIx, augmentation index; MAP, mean arterial pressure; HR, heart rate; LDL, low-density lipoprotein; HDL, high-density lipoprotein.

*Glucose was measured in non-fasting state.
multivariable adjustment. Also no association was found between BMI and aortic or peripheral blood pressure components (Table 2).

We have also performed an analysis categorised per BMI subgroup (<20; 20–25; 25–30; >30). The positive association between regional truncal fat mass percentage and SBP and PP and a negative association with DBP, both central and peripheral, are strongest in subjects with a normal BMI (20–25) [respectively, beta 0.58 (95% CI: 0.17 to 0.99), beta 0.95 (95% CI: 0.38 to 1.51) and beta −0.37 (95% CI: −0.60 to −0.14)].

We also analysed the association between the different blood pressure components and truncal fat as a percentage of total body fat mass. Where the univariate analysis showed no associations, the multivariate analysis demonstrated comparable results as described for the regional truncal fat mass percentage: Aortic PP was positively [beta 0.07 (95% CI: 0.00 to 0.15)] and aortic DBP was negatively associated [beta −0.17 (95% CI: −0.35 to 0.00)] with the proportion of truncal fat of total body fat mass. However, aortic SBP did not remain significant [beta 0.09 (95% CI: −0.02 to 0.20)].

**Discussion**

In this study, performed in old ambulatory persons, we found that truncal fat as a percentage of truncal mass was associated with both peripheral and central SBP, DBP and PP. SBP and PP were positively and DBP was negatively associated with the relative amount of the truncal fat mass. Also when the truncal fat mass was expressed as a percentage of total body fat mass an association with aortic PP and aortic DBP was present.

Since an increase in PP in most instances is caused by an increase in vascular stiffness [22, 23] our results suggest that an increase in the truncal fat mass corresponds with an increase in arterial stiffening in our elderly population. Notably, the association between truncal fat and increased blood pressure components in the elderly also held true for lean participants, shown by the fact that the results were not affected by the BMI. Our results are in agreement with the findings of the study of Sutton-Tyrrell et al., showing a significant association between visceral fat mass and arterial stiffness [7]. Though, they determined visceral fat mass with computed tomography and arterial stiffening with pulse wave velocity. Another study addressing this topic showed comparable results, although they pertained to a younger (middle aged) population [24].

The AIx is regarded as a surrogate of vascular stiffness; however, it is also affected by many other factors as peripheral resistance. We presented no association between this marker and the relative amount of the truncal fat mass in our population. A possible explanation for this unanticipated finding may be the curvilinear pattern of the change of the AIx with age [25]. Although AIx like PWV-increases with advancing age a plateau in the AIx is reached beyond the age of 60 [25]. Our findings showing no age-related change in the AIx within our elderly population are in concordance with the hypotheses of Namasivayam. Notably, AP alone demonstrated a significant positive association with the truncal fat mass. Because the AP is not influenced by the changes in PP, which also has an age-related
increase, it is a more appropriate marker for arterial stiffening in an elderly population. Importantly, the association between truncal fat mass percentage and blood pressure components was independent of the BMI or the total amount of body fat mass. Subgroup analysis per BMI category (<20; 20–25; 25–30; >30) did show a tendency towards a stronger association in the normal weight group; however, this was not confirmed by the multiple regression analysis. The observed variation was most likely due to the small sample-size of the subgroups and hence limited power. Furthermore, no significant association was found for the absolute truncal fat mass. These observations demonstrate that not the amount of fat per se, but fat mass distribution is a correlate of PP and hence of vascular stiffness. An implication of this finding is that in old age not the total amount, but a higher percentage of central fat mass might be a predictor of cardiovascular disease.

Body composition can be computed using several techniques. In this study, DEXA for measuring body composition has been used. This provides measurements of fat, bone and mineral content and fat-free soft tissue in defined regions [13]. Because DEXA measurements are two-dimensional, differentiation between visceral and subcutaneous fat cannot be made directly. In spite of this limitation, DEXA is increasingly used for measurements of central fat using the standard trunk region. This region has been shown to correlate closely with visceral fat [13, 18, 19]. Using DEXA as a technique for assessing central fat, the abdominal fat can be calculated in several ways. First of all, truncal mass is measured, followed by an automated calculation of the percentage of fat present in the mentioned region. Besides this parameter, central fat can also be expressed as a proportion of total body fat mass. The latter method allows to better distinguish between truncal and overall obesity, without the need to adjust for the BMI or peripheral fat percentage as a covariate. Nevertheless, our results showed similar results for both calculation methods, indicating that the use of the automatic calculation is valid for testing this association.

Limitations of our study include the cross-sectional design. Although we showed a clear association between blood pressure components and central obesity, we cannot

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**Table 2.** Multivariate linear regression analysis of peripheral and central blood pressure components to percentages of fat mass at different locations

<table>
<thead>
<tr>
<th></th>
<th>Regional peripheral fat (%)</th>
<th>Regional truncal fat (%)</th>
<th>BMI (kg/m²)</th>
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<tbody>
<tr>
<td></td>
<td>β (95% CI)</td>
<td>β (95% CI)</td>
<td>β (95% CI)</td>
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<tr>
<td>Peripheral</td>
<td></td>
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<tr>
<td>SBP</td>
<td>Model 1 0.04 (~0.03 to 0.10)</td>
<td>0.09 (0.03 to 0.15)*</td>
<td>0.02 (~0.01 to 0.05)</td>
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<tr>
<td></td>
<td>Model 2 0.03 (~0.02 to 0.08)</td>
<td>0.07 (0.02 to 0.11)*</td>
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<tr>
<td>DBP</td>
<td>Model 1 −0.10 (~0.22 to 0.02)</td>
<td>−0.19 (~0.34 to −0.04)*</td>
<td>−0.03 (~0.11 to 0.04)</td>
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<tr>
<td></td>
<td>Model 2 −0.07 (~0.16 to 0.03)</td>
<td>−0.16 (~0.27 to −0.04)*</td>
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<tr>
<td>PP</td>
<td>Model 1 0.04 (~0.01 to 0.09)</td>
<td>0.08 (0.02 to 0.14)*</td>
<td>0.01 (~0.02 to 0.04)</td>
</tr>
<tr>
<td></td>
<td>Model 2 0.03 (~0.01 to 0.06)</td>
<td>0.07 (0.02 to 0.11)*</td>
<td></td>
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<tr>
<td>Central</td>
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<tr>
<td>SBP</td>
<td>Model 1 0.05 (~0.03 to 0.13)</td>
<td>0.11 (0.02 to 0.21)*</td>
<td>0.01 (~0.04 to 0.06)</td>
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<tr>
<td></td>
<td>Model 2 0.04 (~0.02 to 0.10)</td>
<td>0.10 (0.03 to 0.18)*</td>
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<tr>
<td>DBP</td>
<td>Model 1 −0.11 (~0.24 to 0.02)</td>
<td>−0.19 (~0.35 to −0.03)*</td>
<td>−0.03 (~0.11 to 0.05)</td>
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<td></td>
<td>Model 2 −0.07 (~0.17 to 0.02)</td>
<td>−0.16 (~0.28 to −0.05)*</td>
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<tr>
<td>PP</td>
<td>Model 1 0.05 (~0.01 to 0.10)</td>
<td>0.09 (0.03 to 0.16)*</td>
<td>0.02 (~0.02 to 0.05)</td>
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<td>Model 2 0.03 (~0.01 to 0.07)</td>
<td>0.08 (0.03 to 0.13)*</td>
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<tr>
<td>PPA</td>
<td>Model 1 −0.02 (~0.19 to 0.16)</td>
<td>−0.01 (~0.09 to 0.08)</td>
<td>−0.03 (~0.14 to 0.08)</td>
</tr>
<tr>
<td></td>
<td>Model 2 0.02 (~0.12 to 0.15)</td>
<td>0.02 (~0.10 to 0.13)</td>
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<tr>
<td>AP</td>
<td>Model 1 0.14 (~0.10 to 0.39)</td>
<td>0.14 (~0.01 to 0.30)</td>
<td>−0.01 (~0.08 to 0.08)</td>
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<td>Model 2 0.15 (~0.04 to 0.34)</td>
<td>0.15 (0.03 to 0.26)*</td>
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<tr>
<td>AIx</td>
<td>Model 1 0.06 (~0.04 to 0.16)</td>
<td>0.07 (~0.08 to 0.22)</td>
<td>−0.01 (~0.07 to 0.06)</td>
</tr>
<tr>
<td></td>
<td>Model 2 0.06 (~0.01 to 0.14)</td>
<td>0.15 (~0.05 to 0.35)</td>
<td></td>
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</tbody>
</table>

Model 1: adjusted for age, gender, mean arterial pressure (MAP) and heart rate. Model 2: adjusted for age, gender, mean arterial pressure (MAP), heart rate and BMI. Abbreviations as in Table 1.
P* < 0.05.
be certain that this association is truly a causal one. Second, PWV in this study was not measured. PWV is a reflection of vessel wall stiffness of several territories, providing information about both elastic and muscular arteries. Because arterial stiffening depends on structural and functional properties of the arterial wall, carotid-femoral (cf)PWV is a widely accepted marker of arterial stiffening. However, the use of blood pressure components is increasingly acknowledged as an easy performable and strongly significant predictor for arterial stiffness [26]. Finally, the current study was limited to an older age group and therefore no statements can be made with respect to the potential association between the truncal fat mass and arterial stiffness in younger age groups. However, comparable research performed in middle age participants showing similar results [24].

In conclusion, we have found that also among old individuals, the central fat mass either as a percentage of truncal mass or as a percentage of total fat mass is associated with peripheral and aortic PP. This suggests that the pathophysiological role of the central fat mass in influencing blood pressure as reported by other studies in younger populations is still present in old age.

Key points
• Central, but not the peripheral fat mass, is associated with blood pressure components (as a marker for vascular stiffness) in older persons.
• The negative effect of the central fat mass on blood pressure components found in younger populations remain present in old age.
• The negative effect of the central fat mass on blood pressure components also holds true for lean participants, since they were not affected by the BMI.
• The truncal fat mass as measured with DEXA total body scan forms an easily applied alternative for the measurement of the visceral fat mass.

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Conflicts of interest
None declared.

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