

Fat mass changes during menopause: a metaanalysis



Ananthan Ambikairajah, BSc, MTeach, PhD; Erin Walsh, PhD; Hossein Tabatabaei-Jafari, MD; Nicolas Cherbuin, PhD

Overweight and obesity are major societal problems that are associated with a number of deleterious health and wellbeing outcomes that include type II diabetes mellitus,¹ dementia,² and cardiovascular disease (CVD)³ and result in a significant global economic burden⁴ and poorer quality of life.⁵ This is of particular importance for women because CVD is the leading cause of death in women worldwide.⁶ Many potential factors/mechanisms have been implicated in the accumulation of fat mass at midlife; these include aging,⁷ decreased physical activity levels,⁸ and sarcopenia (ie, loss of lean muscle mass), which can decrease the resting metabolic rate.⁹ However, hormonal changes in middle-aged women may also be relevant particularly in moderating increases in body fat.^{10,11} Given that the average age of menopause lies between 46–52 years¹² and that the average life expectancy of women in developed countries lies at approximately 81 years,¹³ women will spend, on average, almost 40% of their lives in a postmenopausal state. It is therefore necessary to better understand whether and how menopause might predispose to increasing body fat to better target interventions and health policy responses.

Menopause is defined as the final menstrual period and is characterized by the progressive decline of endogenous estrogen levels.¹⁴ Some studies have

OBJECTIVE: Data: Fat mass has been shown to increase in aging women; however, the extent to which menopausal status mediates these changes remains unclear. The purpose of this review was to determine (1) how fat mass differs in quantity and distribution between premenopausal and postmenopausal women, (2) whether and how age and/or menopausal status moderates any observed differences, and (3) which type of fat mass measure is best suited to the detection of differences in fat mass between groups.

STUDY: This review with metaanalyses is reported according to Metaanalysis of Observational Studies in Epidemiology guidelines.

STUDY APPRAISAL AND SYNTHESIS METHODS: Studies (published up to May 2018) were identified via PubMed to provide fat mass measures in premenopausal and postmenopausal women. We included 201 cross-sectional studies in the metaanalysis, which provided a combined sample size of 1,049,919 individuals and consisted of 478,734 premenopausal women and 571,185 postmenopausal women. Eleven longitudinal studies were included in the metaanalyses, which provided a combined sample size of 2472 women who were premenopausal at baseline and postmenopausal at follow up.

RESULTS: The main findings of this review were that fat mass significantly increased between premenopausal and postmenopausal women across most measures, which included body mass index (1.14 kg/m²; 95% confidence interval, 0.95–1.32 kg/m²), bodyweight (1 kg; 95% confidence interval, 0.44–1.57 kg), body fat percentage (2.88%; 95% confidence interval, 2.13–3.63%), waist circumference (4.63 cm; 95% confidence interval, 3.90–5.35 cm), hip circumference (2.01 cm; 95% confidence interval, 1.36–2.65 cm), waist-hip ratio (0.04; 95% confidence interval, 0.03–0.05), visceral fat (26.90 cm²; 95% confidence interval, 13.12–40.68), and trunk fat percentage (5.49%; 95% confidence interval, 3.91–7.06 cm²). The exception was total leg fat percentage, which significantly decreased (–3.19%; 95% confidence interval, –5.98 to –0.41%). No interactive effects were observed between menopausal status and age across all fat mass measures.

CONCLUSION: The change in fat mass quantity between premenopausal and postmenopausal women was attributable predominantly to increasing age; menopause had no significant additional influence. However, the decrease in total leg fat percentage and increase in measures of central fat are indicative of a possible change in fat mass distribution after menopause. These changes are likely to, at least in part, be due to hormonal shifts that occur during midlife when women have a higher androgen (ie, testosterone) to estradiol ratio after menopause, which has been linked to enhanced central adiposity deposition. Evidently, these findings suggest attention should be paid to the accumulation of central fat after menopause, whereas increases in total fat mass should be monitored consistently across the lifespan.

Key words: adiposity, BMI, body fat percentage, DEXA, fat mass, female, menopause, premenopausal, postmenopausal, waist circumference

From Centre for Research on Ageing, Health and Wellbeing, Research School of Population Health, Australian National University, Canberra, Australia.

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Corresponding author: Ananthan Ambikairajah, BSc, MTeach, PhD. ananthan.ambikairajah@anu.edu.au

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proposed that the decrease in endogenous estrogen levels may modulate body fat quantity and distribution and result in greater overall body fat and an increased amount of central fat

in postmenopausal women.^{10,15–17} However, there is a divide in the literature with some researchers suggesting that any observed differences in fat mass quantity or distribution in women at

AJOG at a Glance

Why was this study conducted?

The purpose of this study was to determine how fat mass differs in quantity and distribution between premenopausal and postmenopausal women and whether age and/or menopausal status moderates any differences between the groups.

Key Findings

Fat mass increased between premenopausal and postmenopausal women across most measures (eg, waist circumference), except for total leg fat percentage, which decreased. No interactive effects were observed between menopausal status and age.

What does this add to what is known?

The change in fat mass quantity was attributable predominantly to increasing age, with menopause having no significant additional influence. However, the decrease in total leg fat percentage and increase in measures of central fat are indicative of a possible change in fat distribution after menopause. Therefore, attention should be paid to the accumulation of central fat after menopause, whereas increases in total fat mass should be monitored consistently across the lifespan.

midlife are primarily due to aging, with menopausal status having little to no effect.^{18–20} The contradictory findings could be due to a number of factors that include (1) the intertwined relationship between menopause and aging, (2) the heterogeneity in criteria that were used between studies when defining premenopausal and postmenopausal women, and (3) the heterogeneity of measures used between studies when they investigated fat mass changes in quantity and distribution.

Because of the inconsistent evidence, it is important to pool data from available studies to determine the differences in fat mass quantity and distribution between premenopausal and postmenopausal women. Moreover, confounding factors that may explain effects that currently are attributed to an altered hormonal profile in women, such as aging, have not been investigated adequately. As far as we are aware, no study to date has comprehensively reviewed the evidence and precisely estimated the results through meta-analysis. Therefore, the current study aimed to determine (1) how fat mass differs in quantity and distribution between premenopausal and postmenopausal women, (2) whether and how age and/or menopausal status moderates any observed differences, and (3) which type of fat mass measure is best

suited to the detection of differences in fat mass between groups.

Methods**Reporting guidelines**

This review with metaanalysis was reported according to Metaanalysis of Observational Studies in Epidemiology guidelines²¹ and was registered prospectively in the PROSPERO database (CRD42018100643), which can be accessed online at the following site: (http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42018100643).

Search string

A search was conducted, limited to the PubMed database, to retrieve both cross-sectional and longitudinal studies that reported fat mass differences in quantity or distribution between premenopausal and postmenopausal women. The following search string was used: (“adipose tissue” OR “adiposity” OR “subcutaneous fat” OR “obesity” OR “overweight” OR “bodyweight” OR “body fat distribution” OR “body mass index” OR “BMI” OR “DEXA” OR “DXA” OR “dual energy x-ray absorptiometry” OR “waist to hip ratio” OR “waist-hip ratio” OR “waist circumference” OR “x-ray computed tomography” OR “computed tomography” OR “CT scan” OR “calliper” OR “skinfold”

OR “skin fold” OR “abdominal MRI” OR “abdominal magnetic resonance imaging” OR “intra-abdominal fat”) AND (“menarche” OR “pre-menopause” OR “premenopause” OR “premenopausal” OR “premenopausal” OR “reproductive” OR “menopausal transition”) AND (“post-menopause” OR “postmenopause” OR “postmenopausal” OR “postmenopausal” OR “non-reproductive”).

PubMed filters were used to exclude nonhuman and non-English studies. No time restrictions were applied to the literature search, which was conducted in May 2018.

Inclusion and exclusion criteria

The eligibility criteria for all included and excluded studies were predefined. Inclusion criteria were specified as (1) peer-reviewed manuscripts written in English or translated from their original language of publication to English, (2) studies that assessed human participants, and (3) studies that used continuous unadjusted measures that provide an estimate of fat mass for both healthy premenopausal and healthy postmenopausal women.

Exclusion criteria were (1) studies that exclusively investigated clinical/pathophysiological populations, (2) studies that selectively recruited women based on specific fat mass ranges or reported differences in fat mass within a narrow predetermined fat mass range (ie, only obese women), (3) studies that matched participants on a measure of fat mass, (4) cross-sectional studies with <40 participants to avoid extreme sampling bias and ensure that small studies, which are more likely to be methodologically less robust, are not included, (5) review articles, systematic reviews, and meta-analyses, (6) conference abstracts, and (7) animal studies.

Screening

Duplicate citations were removed from search results and the remaining entries were title screened by a single author (A.A.). All abstracts were then subdivided and independently double-screened by all the authors with the use of the predetermined inclusion/

exclusion criteria; any discrepancies were resolved through consensus. Finally, full-text and supplementary materials of the remaining articles were double-screened against inclusion/exclusion criteria by 3 authors (A.A., H.T.-J., and E.W.), with data extracted from relevant articles. Where data were missing, authors were contacted via email to obtain relevant information that was required for inclusion in the review. A bibliographic search of available articles and reviews was also used to identify further studies that fit the inclusion criteria.

Data extraction

All data from included articles were double extracted by 2 authors (A.A. and E.W.) to avoid transcription errors; any disagreement was resolved by consensus. Data that were extracted from each study included (1) sample size; (2) age; (3) relevant measures that provide an estimate of fat mass ([Supplementary Table 1](#)) and included body mass index (BMI), waist circumference (WC), hip circumference (HC), bodyweight (BW), total body fat percentage (BF%), trunk fat percentage (TF%), waist-to-hip ratio (WTHR), total leg fat percentage (LF%), abdominal (ASF) and suprailiac skinfold thickness (SISF), abdominal subcutaneous fat (AF), and visceral fat (VF); (4) whether information such as menopausal status, WC, and/or BMI was measured or self-reported; (5) definitions used for WC, HC, premenopausal women, and postmenopausal women; (6) whether follicle-stimulating hormone (FSH) criteria were used; (7) whether women were age matched, and (8) whether sample selection that included smoking, surgical menopause, hormone replacement therapy (HRT), CVD, and history of drug and alcohol abuse criteria were used.

Definition of premenopause and postmenopause

The precise definition for “premenopause” and “postmenopause” are known to vary substantially within the

literature, which has motivated a series of attempts by international experts collaboratively to develop a comprehensive standardized set of criteria to describe the terminology that is associated with menopause.^{14,22–25} The current gold standard for defining menopause nomenclature is the Stages of Reproductive Aging+10 criteria, which was established in 2012.¹⁴ The requirement for papers to adhere to the Stages of Reproductive Aging+10 criteria would have limited the scope of the current review and prevented the inclusion of relevant studies, particular those published before 2012. Therefore, all studies that included premenopausal and postmenopausal women (as defined by the authors of those studies) were considered. Furthermore, women who were classified as perimenopausal were not included in the current meta-analysis so that a clear comparison could be made between groups, with premenopausal women acting as controls for any effect observed after menopause.

Quality assessment

The quality of included studies was assessed independently by 2 authors (A.A. and E.W.), who used an adapted version of the Newcastle-Ottawa Scale.²⁶ In short, the Newcastle-Ottawa Scale for cohort studies used 3 categories to evaluate individual study quality that included (1) the selection of participants, (2) the comparability of groups, and (3) the assessment/ascertainment of the outcome of interest. Notably, an item was removed from the selection and outcome sections of the Newcastle-Ottawa Scale that did not address the particular quality requirements of the present review ([Appendix](#)). Furthermore, given that all studies that included premenopausal and postmenopausal women were considered, 2 additional items were added to the comparability section to ensure that studies with better-suited designs for comparing these groups were scored accordingly. Any discrepancy in quality assessment was resolved by consensus. If consensus decisions were not possible, a third rater was used.

Multiple reports

In the cases in which multiple studies had used the same cohort and reported on the same fat mass measures, only 1 publication was used in any single analysis. Which study to include was based on the following criteria, in order of importance: (1) availability of effect sizes in study (or effect sizes provided by authors after contact), (2) sample size, (3) methods quality rating, and (4) publication date of the study (with more recent studies being prioritized). When multiple studies used the same cohort but reported on different fat mass measures, estimates from the same cohort, but with different studies, were used in separate analyses.

Statistical analysis

All statistical analyses were conducted with the open source software R (version 3.3.3)²⁷ running in RStudio (version 1.0.143)²⁸ with the use of the metafor package (version 2.0.0)²⁹ for the metaanalysis.

Summary measures

For both cross-sectional and longitudinal analyses, effect sizes were calculated with the use of the raw (unstandardized) mean difference (D) for fat mass between postmenopausal and premenopausal women:

$$D = \bar{X}_1 - \bar{X}_2$$

The use of raw mean differences was most appropriate, given that the outcome measure of interest (fat mass) was reported on meaningful scales that were used consistently across studies.³⁰ For cross-sectional studies, the variance of the effect sizes was calculated with the following formula:

$$V_{D_{\text{cross-sectional}}} = \frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}$$

where S_1 and S_2 is the standard deviation for independent groups (ie, premenopausal and postmenopausal women) and n represents the number of women in each group.

For longitudinal studies, the variance of the effect sizes was calculated with the use of the following formulas:

$$V_{D_{\text{longitudinal}}} = \frac{S_{\text{diff}}^2}{n}$$

$$S_{\text{diff}} = \sqrt{S_1^2 + S_2^2 - 2 \times r \times S_1 \times S_2}$$

where r is the correlation between premenopausal and postmenopausal fat mass means.

When standard errors of the mean or 95% confidence intervals (CIs) were reported, authors were first contacted and requested to provide the unstandardized means and standard deviations. If the requested information was not provided, the standard errors of the mean and CIs were converted to standard deviations according to the method outlined in Higgins and Green.³¹ Furthermore, volume measurements (cubic centimeters) for computed tomography scans were converted to surface area (square centimeters) in the following manner: thickness of slices $\times$ number of slices.

Metaanalysis

Heterogeneity was assumed because sampling and methods varied across studies and resulted in a distribution of effect sizes.³² Therefore, a random effects model with the use of the restricted maximum likelihood estimator was used in all analyses to estimate the mean of the distribution of these effect sizes.

Heterogeneity across studies was assessed with Cochran's Q statistic (with $P < .01$ indicative of significant heterogeneity) and the I^2 statistic (values 25%, 50%, and 75% suggestive of low, moderate, and high heterogeneity, respectively).³³ To identify studies that excessively contributed to heterogeneity, sensitivity analyses were conducted according to the leave-1-out-method. Metaregression analyses that used a mixed effect model were conducted to determine the influence of moderators, such as aging. For cross-sectional studies, comparisons of fat mass

differences between premenopausal and postmenopausal women were made with a test of interaction.

Reporting bias

The possible impact of publication bias was assessed by visual inspection of the funnel plots and with the Egger regression test.³⁴ The trim-and-fill method was also used to estimate the number of studies that may be missing from the metaanalysis and to estimate adjusted effect sizes.^{35,36}

Results

The search strategy identified 2994 unique citations; bibliography searches identified an additional 11 records. After initial screening that was based on titles and abstracts, 586 publications remained for full-text assessment. After the application of inclusion and exclusion criteria, a further 300 publications were excluded (Figure 1). Of the remaining 286 studies, 210 were eligible for inclusion in the quantitative analysis, with 201 studies reporting cross-sectional data^{15,18–20,35,37–232} and 11 studies reporting longitudinal data.^{10,38,152,233–240}

Some studies included multiple subcohorts of premenopausal and postmenopausal women based on factors such as age,²³³ ethnicity,^{45,107} physical activity level,^{111,213} and geographic location.^{96,155,167} In these cases, the subcohorts were extracted separately and treated as discrete samples. Therefore, 217 cross-sectional (Supplementary Table 2) and 13 longitudinal samples (Supplementary Table 3) were included in the analyses.

Study quality rating

For cross-sectional studies, 101 studies were of high quality, as demonstrated by their scores that ranged from 7–9 stars on the adapted version of the Newcastle Ottawa Scale (maximum, 9 stars); 78 studies were of moderate quality (4–6 stars), and 22 studies were of poor quality (0–3 stars; Supplementary Table 4). Almost all longitudinal studies were of high quality, with the exception of 1 study,²³⁵ which was of moderate quality with a score of 4 (Supplementary Table 5).

Summary estimates

The unstandardized mean differences (ie, estimate) of each fat mass measure for both cross-sectional and longitudinal studies are presented in Tables 1 and 2, respectively. Standardized estimates for cross-sectional and longitudinal studies are presented in Supplementary Tables 6 and 7, respectively. Cross-sectional studies compared separate premenopausal and postmenopausal groups; for longitudinal studies, all women were premenopausal at baseline and postmenopausal at follow up.

Cross-sectional metaanalysis

Cross-sectional BMI. One hundred seventy-one cross-sectional studies investigated the relationship between BMI and menopausal status. The analyses revealed that the mean BMI difference was 1.14 kg/m² (standard error [SE], 0.09 kg/m²), with a yearly mean age difference of 0.07 kg/m² per year (Table 1).

Cross-sectional BW. One hundred nine cross-sectional studies investigated the relationship between BW and menopausal status. The analyses revealed that the mean BW difference was 1.00 kg (SE, 0.29 kg), with a yearly mean age difference of 0.07 kg per year (Table 1).

Cross-sectional WC. Seventy cross-sectional studies investigated the relationship between WC and menopausal status. The analyses revealed that the mean WC difference was 4.63 cm (SE, 0.37 cm), with a yearly mean age difference of 0.30 cm per year (Table 1).

Cross-sectional WTHR. Forty-eight cross-sectional studies investigated the relationship between WTHR and menopausal status. The analyses revealed that the mean WTHR difference was 0.0421 (SE, 0.0045), with a yearly mean age difference of 0.0026 per year (Table 1).

Cross-sectional BF%. Forty-six cross-sectional studies investigated the relationship between BF% and menopausal status. The analyses revealed that the

mean BF% difference was 2.88% (SE, 0.38%), with a yearly mean age difference of 0.21% per year (Table 1).

Cross-sectional HC. Twenty-five cross-sectional studies investigated the relationship between HC and menopausal status. The analyses revealed that the mean HC difference was 2.01 cm (SE, 0.33 cm), with a yearly mean age difference of 0.13 cm per year (Table 1).

Cross-sectional AF and VF. Ten cross-sectional studies investigated the relationship between AF/VF and menopausal status with the use of computed tomography scans. The analyses revealed that the mean AF difference was 28.73 cm² (SE, 10.29 cm²), with a yearly mean age difference of 1.92 cm² per year; the mean VF difference was 26.90 cm² (SE, 7.03 cm²), with a yearly mean age difference of 1.81 cm² per year (Table 1).

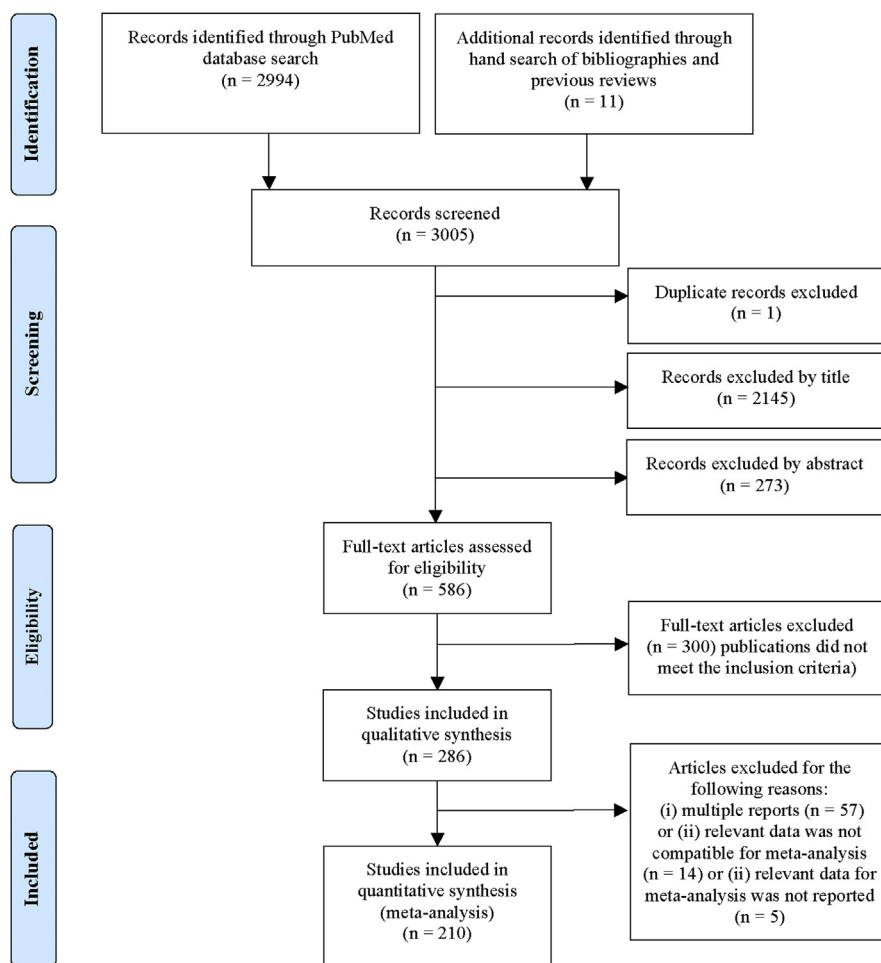
Cross-sectional SISF. Nine cross-sectional studies investigated the relationship between SISF and menopausal status. The analyses revealed that the mean SISF difference was 2.65 mm (SE, 1.12 mm), with a yearly mean age difference of 0.13 mm per year (Table 1).

Cross-sectional TF%. Seven cross-sectional studies investigated the relationship between TF% and menopausal status. The analyses revealed that the mean TF% difference was 5.49% (SE, 0.80%), with a yearly mean age difference of 0.40% per year (Table 1).

Cross-sectional ASF. Four cross-sectional studies investigated the relationship between ASF and menopausal status. The analyses revealed that the mean ASF difference was 6.46 mm (SE, 3.04 mm), with a yearly mean age difference of 0.35 mm per year (Table 1).

Cross-sectional LF%. Three cross-sectional studies investigated the relationship between LF% and menopausal status. The analyses revealed that the mean LF% difference was -3.19% (SE, 1.42%), with a yearly mean age difference of -0.17% per year (Table 1).

FIGURE 1
Flow chart



The flow chart shows the search, screening, and selection process for the studies that were included in the review and metaanalyses.

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Longitudinal metaanalysis

Longitudinal BMI. Eight longitudinal studies investigated the relationship between BMI and menopausal status. The analyses revealed that the mean BMI change was 0.93 kg/m² (SE, 0.34 kg/m²), with an annual change of 0.14 kg/m² per year (Table 2).

Longitudinal BW. Seven longitudinal studies investigated the relationship between BW and menopausal status. The analyses revealed that the mean BW change was 2.99 kg (SE, 0.83 kg), with an annual change of 0.37 kg per year (Table 2).

Longitudinal BF%. Four longitudinal studies investigated the relationship

between BF% and menopausal status. The analyses revealed that the mean BF % change was 2.18% (SE, 1.01%), with an annual change of 0.41% per year (Table 2).

Longitudinal WC. Three longitudinal studies investigated the relationship between WC and menopausal status. The analyses revealed that the mean WC change was 3.82 cm (SE, 1.51 cm), with an annual change of 0.51 cm per year (Table 2).

Longitudinal AF and VF. Three longitudinal studies investigated the relationship between AF/VF and menopausal status with the use of computed

TABLE 1

Output for cross-sectional studies

Fat mass measure	Studies, n (samples)	Total sample size, n		Mean age, y (standard deviation) ^a		Age difference	Mean fat mass (standard deviation) ^a		Unstandardized estimate (95% confidence interval) ^b	P value
		Premenopausal	Postmenopausal	Premenopausal	Postmenopausal		Premenopausal	Postmenopausal		
Body mass index	171 (181)	453,036	523,796	41.96 (3.69)	59.42 (3.06)	14.82 (5.36)	24.75 (1.60)	26.64 (1.25)	1.14 (0.95–1.32)	<.0001
Bodyweight	109 (122)	113,603	204,845	43.36 (4.71)	59.55 (3.27)	15.00 (5.37)	64.82 (7.91)	66.12 (9.17)	1.00 (0.44–1.57)	.0005
Waist circumference	70 (72)	214,712	326,639	42.28 (3.65)	59.07 (1.91)	16.23 (4.24)	78.58 (4.24)	83.61 (3.19)	4.63 (3.90–5.35)	<.0001
Waist-to-hip ratio	47 (50)	199,140	309,797	42.39 (3.44)	59.09 (1.42)	16.17 (3.20)	0.78 (0.03)	0.81 (0.03)	0.04 (0.03–0.05)	<.0001
Body fat percentage	46 (52)	58,605	113,226	43.81 (4.67)	59.55 (3.81)	14.83 (6.56)	32.44 (3.47)	35.69 (3.84)	2.88 (2.13–3.63)	<.0001
Hip circumference	25 (25)	185,885	297,189	42.48 (3.08)	59.15 (0.95)	16.22 (2.61)	100.30 (2.66)	102.73 (2.25)	2.01 (1.36–2.65)	<.0001
Subcutaneous abdominal fat	10 (10)	696	833	41.01 (6.96)	57.48 (5.36)	15.00 (10.70)	194.05 (23.65)	221.21 (32.09)	28.73 (8.56–48.91)	.0053
Visceral fat	10 (10)	696	833	41.01 (6.96)	57.48 (5.36)	15.00 (10.70)	69.22 (15.75)	104.36 (13.92)	26.90 (13.12–40.68)	.0001
Suprailiac skinfold thickness	9 (10)	1,103	745	39.76 (4.41)	61.89 (4.77)	21.46 (6.49)	22.16 (7.04)	24.55 (9.90)	2.65 (0.45–4.85)	.0181
Trunk fat percentage	7 (7)	39,335	95,756	45.28 (6.61)	59.68 (3.41)	14.32 (6.21)	31.27 (4.78)	33.74 (5.36)	5.49 (3.91–7.06)	<.0001
Abdominal skinfold thickness	4 (5)	199	359	40.64 (6.32)	62.99 (5.16)	21.04 (5.00)	26.65 (8.14)	29.43 (9.82)	6.46 (0.51–12.42)	.0335
Total leg fat percentage	3 (3)	991	524	36.96 (1.13)	55.18 (5.17)	19.41 (5.87)	36.33 (5.47)	36.00 (2.62)	–3.19 (–5.98 to –0.41)	.0246

^a Computed as weighted means and weighted standard deviations, taking into account sample size; ^b Indicates significance at the $P < .05$ level.

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tomography scans. The analyses revealed that there was no significant mean AF difference; however, a significant difference in VF of 12.95 cm² (SE, 2.20 cm²) was detected, with an annual change of 3.43 cm² per year (Table 2).

Sensitivity analyses

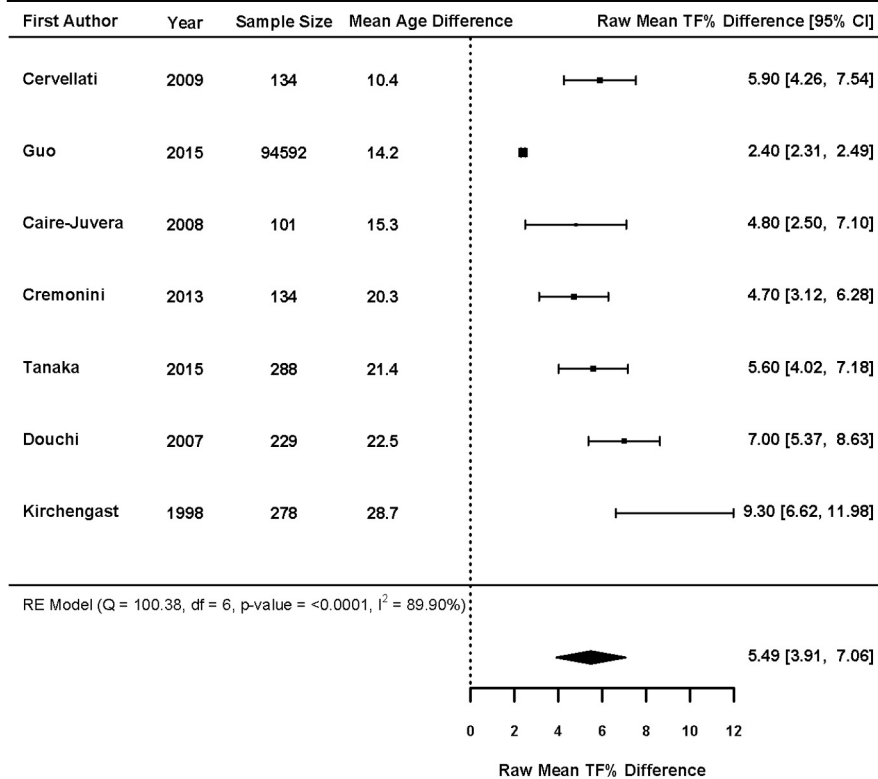
Significant heterogeneity was found in all metaanalyses performed, and the proportion of real observed variance (not related to random error) between studies (I^2) was high across all analyses (Supplementary Figures 1–17). The influence of single studies was investigated further wherever possible (ie, samples, >3) through leave-1-out analyses. The analyses predominantly demonstrated no particularly influential study and showed relative consistency in reported estimates, with a few notable exceptions. For TF% analyses, the study by Guo et al¹⁰⁶ was found to be influential, which could be due to the large sample size reported (Figure 2) or because bioelectrical impedance analysis was used in comparison with the other 6 studies that used dual-energy x-ray absorptiometry (DEXA) scans. When excluded from the analyses, the mean TF% difference between premenopausal and postmenopausal women increased from 5.49–6.05% (95% CI, 4.94–7.15%), with I^2 decreasing from 89.90–54.44%.

For BF% analyses (cross-sectional), the study by Sherk et al¹⁹⁸ was identified as influential; whereas for BMI and BW analyses (longitudinal), the study by Soreca et al²⁴⁰ was identified as influential, which could be due to the relatively large mean age difference and follow-up period (41.2 years and 20 years, respectively). When removed from analyses, all estimates decreased (BF%, 2.71 [95% CI, 2.02–3.40]; BMI, 0.63 [95% CI, 0.32–0.94]; BW, 2.3 [95% CI, 1.22–3.55]), with I^2 remaining high. For AF analyses (cross-sectional), Hunter et al¹¹⁸ was found to be influential. Despite being a relatively older study (published >20 years ago), metaanalysis revealed that the year of publication had no effect on the overall estimate. When excluded from the analyses, the mean AF difference decreased from 28.73–18.81 cm² (95%

TABLE 2
Output for longitudinal studies

Fat mass measure	Studies, n (samples)	Total sample size, n	Mean age, y (standard deviation) ^a		Mean follow-up period, y (standard deviation) ^a	Mean fat mass (standard deviation) ^a		Unstandardized Estimate (95% confidence interval)	P value
			Premenopausal	Postmenopausal		Premenopausal	Postmenopausal		
Body mass index	8 (10)	2355	46.67 (2.53)	52.80 (3.71)	6.68 (2.38)	24.30 (1.97)	25.03 (2.37)	0.93 (0.26–1.59) ^b	.0061
Bodyweight	7 (7)	525	47.64 (3.06)	55.76 (5.08)	7.82 (5.35)	66.11 (3.89)	69.19 (3.71)	2.99 (1.36–4.63) ^b	.0003
Total body fat percentage	4 (4)	176	49.59 (1.24)	55.49 (3.65)	5.82 (3.25)	36.29 (4.88)	37.84 (3.33)	2.18 (0.21–4.16) ^b	.0299
Waist circumference	3 (3)	915	46.99 (2.04)	52.73 (5.17)	7.17 (1.98)	80.79 (3.62)	84.06 (2.61)	3.82 (0.87–6.77) ^b	.0111
Abdominal fat	3 (3)	133	49.65 (1.61)	53.51 (1.64)	3.90 (0.39)	215.14 (66.15)	242.28 (77.34)	18.53 (–3.64–40.69)	.1014
Visceral fat	3 (3)	133	49.65 (1.61)	53.51 (1.64)	3.90 (0.39)	78.63 (14.45)	92.23 (12.77)	12.95 (8.65–17.25) ^b	<.0001

^a Computed as weighted means and weighted standard deviations, taking into account sample size; ^b Indicates significance at the P<.05 level. Ambikairajah. Fat mass changes during menopause. Am J Obstet Gynecol 2019.

FIGURE 2
Forest plot

The forest plot shows the cross-sectional raw mean trunk fat percentage difference between premenopausal and postmenopausal women. Studies are arranged by mean age difference.

CI, confidence interval; RE, random effects; TF%, trunk fat percentage.

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CI, 3.38–34.25 cm²), with I² remaining high.

One study, Franklin et al,²³⁵ was found to be influential for BF% analyses (longitudinal), which could be, in part, for the following reasons: (1) the relatively lower quality of the study (4 stars) when compared with other studies that were included in the analyses (8 stars) or (2) the BF% was measured by 2 different methods (ie, hydrostatic weighing [at baseline] and air displacement plethysmograph [at follow up]) compared with other studies that all used DEXA at baseline and follow-up assessment or (3) the very small sample size of the study (8 participants), compared with other studies that have a mean of 56 participants (range, 48–69). When the study by Franklin et al was excluded from the analyses, there was no significant difference in mean BF%.

Publication bias

Funnel plot asymmetry diagnostics and the trim-and-fill test revealed some evidence of publication bias. Eggers regression test was significant for ASF, TF%, and LF% (cross-sectional analyses), BF% (both cross-sectional and longitudinal analyses), and VF (longitudinal analyses), which indicates some degree of asymmetry for these groups. For cross-sectional studies (Supplementary Figures 18–20), the trim-and-fill analyses identified 30 missing studies for BMI and 2 for AF, which produced larger estimates for both. For longitudinal studies (Supplementary Figures 21 and 22), however, 2 missing studies were identified for VF, which produced a smaller estimate.

Subgroup and metaregression analyses

The influence of moderators such as aging (represented as the mean age

difference for cross-sectional analyses or length of follow up for longitudinal analyses) and study quality on pooled estimates was investigated by metaregression analyses that used a mixed effects model, for which a sufficient number of studies were available to assess the effect of a single predictor (ie, samples, ≥ 10).^{31,242} Where metaregression was possible (ie, longitudinal BMI and cross-sectional BMI, BW, WC, WTHR, BF%, HC, AF, VF, and SISF), aging significantly predicted the unexplained variance (9.99–73.90%) in fat mass estimates, except for HC, AF, and SISF (Table 3). No interactive effects were observed between menopausal status and age across all fat mass measures. Furthermore, study quality had no significant effect on the overall estimate.

To examine whether the type of measure could influence the results, we performed subgroup analyses on cross-sectional studies that examined BF% to investigate the impact of DEXA scans vs other methods, such as bioelectrical impedance analysis and hydrodensitometry, on quantifying total and regional body fat percentage. Interestingly, bioelectrical impedance analysis significantly underestimated the quantity of total body fat compared with DEXA ($\beta = -2.64\%$; 95% CI, -4.23 to -1.04 ; $P = .0012$), which supports previous findings.²⁴³ Similarly, when we investigated the effects of measured vs self-reported BMI in cross-sectional studies, self-report significantly underestimated BMI ($\beta = -0.72$ kg/m²; 95% CI, -1.34 to -0.09 ; $P = .0240$) compared with direct measurement, which aligns with previous findings.²⁴⁴ After adjustment for the effect of age, however, self-report had no significant effect on the overall estimate for BMI. All longitudinal studies computed BMI based on objectively measured height and weight. For VF and AF analyses, the use of surface area estimates that were converted from volumes (which was conducted for 1 particular study²⁰) had no significant effect on the overall estimate. Notably, almost all subgroup analyses that included women who were using HRT had no significant effect on estimates, except for BF% (significantly increased;

TABLE 3

Metaregression analyses after removal of the effect that is attributable to normal aging

Analyses	Samples, n	Fat mass measure	R ^{2a}	Unstandardized β estimate (95% confidence interval)	P value
Longitudinal	10	Body mass index	73.88	0.20 (0.12–0.29) ^b	<.0001
Cross-sectional	176	Body mass index	21.61	0.06 (0.04–0.08) ^b	<.0001
	119	Bodyweight	9.99	0.10 (0.04–0.16) ^b	.0008
	71	Waist circumference	40.13	0.24 (0.16–0.32) ^b	<.0001
	51	Waist-to-hip ratio	24.87	0.0025 (0.0013–0.0037) ^b	<.0001
	50	Total body fat percentage	24.75	0.15 (0.07–0.24) ^b	.0005
	25	Hip circumference	15.74	0.09 (–0.02–0.21)	.1201
	10	Abdominal fat	9.03	1.29 (–0.70–3.28)	.2035
	10	Visceral fat	73.90	1.85 (1.04–2.67) ^b	<.0001
	10	Suprailiac skinfold thickness	0.00	0.21 (–0.19–0.60)	.3033

^a Proportion of observed variance explained by the model; ^b Indicates significance at the $P < .05$ level; studies that did not report age were omitted from model fitting.

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$\beta = 2.46\%$; 95% CI, 0.16–4.76; $P = .0358$) and TF% (significantly decreased; $\beta = -3.65\%$; 95% CI, –5.91 to –1.38; $P = .0016$).

Comment

This large scale, comprehensive review with metaanalyses investigated the differences in fat mass between healthy premenopausal and postmenopausal women in both cross-sectional and longitudinal studies. The main findings were that (1) there was an increase in fat mass between premenopausal and postmenopausal women across most measures, specifically BMI, BW, WC, WTHR, BF%, HC, ASF, SISE, VF, and TF%, with the exception of LF%, which decreased, and (2) the change in fat mass quantity is largely attributable to increasing age, with menopause having no detectable additional influence. These findings are important because they suggest attention should be paid to the accumulation of central fat after menopause, whereas increases in total fat mass should be monitored consistently across the lifespan.

The relationship between menopause and aging can be difficult to disentangle because both progress concurrently. Previous research indicates that, for women who are 18–45 years old, the

typical trend for BMI and BF% is an increase of 0.16 kg/m² per year and 0.41% per year, respectively.²⁴⁵ Interestingly, the longitudinal analyses presented in this paper reflect similar annual estimates for BMI (0.14 kg/m² per year) and BF% (0.41% per year), which indicates that the rates of change remain the same throughout early adulthood and middle age, with menopause having no detectable additional influence above and beyond the effect of aging. Furthermore, the metaregression analyses revealed consistent, but comparatively lower, estimates for cross-sectional BMI (0.06 kg/m² per year) and BF% (0.15% per year). The reason for the relatively smaller estimates remains to be elucidated; however, it is possible that unmeasured and/or unreported genetic and environmental factors (eg, ethnicity, dietary changes, mood disorders and medications used in their treatment, physical activity levels, metabolic activity, and variation in sleep length and quality^{8,246–248}) that varied between groups in cross-sectional studies account for this. Alternatively, this also may be explained by the well-documented differences that emerge from the less robust design of cross-sectional, compared with longitudinal, studies. As a result, the longitudinal

study design is better suited to provide yearly rates of change in fat mass, which are more precise than cross-sectional estimates.

Too few longitudinal studies produced precise estimates of fat mass changes across multiple regions; however, the analysis of cross-sectional studies revealed that LF% decreased by 0.17% per year, whereas fat mass increased in abdominal indexes, such as TF% by 0.40% per year and WC (longitudinal) by 0.51 cm per year, which is indicative of a potential change in fat mass distribution after menopause. These changes, at least in part, are likely to be due to hormonal shifts that occur during midlife when women have a higher androgen (ie, testosterone)-to-estradiol ratio after menopause, which has been linked to enhanced central adiposity deposition.²⁴⁹ Importantly, the increased central deposition of fat has significant clinical implications, given that a 1-cm increase in WC has been associated with a 2% increase in risk of CVD.²⁵⁰ Furthermore, a higher testosterone/estradiol ratio has also been associated with deleterious health consequences in women, such as CVD.²⁵¹ Taken together, these results may help explain the fact that premenopausal women have been found to have lower

CVD incidence and mortality rates compared with men of the same age,²⁵² whereas postmenopausal women experience higher mortality rates because of CVD compared with men of the same age.²⁵³ The current analyses suggests that measures that are sensitive to detecting the central deposition of adiposity, such as TF% and WC, would be preferable to BW and BMI, which are commonly used indicators of overweight and obesity. This is of particular importance because of the multifactorial changes in body composition that occur in aging women that can influence BW and/or BMI estimates, such as (1) a decrease in bone density,^{254,255} (2) sarcopenia,²⁵⁶ and (3) shrinking,²⁵⁷ which indicate that measures that are less influenced by these changes, such as TF% and WC, would be preferable. Furthermore, when measures of fat mass were standardized (Supplementary Tables 6 and 7), cross-sectional analyses revealed that BF% had the largest magnitude of effect across estimates. However, WTHR, WC, and TF% produced comparatively more reliable estimates when we compared the precision of CIs. These results should be interpreted with caution, given that variability across measures, which include different samples, sample sizes, and measurement error, could not be accounted for.

Hormone replacement therapy and fat mass

Subgroup analyses revealed that the inclusion of women who used HRT resulted in a significant increase in BF% ($\beta=2.46\%$; 95% CI, 0.16–4.76; $P=.0358$) and a significant decrease in TF% ($\beta=-3.65\%$; 95% CI, -5.91 to -1.38; $P=.0016$), which is suggestive of a potential protective role of HRT in preventing/reducing trunk fat deposition, although not in preventing overall fat mass gain. These results align with a previous metaanalysis of 8 randomized control trials, which found that postmenopausal women who used HRT had less WC and TF% compared with placebo.²⁵⁸ Taken together, these findings provide useful estimates for the potential protective effect of HRT on central

adiposity, given that, to our knowledge, the most recent systematic review on this topic was published almost 20 years ago²⁵⁹ and had insufficient studies at the time to evaluate the effect of HRT on fat mass distribution. Moreover, because HRT use has complex interactions with the body and brain, with varying benefits and disadvantages depending on the time of initiation and type and duration of treatment,²⁶⁰ it is important for this topic to be investigated systematically in future with longitudinal studies.

Strengths and limitations

A key strength of the present study was that a large number of individuals were assessed for cross-sectional analyses across a wide range of measures that estimated fat mass changes in quantity and distribution between premenopausal and postmenopausal women, which resulted in a holistic understanding of body fat changes in women at midlife. Specifically, 201 cross-sectional studies were included in the metaanalysis, which provided a combined sample size of 1,049,919 individuals that consisted of 478,734 premenopausal women and 571,185 postmenopausal women.

Notable limitations included the fact that only 11 longitudinal studies were available for inclusion in the metaanalysis, which provided a combined sample size of 2472 women who were premenopausal at baseline and postmenopausal at follow up. Furthermore, it is possible that relevant studies may have been missed, given that our search was limited to the PubMed database. However, these relative weaknesses were somewhat counterbalanced by the large number of cross-sectional results that facilitated richer and comprehensive analyses that led to very consistent findings. In addition, women who were classified as perimenopausal were not included in the current metaanalysis. This was done to ensure that a clear comparison could be made between groups, with premenopausal women acting as control subjects for any effect that was observed after menopause. Moreover, the criteria that were used to identify premenopausal and postmenopausal women varied

substantially among studies and may have reduced the accuracy of the reported effects.

Conclusion

To our knowledge, this is the first comprehensive review with metaanalysis of both longitudinal and cross-sectional studies to investigate changes in fat mass between premenopausal and postmenopausal women. The analyses revealed that fat mass was higher in postmenopausal, compared with premenopausal, women across most measures, with the exception of LF% (which decreased), which was indicative of a potential change in fat mass distribution after menopause. However, the change in fat mass quantity was attributable predominantly to increasing age; menopause had no significant additional influence. Given that central fat accumulation is associated with an increase in CVD risk, these results may help explain the fact that premenopausal women have been found to have lower CVD incidence and mortality rates compared with men of the same age, whereas postmenopausal women experience higher mortality rates because of CVD compared with men of the same age. An important implication of these findings is that attention should be paid to the accumulation of central fat after menopause, whereas increases in total fat mass should be monitored consistently across the lifespan. Further investigation regarding the role of other potential moderators (eg, genetics, ethnicity, dietary changes, physical activity levels, metabolic activity, mood disorders and medications used in their treatment, age of menopause onset, and variation in sleep length and quality) is required to facilitate the development of targeted and effective intervention programs and of health policies aimed at mitigating the risk posed by increased central adiposity in women at midlife. ■

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Appendix

Adapted Newcastle-Ottawa Quality Assessment Form for Cohort Studies

Selection of premenopausal and postmenopausal women

1. Representativeness of the postmenopausal cohort
 - A. Truly representative of the average postmenopausal woman in the community
 - B. Somewhat representative of the average postmenopausal woman in the community
 - C. Selected group of users eg nurses, volunteers
 - D. No description of the derivation of the cohort
2. Selection of the premenopausal cohort
 - A. Drawn from the same or similar community as the postmenopausal cohort
 - B. Drawn from a different source
 - C. No description of the derivation of the premenopausal cohort
3. Ascertainment of menopausal status
 - A. Secure record (eg, surgical records)
 - B. Structured interview
 - C. Written self report
 - D. No description
 - E. Other

Comparability of premenopausal and postmenopausal women

4. Comparability of premenopausal and postmenopausal women on the basis of the study design
 - A. Lifestyle/demographic characteristics of premenopausal and postmenopausal women recorded and reported, with age as a minimum.
 - B. The mean difference in age between premenopausal and postmenopausal women enables a reasonable comparison which is not highly confounded by age (ie, approximately ≤ 10 years for cross-sectional studies). Note: For longitudinal studies, an appropriate follow-up period is required (ie, premenopausal at baseline and postmenopausal at follow up).
5. Was a clear definition used to describe premenopausal women?
 - A. Yes
 - B. No
6. Was a clear definition used to describe postmenopausal women?
 - A. Yes
 - B. No

Outcome

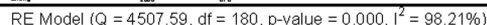
7. Assessment of fat mass
 - A. Measured
 - B. Self report
 - C. No description
8. Was the same method of measurement of fat mass conducted for both premenopausal and postmenopausal women?
 - A. Yes
 - B. No
 - C. No description

SELECTION	/3
COMPARABILITY	/4
OUTCOME	/2
TOTAL	/9
Rater #1 Initials: _____	
SELECTION	/3
COMPARABILITY	/4
OUTCOME	/2
TOTAL	/9
Rater #2 Initials: _____	

Note: A study can be given a maximum of 1 star for each numbered item within the Selection and Outcome categories. The exception to this is for the Comparability section.

Ambikairajah. Fat mass changes during menopause. Am J Obstet Gynecol 2019.

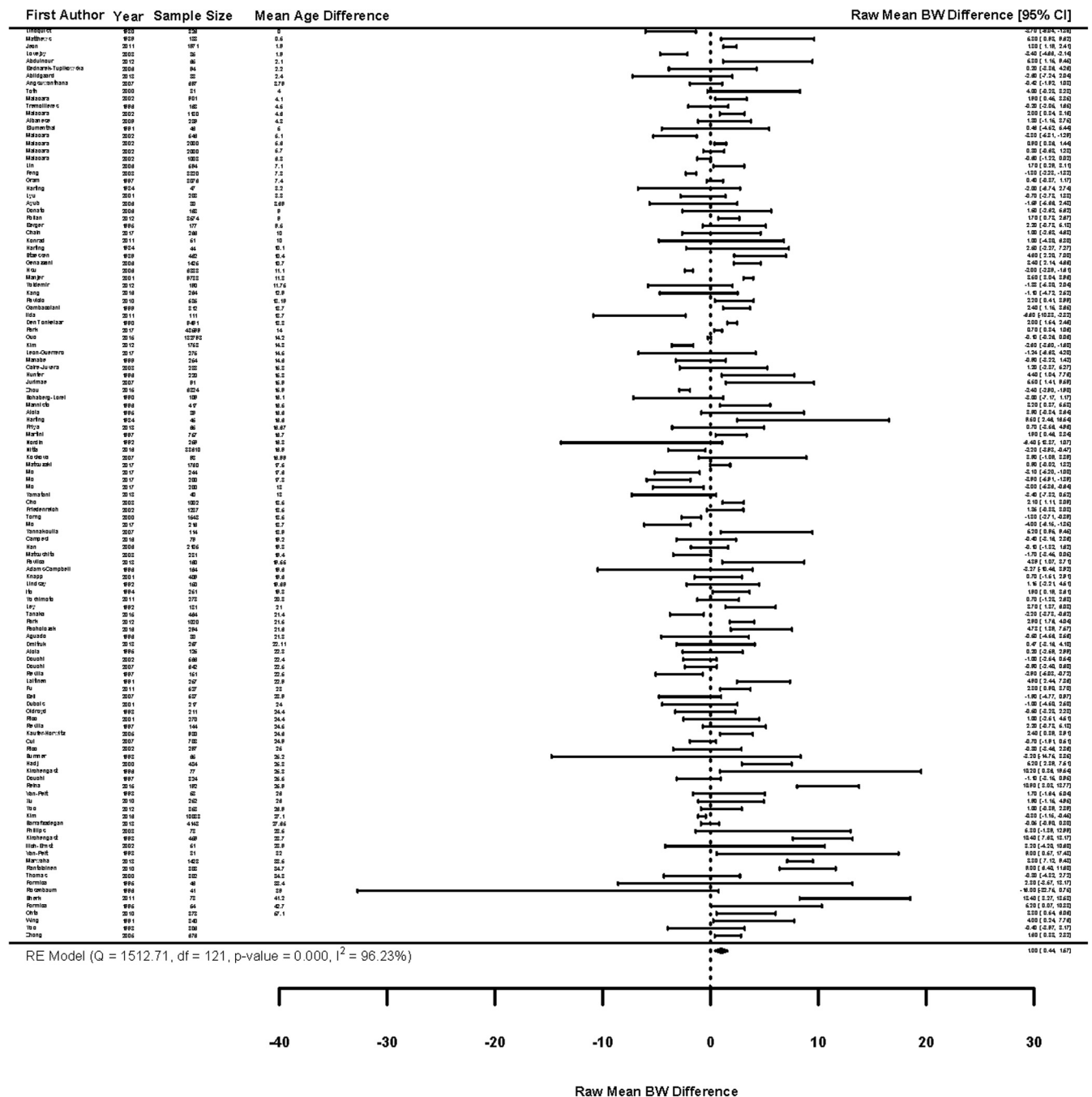
Forest plot of the cross-sectional raw mean body mass index difference between premenopausal and postmenopausal women



Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

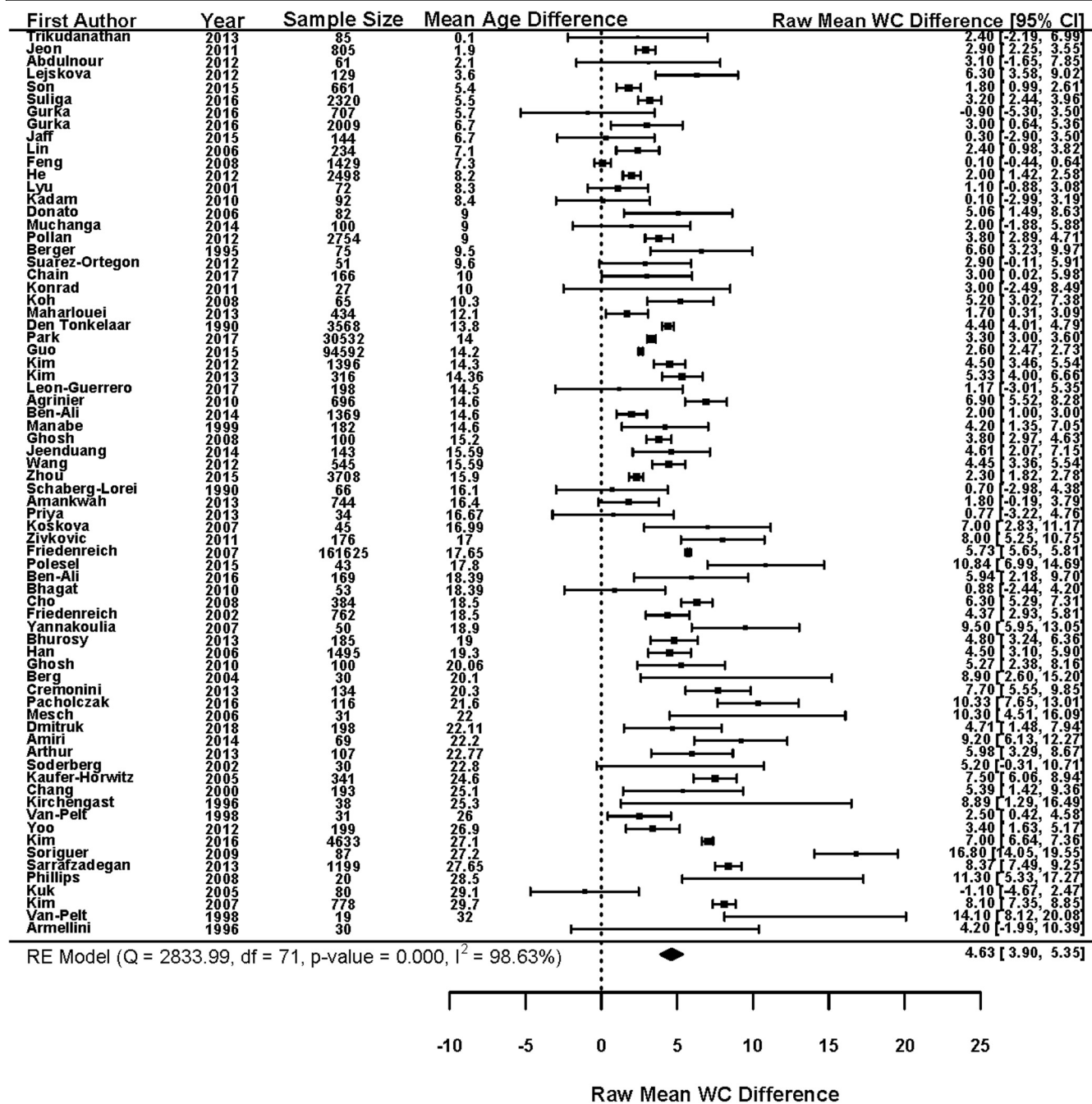
SUPPLEMENTARY FIGURE 2

Forest plot of the cross-sectional raw mean bodyweight difference between premenopausal and postmenopausal women



SUPPLEMENTARY FIGURE 3

Forest plot of the cross-sectional raw mean waist circumference difference between premenopausal and postmenopausal women



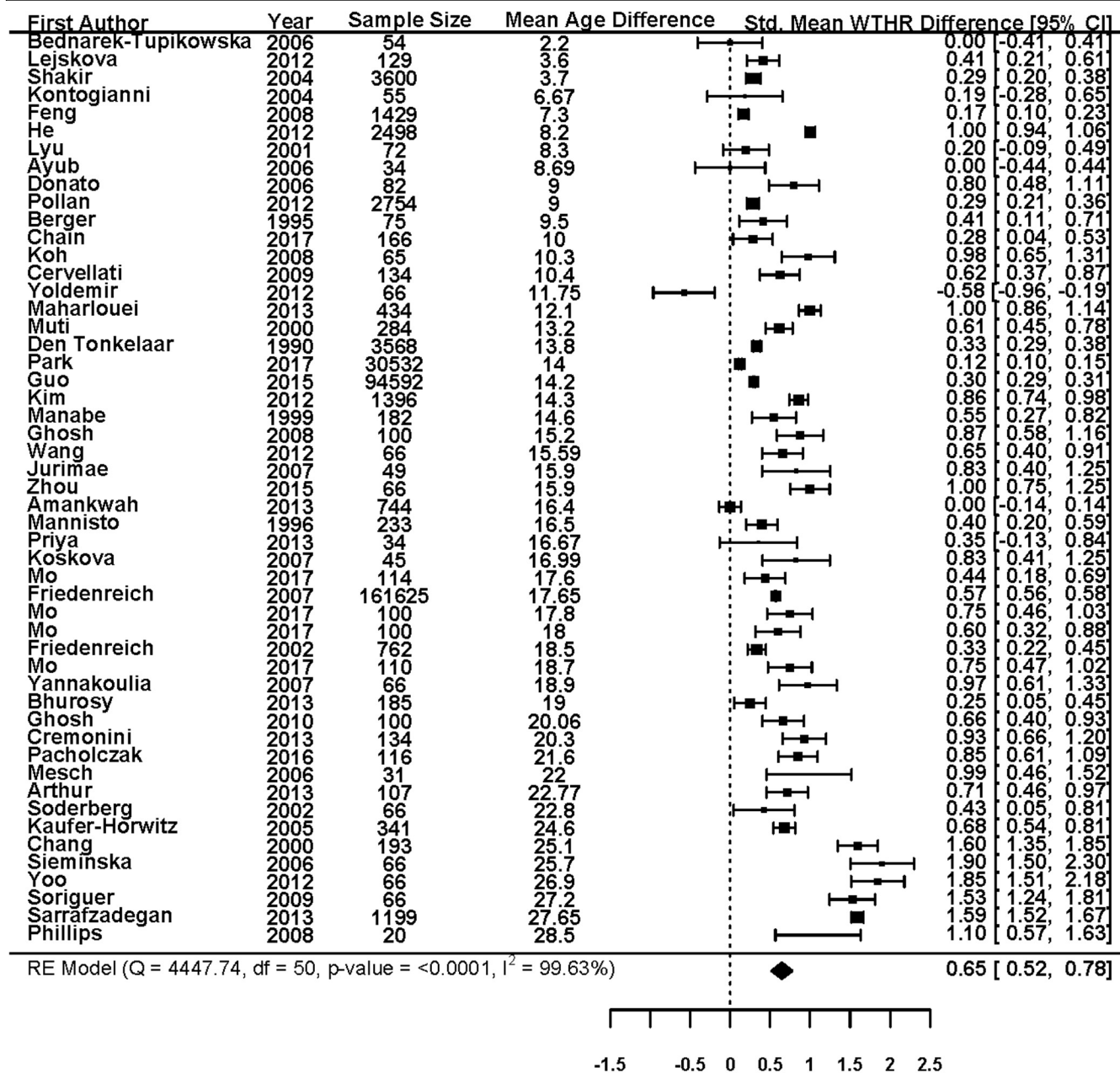
Studies are arranged by mean age difference.

CI, confidence interval; RE, random effects; WC, waist circumference.

Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 4

Forest plot of the cross-sectional standardized mean waist-to-hip ratio difference between premenopausal and postmenopausal women



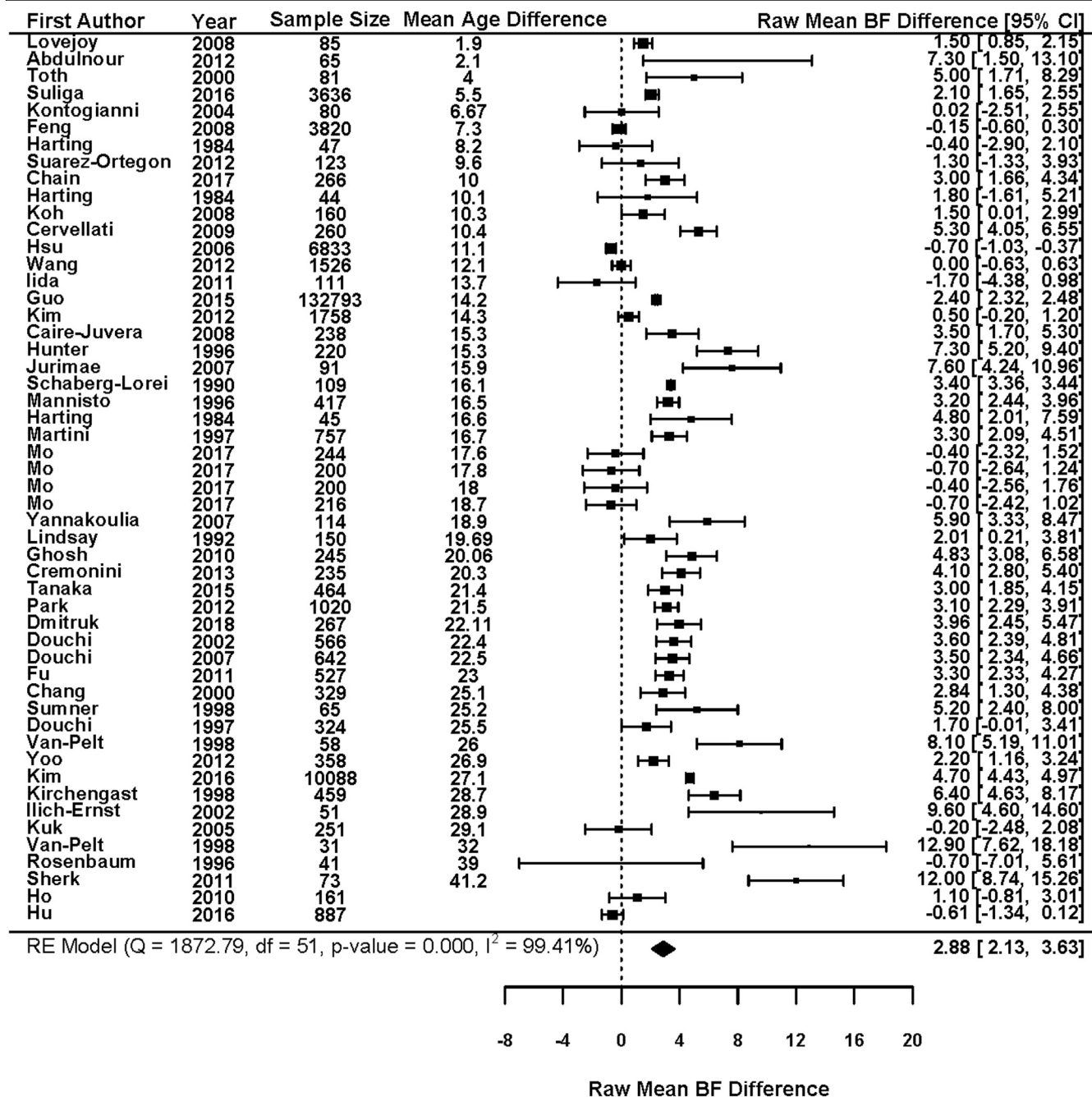
Studies are arranged by mean age difference. Standardized units have been used because of the amount of (residual) heterogeneity with nonpositive sampling variances.

CI, confidence interval; RE, random effects; Std, standardized; WTHR, waist-to-hip ratio.

Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 5

Forest plot of the cross-sectional raw mean body fat percentage difference between premenopausal and postmenopausal women



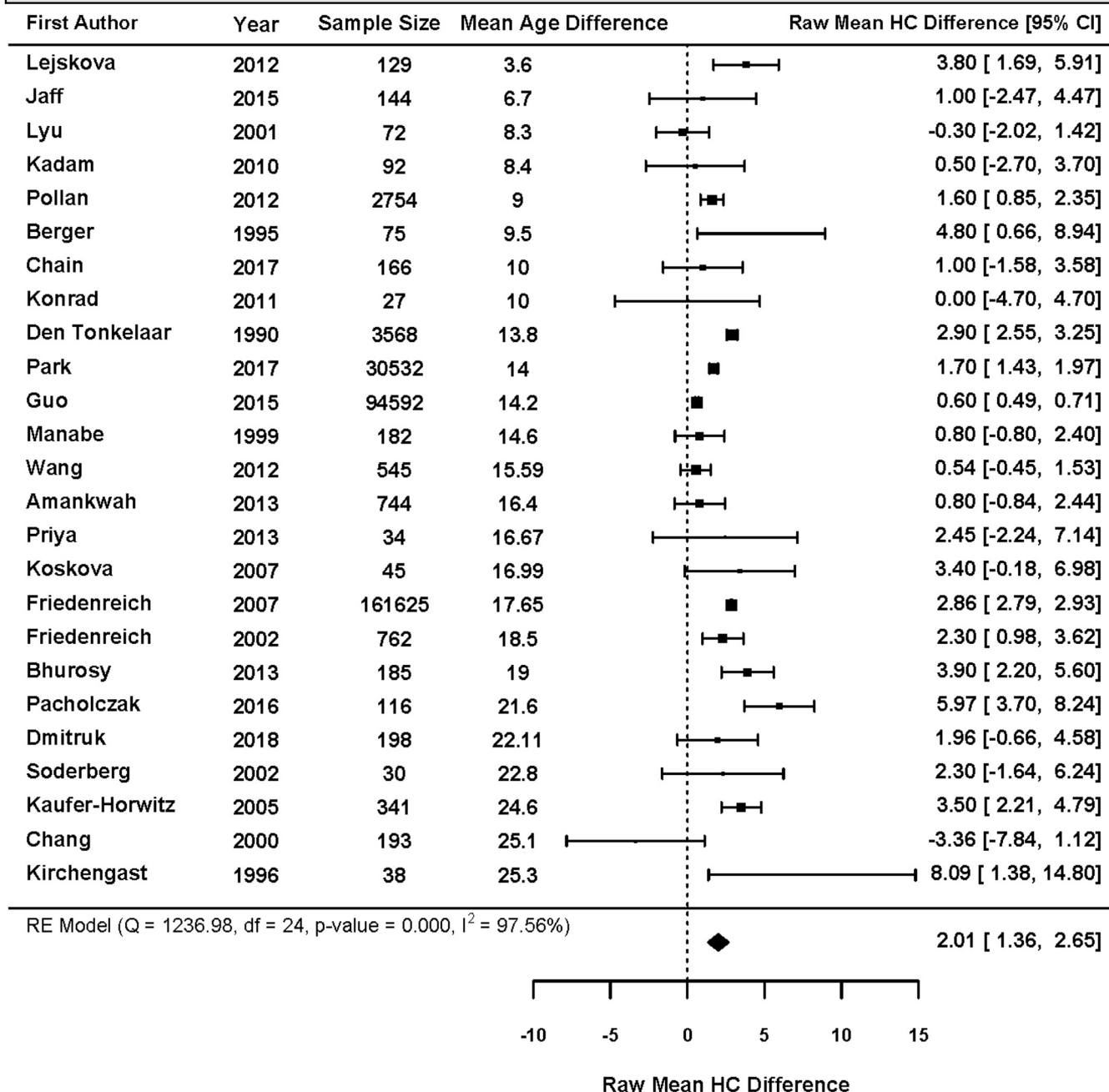
Studies are arranged by mean age difference.

BF, body fat; CI, confidence interval; RE, random effects.

Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 6

Forest plot of the cross-sectional raw mean hip circumference difference between premenopausal and postmenopausal women

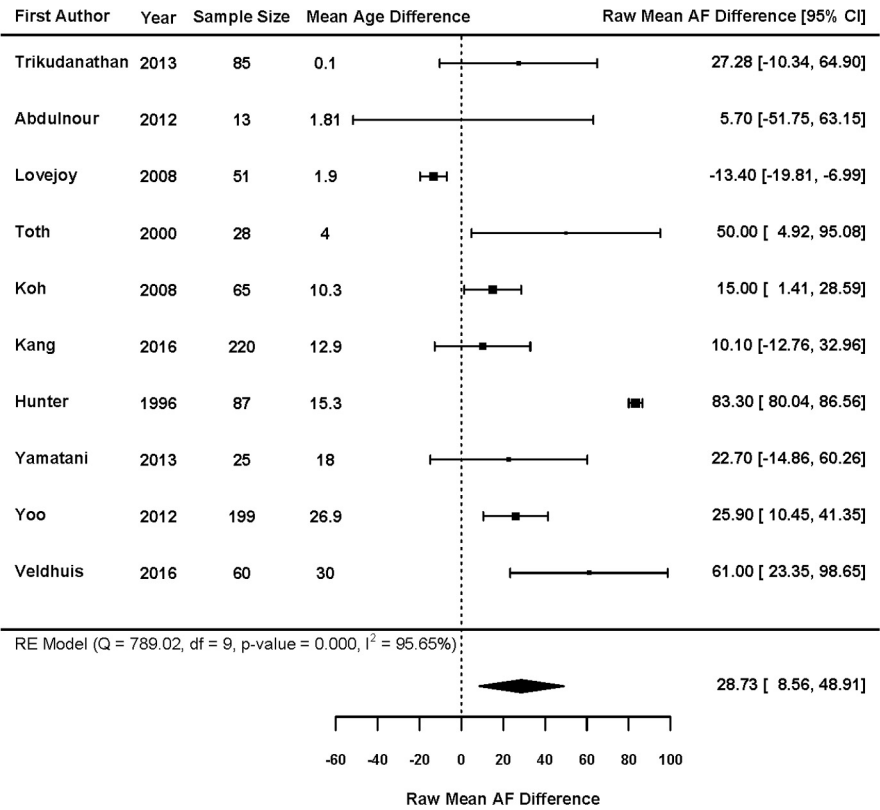


Studies are arranged by mean age difference.

CI, confidence interval; HC, hip circumference; RE, random effects.

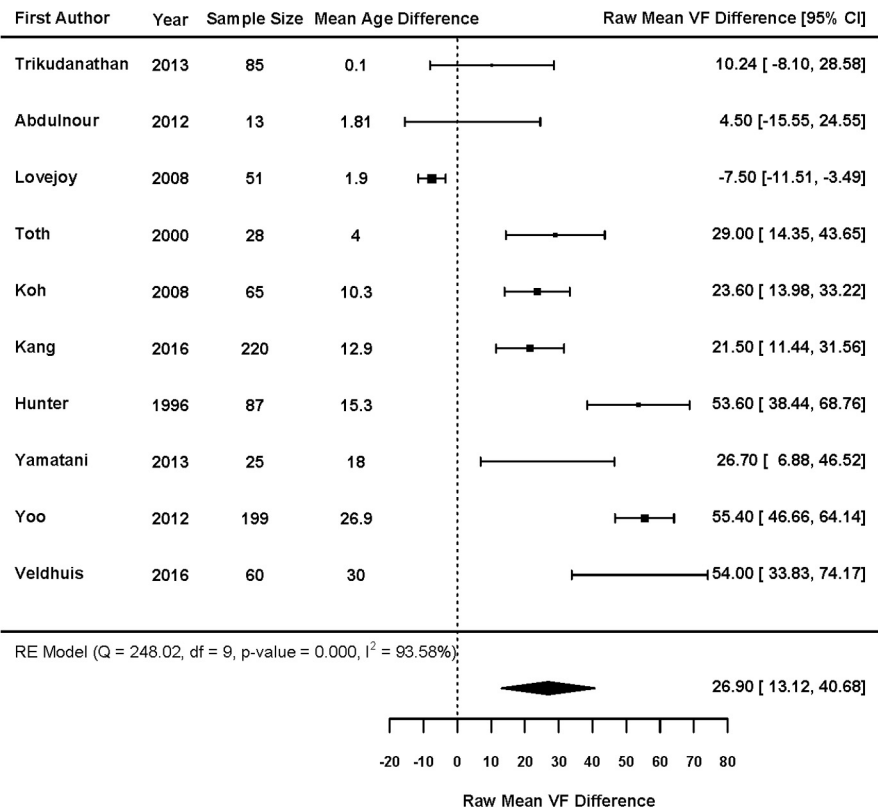
Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 7
Forest plot of the cross-sectional raw mean abdominal fat difference between premenopausal and postmenopausal women



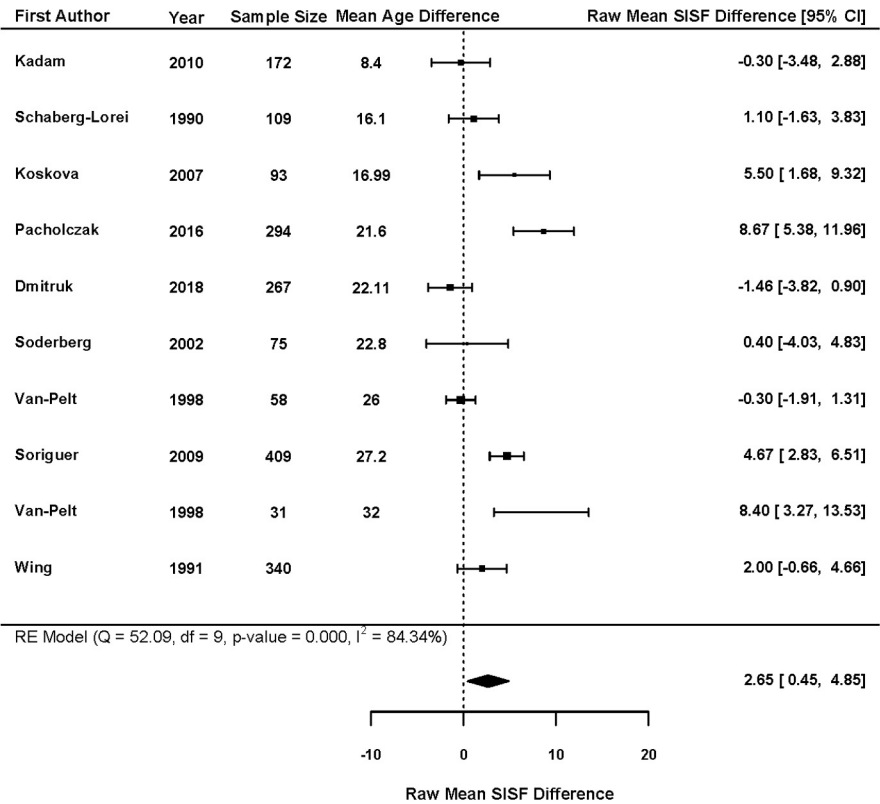
Studies are arranged by mean age difference.
AF, abdominal fat; CI, confidence interval; RE, random effects.
Ambikairajah. Fat mass changes during menopause. Am J Obstet Gynecol 2019.

SUPPLEMENTARY FIGURE 8
Forest plot of the cross-sectional raw mean visceral fat difference between premenopausal and postmenopausal women



Studies are arranged by mean age difference.
CI, confidence interval; *RE*, random effects; *VF*, visceral fat.
Ambikairajah. Fat mass changes during menopause. Am J Obstet Gynecol 2019.

SUPPLEMENTARY FIGURE 9
Forest plot of the cross-sectional raw mean suprailiac skinfold thickness difference between premenopausal and postmenopausal women

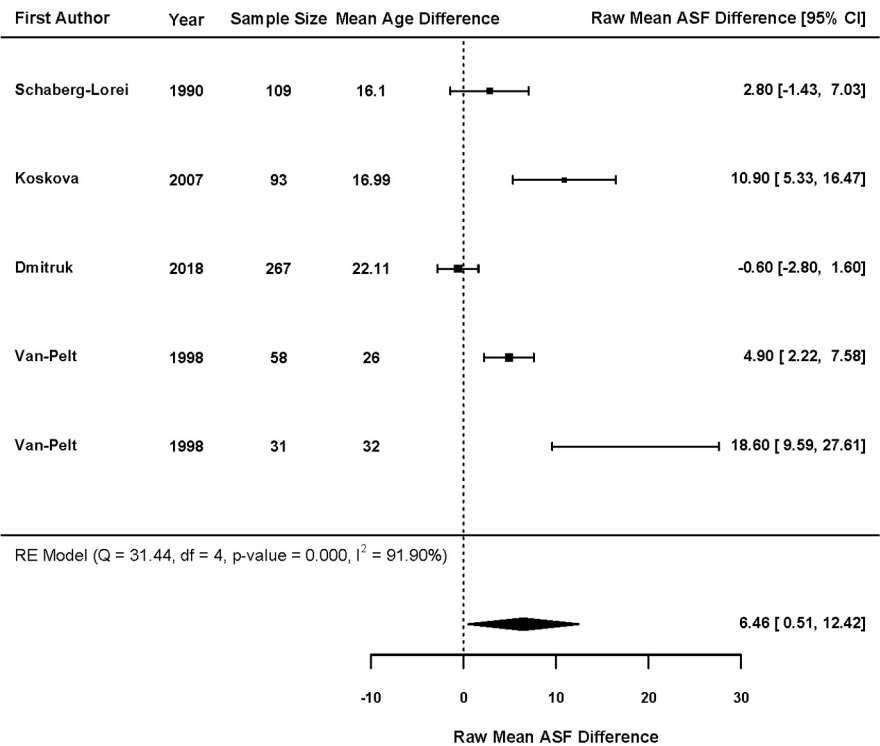


Studies are arranged by mean age difference.

CI, confidence interval; RE, random effects; SISF, suprailiac skinfold thickness.

Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 10
Forest plot of the cross-sectional raw mean abdominal skinfold thickness difference between premenopausal and postmenopausal women



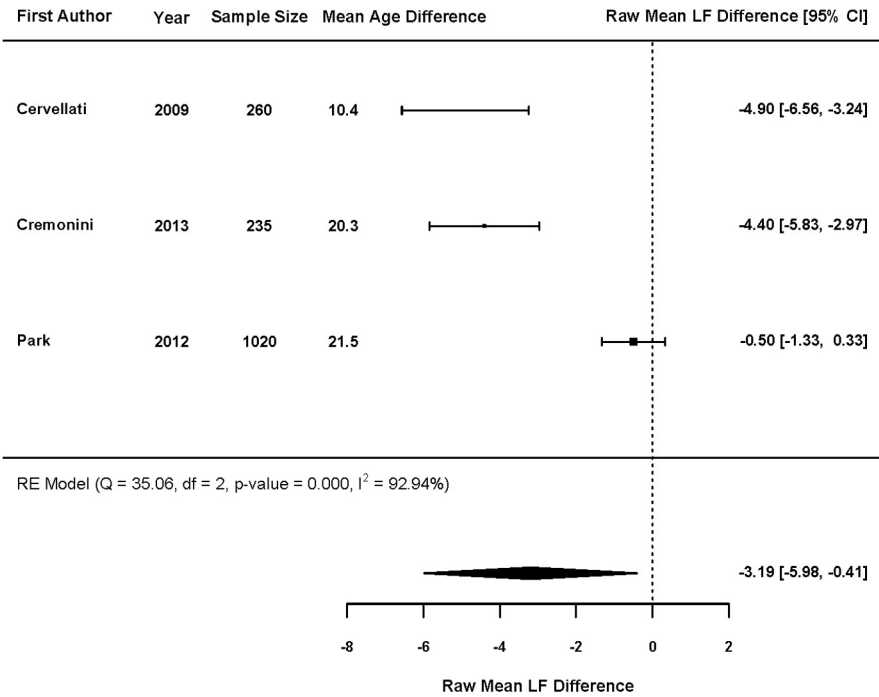
Studies are arranged by mean age difference.

ASF, abdominal skinfold thickness; CI, confidence interval; RE, random effects.

Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 11

Forest plot of the cross-sectional raw mean leg fat percentage difference between premenopausal and postmenopausal women

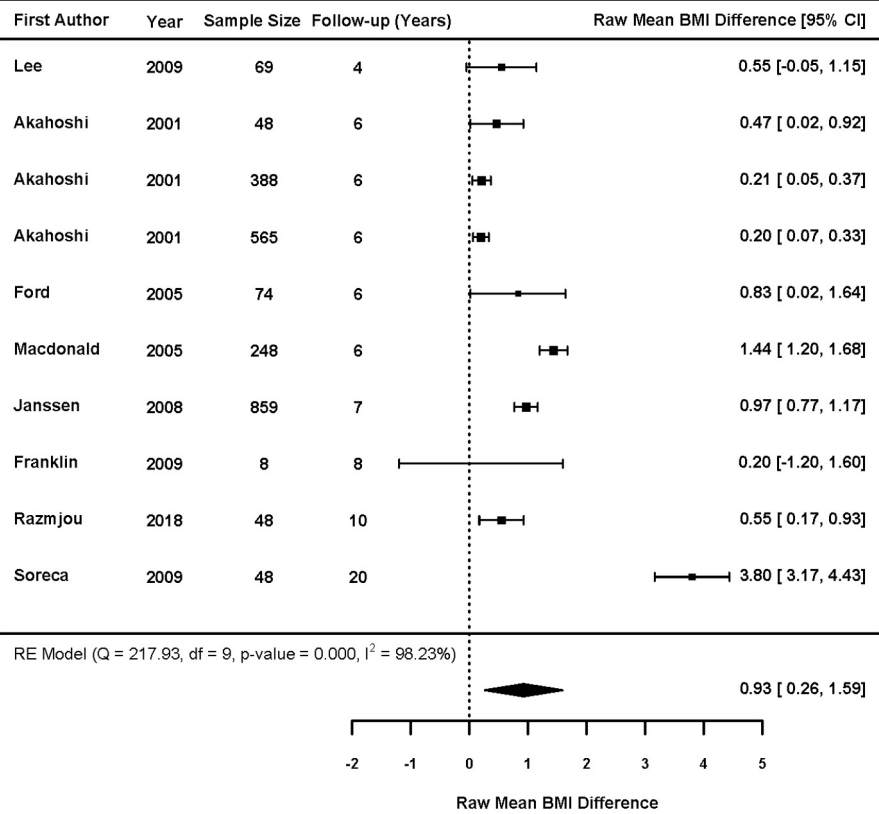


Studies are arranged by mean age difference.

CI, confidence interval; LF, leg fat; RE, random effects.

Ambikairajah. Fat mass changes during menopause. Am J Obstet Gynecol 2019.

SUPPLEMENTARY FIGURE 12
Forest plot of the longitudinal body mass index change for postmenopausal women who were premenopausal at baseline



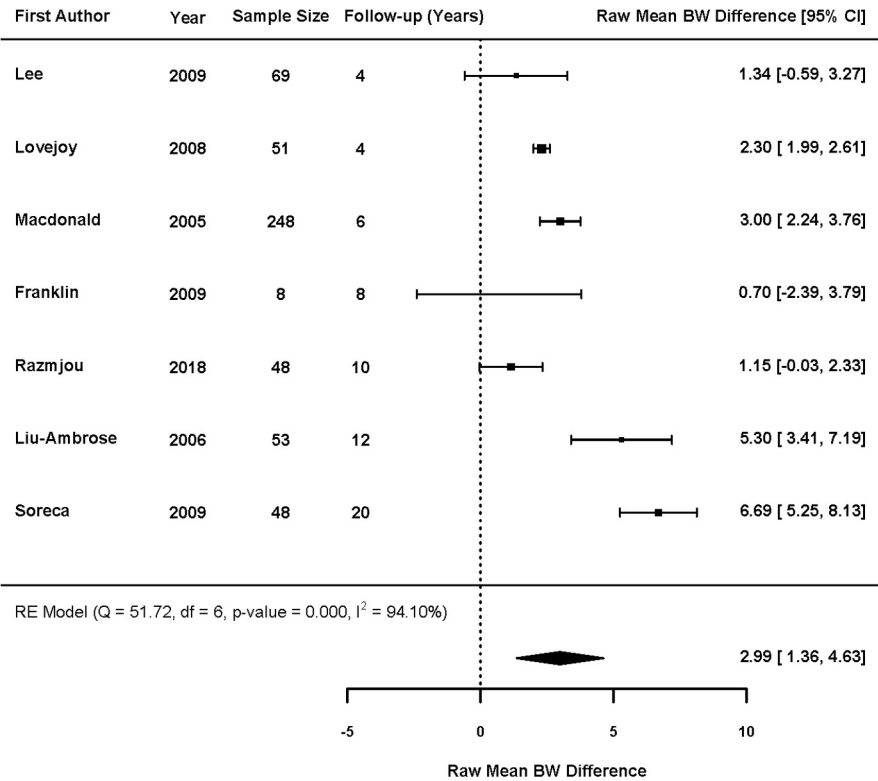
Studies are arranged by follow-up period.

BMI, body mass index; CI, confidence interval; RE, random effects.

Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

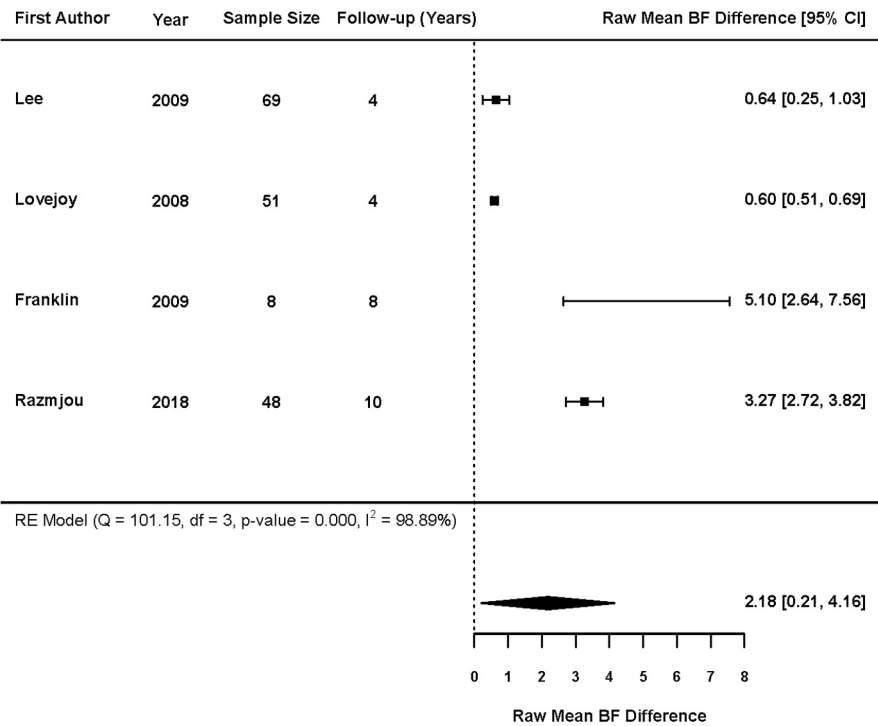
SUPPLEMENTARY FIGURE 13

Forest plot of the longitudinal bodyweight change for postmenopausal women who were premenopausal at baseline



Studies are arranged by follow-up period.
BW, bodyweight; CI, confidence interval; RE, random effects.
Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 14
Forest plot of the longitudinal body fat percentage change for postmenopausal women who were premenopausal at baseline

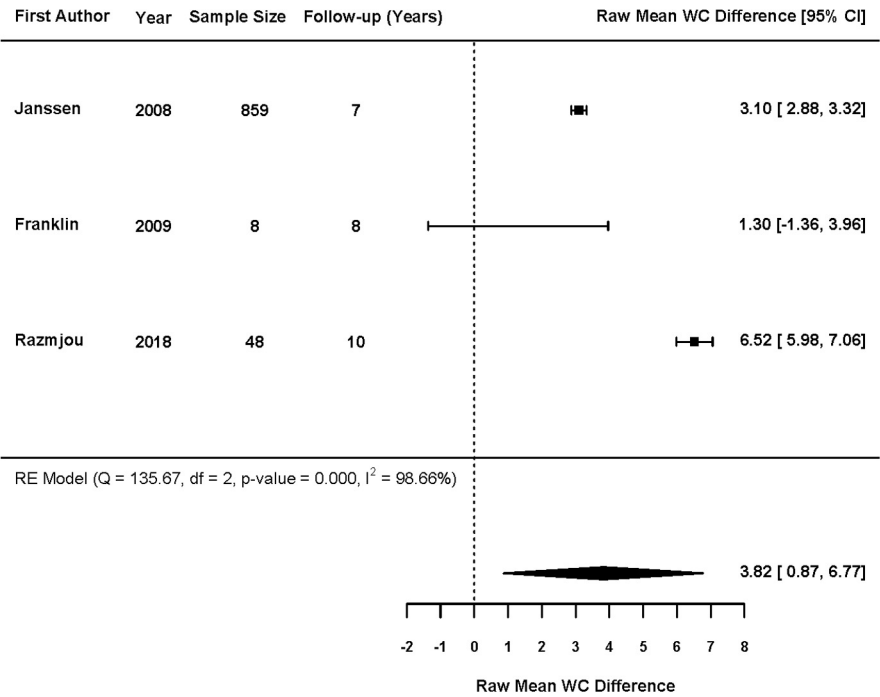


Studies are arranged by follow-up period.

BF, body fat; CI, confidence interval; RE, random effects.

Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 15
Forest plot of the longitudinal waist circumference change for postmenopausal women who were premenopausal at baseline

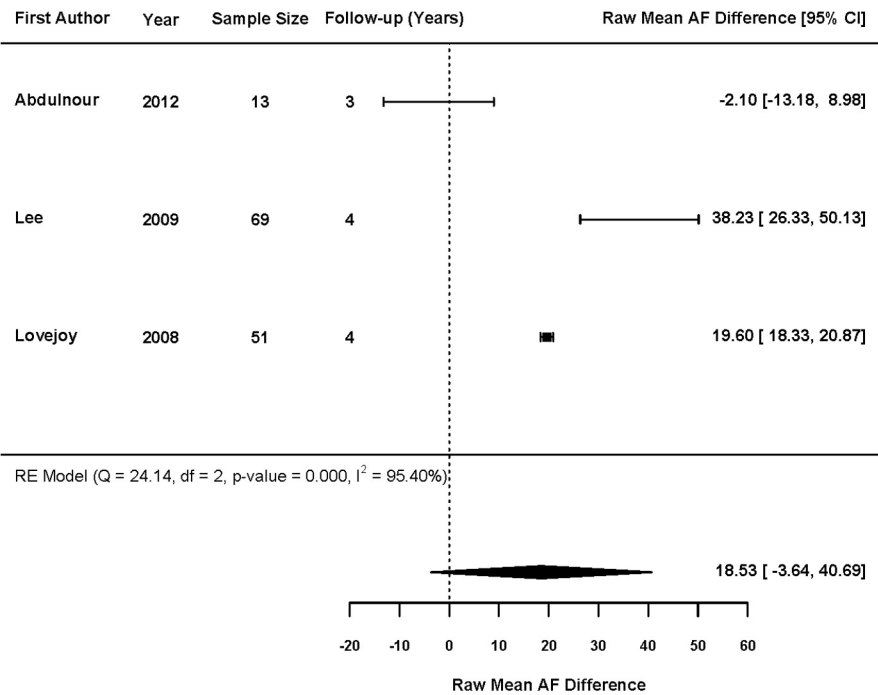


Studies are arranged by follow-up period.

CI, confidence interval; RE, random effects; WC, waist circumference.

Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 16
Forest plot of the longitudinal abdominal fat change for postmenopausal women who were premenopausal at baseline



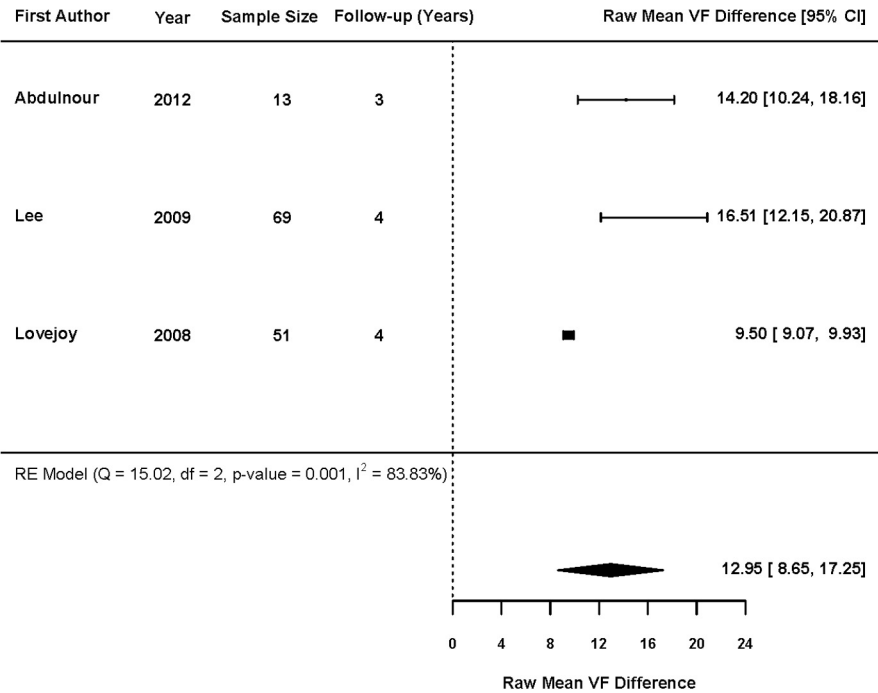
Studies are arranged by follow-up period.

AF, abdominal fat; CI, confidence interval; RE, random effects.

Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 17

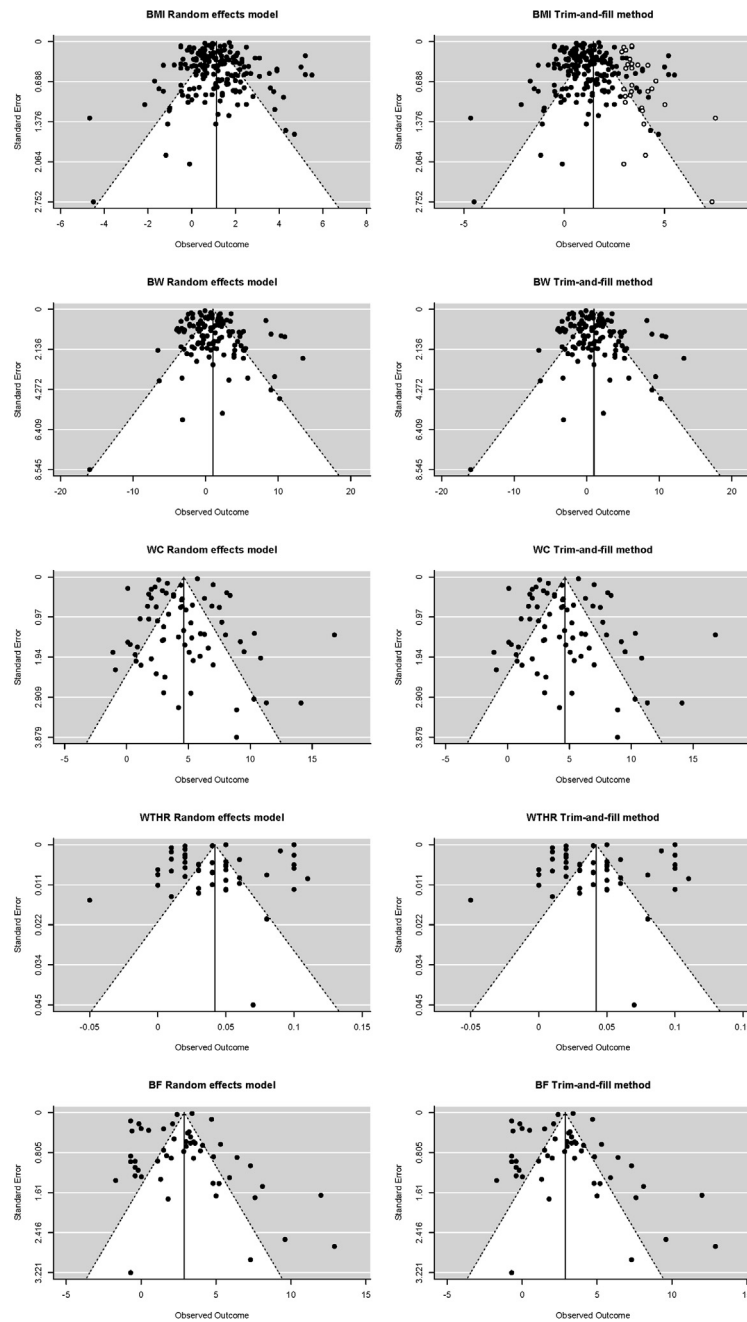
Forest plot of the longitudinal visceral fat change for postmenopausal women who were premenopausal at baseline



Studies are arranged by follow-up period.

CI, confidence interval; RE, random effects; VF, visceral fat.

Ambikairajah. Fat mass changes during menopause. Am J Obstet Gynecol 2019.

SUPPLEMENTARY FIGURE 18**Funnel plots for cross-sectional studies with the use of a random effects model and the trim and fill method**

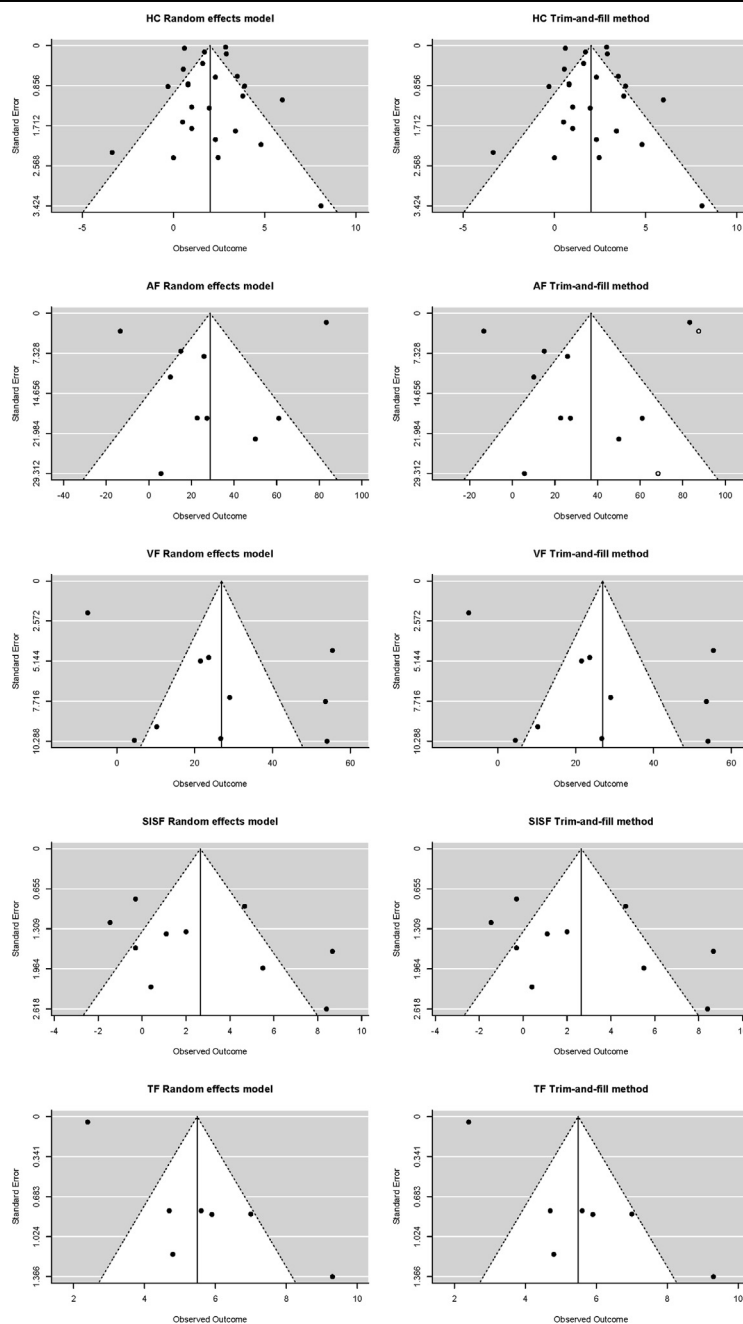
Left column, random effects model; **right column**, trim and fill method. *Filled circles* represent studies that were included in the metaanalyses; *open circles* represent possible missing studies.

BF, body fat; BMI, body mass index; BW, bodyweight; WC, waist circumference; WTHR, waist-to-hip ratio.

Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 19

Funnel plots for cross-sectional studies with the use of a random effects model and the trim and fill method

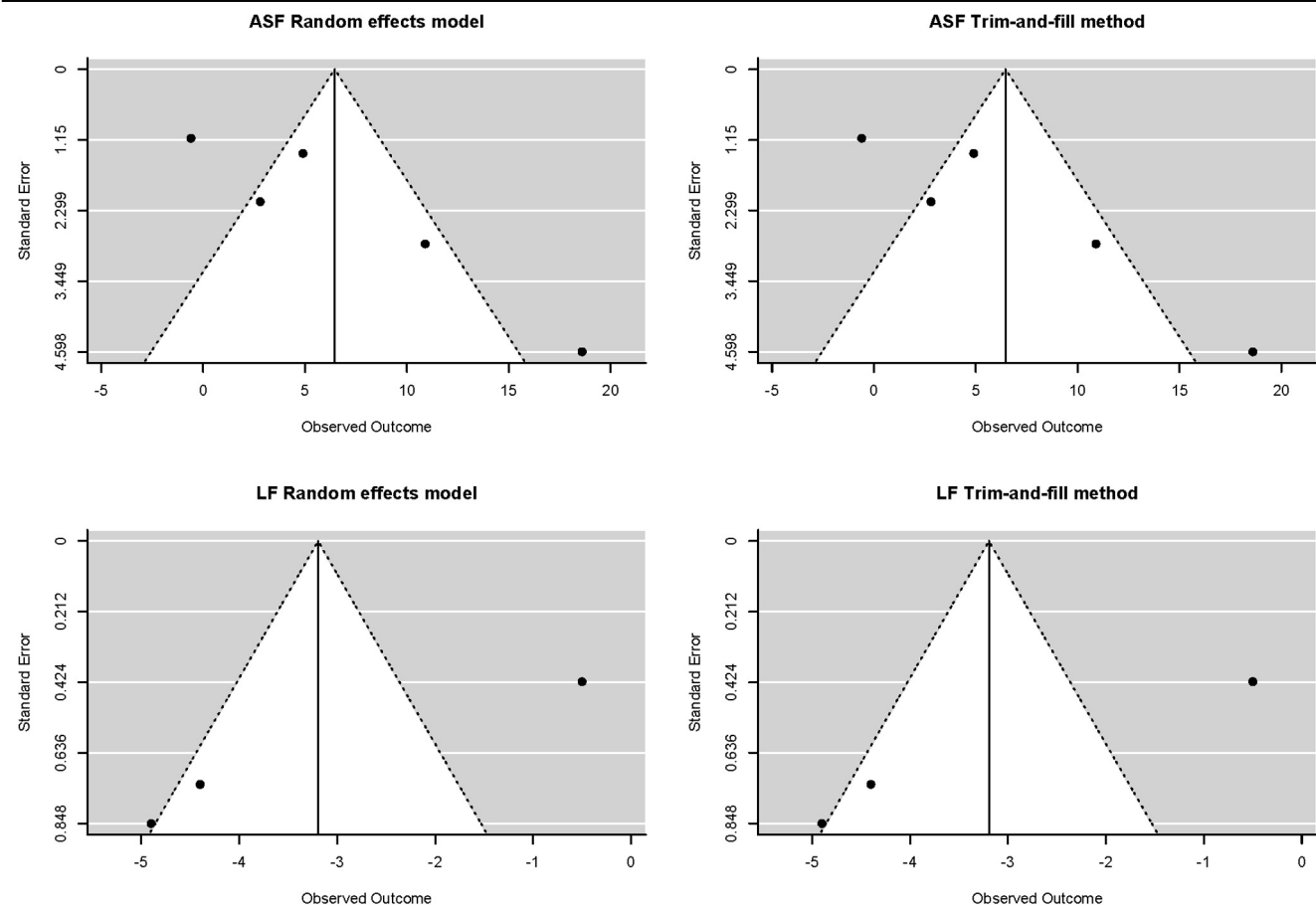


Left column, random effects model; **right column**, trim and fill method. *Filled circles* represent studies that were included in the metaanalyses; *open circles* represent possible missing studies.

AF, abdominal fat; HC, hip circumference; SISF, suprailiac skinfold thickness; TF, trunk fat; VF, visceral fat.

Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 20
Funnel plots for cross-sectional studies with the use of a random effects model and the trim and fill method



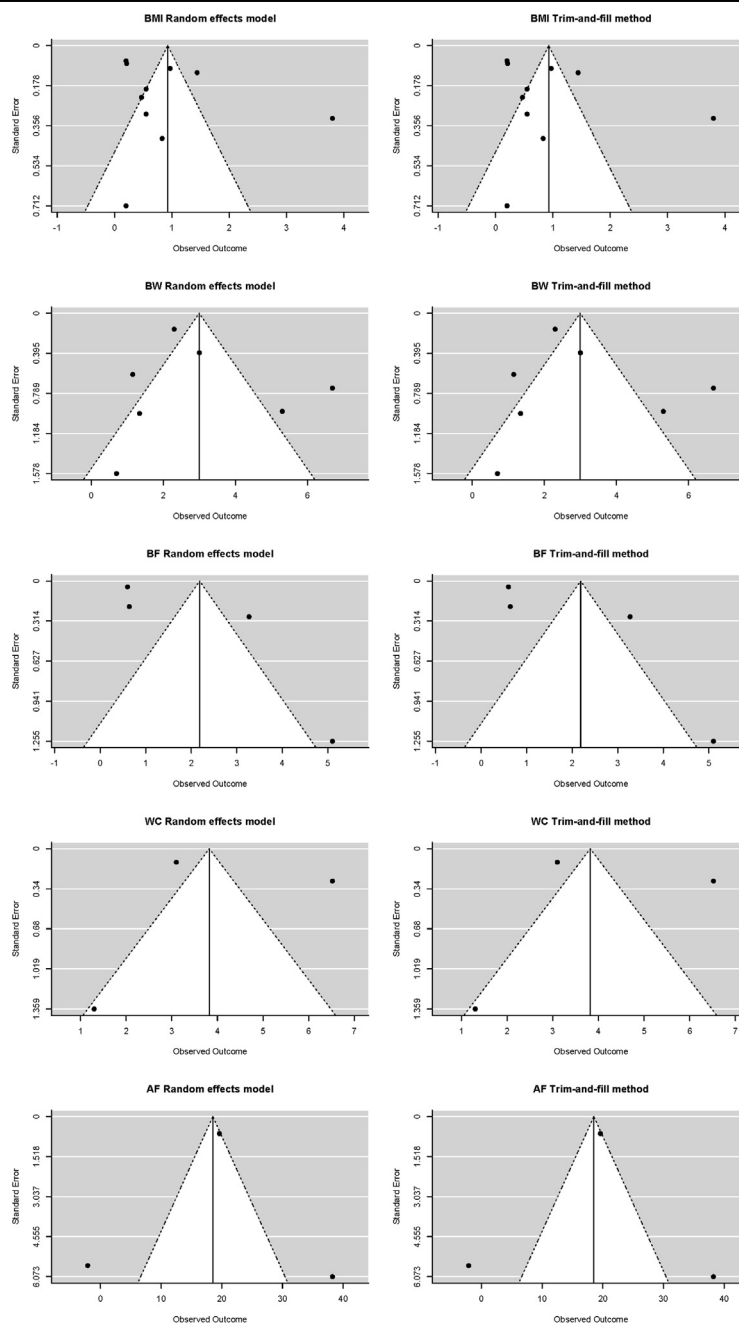
Left column, random effects model; **right column**, trim and fill method. *Filled circles* represent studies that were included in the metaanalyses; *open circles* represent possible missing studies.

ASF, abdominal skinfold thickness; LF, leg fat.

Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 21

Funnel plots for longitudinal studies with the use of a random effects model and the trim and fill method

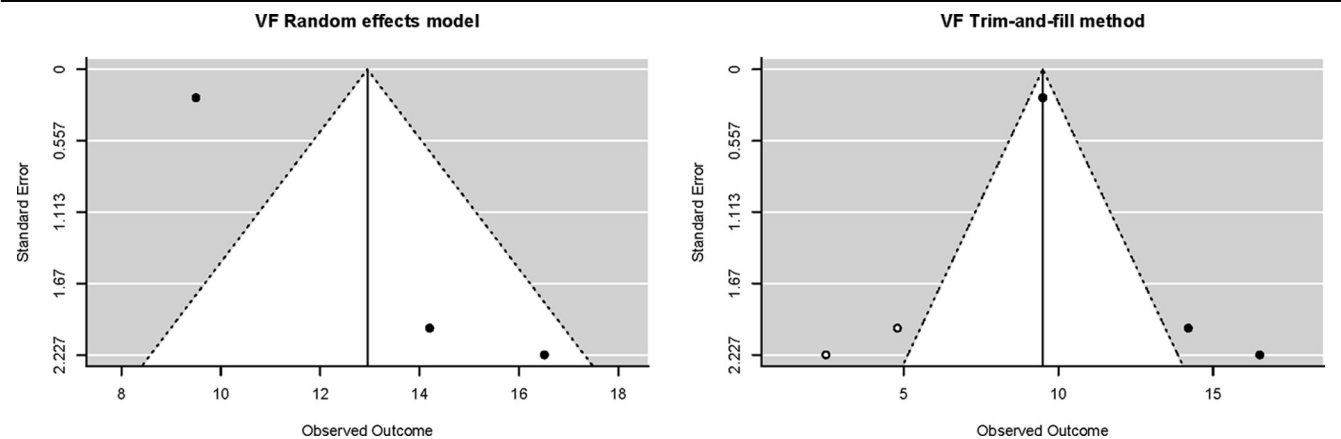


Left column, random effects model; **right column**, trim and fill method. *Filled circles* represent studies that were included in the metaanalyses; *open circles* represent possible missing studies.

AF, abdominal fat; BF, body fat; BMI, body mass index; BW, bodyweight; WC, waist circumference.

Ambikairajah. Fat mass changes during menopause. *Am J Obstet Gynecol* 2019.

SUPPLEMENTARY FIGURE 22
Funnel plot for a longitudinal study with the use of a random effects model and the trim and fill method



Left column, random effects model; right column, trim and fill method. Filled circles represent studies that were included in the metaanalyses; open circles represent possible missing studies.

VF, visceral fat.
Ambikairajah. Fat mass changes during menopause. Am J Obstet Gynecol 2019.

SUPPLEMENTARY TABLE 1
Definition of data elements

Data element name	Abbreviation	Unit of measurement	Type/method of measurement
Body mass index	BMI	Weight in kilograms divided by height in meters squared (kg/m ²)	Measured directly or with self-reported weight and height
Bodyweight	BW	Weight in kilograms (kg)	Measured directly or with self-report weight
Waist circumference	WC	Centimeters (cm)	According to the World Health Organization, measured at the midpoint between the lower margin of the least palpable rib and the top of the iliac crest
Hip circumference	HC	Centimeters (cm)	According to the World Health Organization, measured around the widest portion of the buttocks
Waist-to-hip ratio	WTHR	A ratio of waist circumference to hip circumference	Divide waist circumference by hip circumference
Body fat percentage	BF%	Percentage (%)	Dual energy x-ray absorptiometry (DEXA) or bioelectrical impedance analysis (BIA) or hydrodensitometry or near infrared interactance or skinfold estimates
Trunk fat percentage	TF%	Percentage (%)	Dual energy x-ray absorptiometry (DEXA) or bioelectrical impedance analysis (BIA)
Total leg fat percentage	LF%	Percentage (%)	Dual energy x-ray absorptiometry (DEXA) or bioelectrical impedance analysis (BIA)
Subcutaneous abdominal fat	AF	Centimeters cubed (cm ³)	Computed tomography (CT) scan
Visceral fat	VF	Centimeters cubed (cm ³)	Computed tomography (CT) scan
Suprailiac skinfold thickness	SISF	Millimeters (mm)	Measure the thickness of skin at the suprailiac, with the use of calipers
Abdominal skinfold thickness	ASF	Millimeters (mm)	Measure the thickness of skin at the suprailiac, with the use of calipers

Ambikairajah. Fat mass changes during menopause. Am J Obstet Gynecol 2019.

SUPPLEMENTARY TABLE 2
Table of study characteristics for cross-sectional studies

Study	Year	Sample size, n	Premeno- pausal women		Postmeno- pausal women		Body mass index	Body-weight	Waist circumference	Waist-to-hip ratio	Total body fat percentage	Hip circumference	Subcutaneous abdominal fat	Visceral fat	Suprailiac skinfold thickness	Trunk fat percentage	Abdominal skinfold thickness	Leg fat percentage
			Mean age, y	Standard deviation	Mean age, y	Standard deviation												
Abate et al ¹	2014	205	46.7	1.9	52.7	3.4	*	—	—	—	—	—	—	—	—	—	—	—
Abdulnour et al ²	2012	65	52.3	0.5	54.4	2	*	*	*	—	*	—	—	—	—	—	—	—
	2012	31	50.95	1.31	52.76	2.16	*	*	*	—	*	—	*	*	—	—	—	—
Abildgaard et al ³	2013	33	49.6	1.8	52	2	—	*	—	—	—	—	—	—	—	—	—	—
Adams-Campbell et al ⁴	1996	164	39.3	6.9	58.9	10.1	*	*	—	—	—	—	—	—	—	—	—	—
Agrinier et al ⁵	2010	1355	42.8	4.4	57.4	5.4	*	—	*	—	—	—	—	—	—	—	—	—
Aguado et al ⁶	1996	80	38.8	8.4	60.6	9.6	*	*	—	—	—	—	—	—	—	—	—	—
Albanese et al ⁷	2009	289	48.8	3.8	53.6	3.7	*	*	—	—	—	—	—	—	—	—	—	—
Allali et al ⁸	2009	200	43.9	6.3	61.5	8.8	*	—	—	—	—	—	—	—	—	—	—	—
Aloia et al ⁹	1995	39	37.5	5.82	54.1	7.96	*	*	—	—	—	—	—	—	—	—	—	—
	1995	125	40.2	7.2	62.5	7.81	*	*	—	—	—	—	—	—	—	—	—	—
Amankwah et al ¹⁰	2013	1,031	46.3	6.5	62.7	7.2	*	—	*	*	—	*	—	—	—	—	—	—
Amarante et al ¹¹	2011	80	43.96	7.08	52.16	3.65	*	—	—	—	—	—	—	—	—	—	—	—
Amiri et al ¹²	2014	340	36.8	11.52	59	7.48	*	—	*	—	—	—	—	—	—	—	—	—
Angsuwanthana et al ¹³	2007	697	49.4	3.39	53.19	5.94	*	*	—	—	—	—	—	—	—	—	—	—
Armellini et al ¹⁴	1996	72	NA		NA		—	—	*	—	—	—	—	—	—	—	—	—
Arthur et al ¹⁵	2013	250	34.48	8.85	57.25	8.28	*	—	*	*	—	—	—	—	—	—	—	—
Aydin et al ¹⁶	2010	1,106	48.7	2.6	54	3.4	*	—	—	—	—	—	—	—	—	—	—	—
Ayub et al ¹⁷	2006	80	42.46	7.3	51.15	7.71	*	*	—	*	—	—	—	—	—	—	—	—
Bancroft and Cawood ¹⁸	1996	103	47.6	3.7	55.4	3.05	*	—	—	—	—	—	—	—	—	—	—	—
Bednarek-Tupikowska et al ¹⁹	2006	94	48.3	2.3	50.5	3	*	*	—	*	—	—	—	—	—	—	—	—
Bell et al ²⁰	2007	587	38.9	7.9	62.8	8.3	*	*	—	—	—	—	—	—	—	—	—	—
Ben-Ali et al ²¹	2016	242	39.48	7.79	57.87	7.65	*	—	*	—	—	—	—	—	—	—	—	—
Ben-Ali et al ²²	2014	2,680	42.9	5	57.5	7.3	*	—	*	—	—	—	—	—	—	—	—	—
Ben-Ali et al ²³	2011	376	35.3	7.6	53.4	6.2	*	—	—	—	—	—	—	—	—	—	—	—

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(continued)

SUPPLEMENTARY TABLE 2

Table of study characteristics for cross-sectional studies (continued)

Study	Year	Sample size, n	Premeno-pausal women		Postmeno-pausal women		Body mass index	Body-weight	Waist circumference	Waist-to-hip ratio	Total body fat percentage	Hip circumference	Subcutaneous abdominal fat	Visceral fat	Suprailiac skinfold thickness	Trunk fat percentage	Abdominal skinfold thickness	Leg fat percentage
			Mean age, y	Standard deviation	Mean age, y	Standard deviation												
Berg et al ²⁴	2004	50	36.9	4.1	57	5.3	*	—	*	—	—	—	—	—	—	—	—	—
Berge et al ²⁵	1994	159	38.9	7.2	55.3	6.1	*	—	—	—	—	—	—	—	—	—	—	—
Berger et al ²⁶	1995	177	38.2	5	47.7	3.8	*	*	*	*	—	*	—	—	—	—	—	—
Berstad et al ²⁷	2010	4,041	42.83	5.1	56.42	5.46	*	—	—	—	—	—	—	—	—	—	—	—
Bhagat et al ²⁸	2010	214	33.77	6.57	52.16	6.27	—	—	*	—	—	—	—	—	—	—	—	—
Bhurosy and Jeewon ²⁹	2013	400	34	NA	53	NA	*	—	*	*	—	*	—	—	—	—	—	—
Blumenthal et al ³⁰	1991	46	47	2	52	3	—	*	—	—	—	—	—	—	—	—	—	—
Bonithon-Kopp et al ³¹	1990	416	47.8	2.2	52.3	1.8	*	—	—	—	—	—	—	—	—	—	—	—
Caire-Juvera et al ³²	2008	238	44.8	2.39	60.1	3.59	*	*	—	—	*	—	—	—	—	*	—	—
Campesti et al ³³	2016	79	36.2	7.6	55.4	5.1	—	*	—	—	—	—	—	—	—	—	—	—
Carr et al ³⁴	2000	56	35.4	8.6	61	4.1	*	—	—	—	—	—	—	—	—	—	—	—
Castracane et al ³⁵	1998	76	27.3	0.63	55.8	0.85	*	—	—	—	—	—	—	—	—	—	—	—
Catsburg et al ³⁶	2014	3,320	45.8	8.9	67.9	11.2	*	—	—	—	—	—	—	—	—	—	—	—
Cecchini et al ³⁷	2012	12,243	46.34	4.28	60.81	7.51	*	—	—	—	—	—	—	—	—	—	—	—
Cervellati et al ³⁸	2009	260	38.1	6.73	48.5	6.95	*	—	—	*	*	—	—	—	—	*	—	*
Chain et al ³⁹	2017	266	47	5	57	7	*	*	*	*	*	*	—	—	—	—	—	—
Chang et al ⁴⁰	2000	329	36.1	6.5	61.2	6.2	*	—	*	*	*	*	—	—	—	—	—	—
Cho et al ⁴¹	2008	1,002	40.5	7.8	59	6.6	*	*	*	—	—	—	—	—	—	—	—	—
Cifkova et al ⁴²	2008	662	48.9	2.39	52.1	1.92	*	—	—	—	—	—	—	—	—	—	—	—
Copeland et al ⁴³	2006	411	36	8.5	51.5	7.7	*	—	—	—	—	—	—	—	—	—	—	—
Cremonini et al ⁴⁴	2013	235	35.2	10.7	55.5	4.8	*	—	*	*	*	—	—	—	—	*	—	*
Cui et al ⁴⁵	2007	703	38.4	8.6	63.3	6.5	—	*	—	—	—	—	—	—	—	—	—	—
D'haeseleer et al ⁴⁶	2011	75	48.3	2.3	58.8	5.4	*	—	—	—	—	—	—	—	—	—	—	—
Da Camara et al ⁴⁷	2015	237	44.63	3.36	54.47	5.24	*	—	—	—	—	—	—	—	—	—	—	—
Dallongeville et al ⁴⁸	1995	2,167	48.3	3.4	57.4	3.9	*	—	—	—	—	—	—	—	—	—	—	—
Dancey et al ⁴⁹	2001	1,315	35	5.65	65	6.83	*	—	—	—	—	—	—	—	—	—	—	—
Davis et al ⁵⁰	1994	729	48.1	1.7	50.2	1.7	*	—	—	—	—	—	—	—	—	—	—	—

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(continued)

SUPPLEMENTARY TABLE 2

Table of study characteristics for cross-sectional studies (continued)

Study	Year	Sample size, n	Premeno-pausal women		Postmeno-pausal women		Body mass index	Body-weight	Waist circumference	Waist-to-hip ratio	Total body fat percentage	Hip circumference	Subcutaneous abdominal fat	Visceral fat	Suprailiac skinfold thickness	Trunk fat percentage	Abdominal skinfold thickness	Leg fat percentage
			Mean age, y	Standard deviation	Mean age, y	Standard deviation												
De Kat et al ⁵¹	2017	53,911	36.9	8.1	55.3	7.4	*	—	—	—	—	—	—	—	—	—	—	—
Den Tonkelaar et al ⁵²	1990	9,491	44	3.6	57.8	7.4	*	*	*	*	—	*	—	—	—	—	—	—
Dmitruk et al ⁵³	2018	267	44.48	2.22	66.59	6.69	—	*	*	—	*	*	—	—	*	—	*	—
Donato et al ⁵⁴	2006	168	44.3	3.6	53.3	3.8	*	*	*	*	—	—	—	—	—	—	—	—
Douchi et al ⁵⁵	1997	324	36.6	9.4	62.1	7.7	*	*	—	—	*	—	—	—	—	—	—	—
Douchi et al ⁵⁶	2002	566	39.1	9.1	61.5	7.2	*	*	—	—	*	—	—	—	—	—	—	—
Douchi et al ⁵⁷	2007	642	39	9	61.5	7.4	*	*	—	—	*	—	—	—	—	*	—	—
Dubois et al ⁵⁸	2001	217	39	9	63	8	*	*	—	—	—	—	—	—	—	—	—	—
Engmann et al ⁵⁹	2017	184,309	46.27	3.75	61.72	7.2	*	—	—	—	—	—	—	—	—	—	—	—
Ertungealp et al ⁶⁰	1999	185	NA		NA		*	—	—	—	—	—	—	—	—	—	—	—
Feng et al ⁶¹	2008	3,820	43.7	3	51	2.6	*	*	*	*	*	—	—	—	—	—	—	—
Formica et al ⁶²	1995	54	26.3	3.64	69	4.68	—	*	—	—	—	—	—	—	—	—	—	—
	1995	46	26.5	3.82	64.9	4.23	—	*	—	—	—	—	—	—	—	—	—	—
Friedenreich et al ⁶³	2007	285,685	41.11	6.9	58.76	6.25	*	—	*	*	—	*	—	—	—	—	—	—
Friedenreich et al ⁶⁴	2002	1,237	44.3	5.9	62.8	9	*	*	*	*	—	*	—	—	—	—	—	—
Fu et al ⁶⁵	2011	527	38	8.6	61	7.2	*	*	—	—	*	—	—	—	—	—	—	—
Fuh et al ⁶⁶	2003	997	43.6	2.9	49.4	3.8	*	—	—	—	—	—	—	—	—	—	—	—
Gambacciani et al ⁶⁷	1999	812	41.3	7.8	55	4.16	*	*	—	—	—	—	—	—	—	—	—	—
Genazzani and Gambacciani ⁶⁸	2006	1,425	42.3	9.3	53	5.95	*	*	—	—	—	—	—	—	—	—	—	—
Ghosh ⁶⁹	2008	200	40.2	6.5	55.4	5.2	*	—	*	*	—	—	—	—	—	—	—	—
Ghosh and Bhagat ⁷⁰	2010	245	32.66	5.75	52.72	5.62	*	—	*	*	*	—	—	—	—	—	—	—
Gram et al ⁷¹	1997	3,076	44.3	3.5	51.7	3.6	*	*	—	—	—	—	—	—	—	—	—	—
Guo et al ⁷²	2015	132,793	45.5	3.4	59.7	5.5	*	*	*	*	*	*	—	—	—	*	—	—
Gurka et al ⁷³	2016	2,177	47.6	3.4	54.3	3.6	—	—	*	—	—	—	—	—	—	—	—	—
	2016	779	47.4	2.1	53.1	4.1	—	—	*	—	—	—	—	—	—	—	—	—
Hadji et al ⁷⁴	2000	434	36.5	10.4	61.8	8.9	*	*	—	—	—	—	—	—	—	—	—	—
Hagner et al ⁷⁵	2009	118	36.5	5.17	62.5	5.43	*	—	—	—	—	—	—	—	—	—	—	—

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(continued)

SUPPLEMENTARY TABLE 2

Table of study characteristics for cross-sectional studies (continued)

Study	Year	Sample size, n	Premeno-pausal women		Postmeno-pausal women		Body mass index	Body-weight	Waist circumference	Waist-to-hip ratio	Total body fat percentage	Hip circumference	Subcutaneous abdominal fat	Visceral fat	Suprailiac skinfold thickness	Trunk fat percentage	Abdominal skinfold thickness	Leg fat percentage
			Mean age, y	Standard deviation	Mean age, y	Standard deviation												
Han et al ⁷⁶	2006	2,105	44.1	4.6	63.4	8.9	—	*	*	—	—	—	—	—	—	—	—	—
Harting et al ⁷⁷	1984	45	33.8	8.2	50.4	3.8	—	*	—	—	*	—	—	—	—	—	—	—
	1984	47	37.9	8.2	46.1	8.2	—	*	—	—	*	—	—	—	—	—	—	—
	1984	44	36.9	8.1	47	7.3	—	*	—	—	*	—	—	—	—	—	—	—
He et al ⁷⁸	2012	4,743	45.8	3.6	54	3.6	*	—	*	*	—	—	—	—	—	—	—	—
Hirose et al ⁷⁹	2003	16,132	42.2	NA	60	NA	*	*	—	—	—	—	—	—	—	—	—	—
	2003	1,716	38	NA	61.4	NA	*	*	—	—	—	—	—	—	—	—	—	—
Hjartaker et al ⁸⁰	2005	102,469	40.7	5	45.4	4.1	*	—	—	—	—	—	—	—	—	—	—	—
Ho et al ⁸¹	2010	161	NA		NA		—	—	—	—	*	—	—	—	—	—	—	—
Hsu et al ⁸²	2006	6,833	41.5	5.3	52.6	4.7	*	*	—	—	*	—	—	—	—	—	—	—
Hu et al ⁸³	2016	887	NA		NA		—	—	—	—	*	—	—	—	—	—	—	—
Hunter et al ⁸⁴	1996	220	36.2	9	51.5	10.2	—	*	—	—	*	—	*	*	—	—	—	—
Iida et al ⁸⁵	2011	111	47.6	3.8	61.3	6.6	*	*	—	—	*	—	—	—	—	—	—	—
Ilich-Ermst et al ⁸⁶	2002	51	33	9.2	61.9	3.3	*	*	—	—	*	—	—	—	—	—	—	—
Ito et al ⁸⁷	1994	251	38.8	10	58.6	5.8	—	*	—	—	—	—	—	—	—	—	—	—
Jaff et al ⁸⁸	2015	338	45.1	3.3	51.8	3.86	*	—	*	—	—	*	—	—	—	—	—	—
Jasienska et al ⁸⁹	2005	1,003	48.5	2.81	57.4	4.41	*	—	—	—	—	—	—	—	—	—	—	—
Jeendumang et al ⁹⁰	2014	361	42.58	6.62	58.17	9.65	*	—	*	—	—	—	—	—	—	—	—	—
Jeon et al ⁹¹	2011	1971	49.3	8.5	51.2	9	*	*	*	—	—	—	—	—	—	—	—	—
Jurimae and Jurimae ⁹²	2007	91	40.8	5.7	56.7	3.6	*	*	—	*	*	—	—	—	—	—	—	—
Kadam et al ⁹³	2010	172	45.6	4.8	54	7.1	—	—	*	—	—	*	—	—	*	—	—	—
Kang et al ⁹⁴	2016	264	47.9	3.3	60.8	6	*	*	—	—	—	—	*	*	—	—	—	—
Kaufer-Horwitz et al ⁹⁵	2005	980	33.7	8.4	58.3	6.9	*	*	*	*	—	*	—	—	—	—	—	—
Kim et al ⁹⁶	2007	2,671	35.4	8.1	65.1	9.3	*	—	*	—	—	—	—	—	—	—	—	—
Kim et al ⁹⁷	2012	1,758	50.7	2.8	65	7.4	*	*	*	*	*	—	—	—	—	—	—	—
Kim et al ⁹⁸	2013	617	42.12	6.22	56.48	6.55	*	—	*	—	—	—	—	—	—	—	—	—
Kim et al ⁹⁹	2016	10,088	36.9	8.7	64	9.7	*	*	*	—	*	—	—	—	—	—	—	—

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(continued)

SUPPLEMENTARY TABLE 2

Table of study characteristics for cross-sectional studies (continued)

Study	Year	Sample size, n	Premeno-pausal women		Postmeno-pausal women		Body mass index	Body-weight	Waist circumference	Waist-to-hip ratio	Total body fat percentage	Hip circumference	Subcutaneous abdominal fat	Visceral fat	Suprailiac skinfold thickness	Trunk fat percentage	Abdominal skinfold thickness	Leg fat percentage
			Mean age, y	Standard deviation	Mean age, y	Standard deviation												
Kirchengast et al ¹⁰⁰	1998	77	27.1	NA	55.8	NA	*	*	—	—	*	—	—	—	—	*	—	—
Kirchengast et al ¹⁰¹	1996	459	26.8	NA	52.1	NA	—	*	*	—	—	*	—	—	—	—	—	—
Knapp et al ¹⁰²	2001	409	40.3	9.5	59.9	7.5	*	*	—	—	—	—	—	—	—	—	—	—
Koh et al ¹⁰³	2008	160	44.2	2.92	54.5	4.35	*	—	*	*	*	—	*	*	—	—	—	—
Konrad et al ¹⁰⁴	2011	51	43	5	53	4	*	*	*	—	—	*	—	—	—	—	—	—
Kontogianni et al ¹⁰⁵	2004	80	47.8	3.14	54.47	5.36	*	—	—	*	*	—	—	—	—	—	—	—
Konukoglu et al ¹⁰⁶	2000	75	35.4	8.3	49.5	4.7	*	—	—	—	—	—	—	—	—	—	—	—
Koskova et al ¹⁰⁷	2007	93	42.54	2.5	59.53	2.71	*	*	*	*	—	*	—	—	*	—	*	—
Kotani et al ¹⁰⁸	2011	262	44.7	4.9	64.6	4.4	*	—	—	—	—	—	—	—	—	—	—	—
Kraemer et al ¹⁰⁹	2001	141	26.8	4.9	57.63	7.47	*	—	—	—	—	—	—	—	—	—	—	—
Kuk et al ¹¹⁰	2005	251	37.6	8.6	66.7	8	*	—	*	—	*	—	—	—	—	—	—	—
Laitinen et al ¹¹¹	1991	257	36.7	9	59.6	6.4	—	*	—	—	—	—	—	—	—	—	—	—
Lejskova et al ¹¹²	2012	480	48.6	2.4	52.2	2	*	—	*	*	—	*	—	—	—	—	—	—
Leon-Guerrero et al ¹¹³	2017	275	43.94	6.63	58.44	8.69	*	*	*	—	—	—	—	—	—	—	—	—
Ley et al ¹¹⁴	1992	131	32	6	53	5	*	*	—	—	—	—	—	—	—	—	—	—
Lin et al ¹¹⁵	2006	594	46	3.6	53.1	4.4	*	*	*	—	—	—	—	—	—	—	—	—
Lindquist and Bengtsson ¹¹⁶	1980	326	50	NA	50	NA	—	*	—	—	—	—	—	—	—	—	—	—
Lindsay et al ¹¹⁷	1992	150	39.65	9.98	59.34	8.37	*	*	—	—	*	—	—	—	—	—	—	—
Lovejoy et al ¹¹⁸	2008	85	50.2	0.3	52.1	0.3	—	*	—	—	*	—	*	*	—	—	—	—
Lyu et al ¹¹⁹	2001	203	45.1	3.4	53.4	5	*	*	*	*	—	*	—	—	—	—	—	—
Maharlouei et al ¹²⁰	2013	924	46.5	5	58.6	6.7	*	—	*	*	—	—	—	—	—	—	—	—
Malacara et al ¹²¹	2002	901	46.8	3.1	50.9	4.4	*	*	—	—	—	—	—	—	—	—	—	—
	2002	1,180	45.2	2.9	49.8	3.28	*	*	—	—	—	—	—	—	—	—	—	—
	2002	546	44.8	3.6	49.9	4.2	*	*	—	—	—	—	—	—	—	—	—	—
	2002	2,000	45.1	3.4	50.8	3.4	*	*	—	—	—	—	—	—	—	—	—	—
	2002	1,008	44.3	2.4	50.6	2.6	*	*	—	—	—	—	—	—	—	—	—	—
	2002	2,000	45.4	2.6	51	2.4	*	*	—	—	—	—	—	—	—	—	—	—

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(continued)

SUPPLEMENTARY TABLE 2

Table of study characteristics for cross-sectional studies (continued)

Study	Year	Sample size, n	Premeno-pausal women		Postmeno-pausal women		Body mass index	Body-weight	Waist circumference	Waist-to-hip ratio	Total body fat percentage	Hip circumference	Subcutaneous abdominal fat	Visceral fat	Suprailiac skinfold thickness	Trunk fat percentage	Abdominal skinfold thickness	Leg fat percentage
			Mean age, y	Standard deviation	Mean age, y	Standard deviation												
Manabe et al ¹²²	1999	254	45.7	4.2	60.3	5.5	*	*	*	*	—	*	—	—	—	—	—	—
Manjer et al ¹²³	2001	9,738	42.8	7.9	54.1	3	*	*	—	—	—	—	—	—	—	—	—	—
Mannisto et al ¹²⁴	1996	417	43.3	6	59.8	7.7	*	*	—	*	*	—	—	—	—	—	—	—
Martini et al ¹²⁵	1997	757	43.2	6.7	59.9	8.1	*	*	—	—	*	—	—	—	—	—	—	—
Marwaha et al ¹²⁶	2013	1,423	31	8.6	64.5	7.4	*	*	—	—	—	—	—	—	—	—	—	—
Matsushita et al ¹²⁷	2003	281	43	6.3	62.4	7.9	*	*	—	—	—	—	—	—	—	—	—	—
Matsuzaki et al ¹²⁸	2017	1,760	29.3	9.9	46.8	6.9	*	*	—	—	—	—	—	—	—	—	—	—
Matthews et al ¹²⁹	1989	138	47.3	1.5	47.8	1.6	*	*	—	—	—	—	—	—	—	—	—	—
Mesch et al ¹³⁰	2006	60	33	5.6	55	5.6	*	—	*	*	—	—	—	—	—	—	—	—
Meza-Munoz et al ¹³¹	2006	113	40.03	7.16	53.75	4.28	*	—	—	—	—	—	—	—	—	—	—	—
Minatoya et al ¹³²	2014	66	NA		NA		*	—	—	—	—	—	—	—	—	—	—	—
Mo et al ¹³³	2017	200	41.7	6.3	59.7	6.8	*	*	—	*	*	—	—	—	—	—	—	—
	2017	200	42	5.4	59.8	7	*	*	—	*	*	—	—	—	—	—	—	—
	2017	216	42.1	6.4	60.8	8.1	*	*	—	*	*	—	—	—	—	—	—	—
	2017	244	43.2	7	60.8	7.6	*	*	—	*	*	—	—	—	—	—	—	—
Muchanga et al ¹³⁴	2014	200	44	3	53	4	*	—	*	—	—	—	—	—	—	—	—	—
Muti et al ¹³⁵	2000	576	44.5	4.8	57.7	5.1	*	—	—	*	—	—	—	—	—	—	—	—
Nitta et al ¹³⁶	2016	38,610	45.5	3.8	62.4	7.8	—	*	—	—	—	—	—	—	—	—	—	—
Noh et al ¹³⁷	2013	540	46.92	4.7	59.34	5.82	*	—	—	—	—	—	—	—	—	—	—	—
Nordin et al ¹³⁸	1992	259	43.1	7.5	59.9	8.5	—	*	—	—	—	—	—	—	—	—	—	—
Ohta et al ¹³⁹	2010	373	14.8	1.7	71.9	4.5	*	*	—	—	—	—	—	—	—	—	—	—
Oldroyd et al ¹⁴⁰	1998	211	37.2	8.8	61.6	7.9	—	*	—	—	—	—	—	—	—	—	—	—
Pacholczak et al ¹⁴¹	2016	294	41.8	6.1	63.4	10.2	*	*	*	*	—	*	—	—	*	—	—	—
Park et al ¹⁴²	2012	1,020	37	7.25	58.5	7.7	—	*	—	—	*	—	—	—	—	—	—	*
Park et al ¹⁴³	2017	43,599	45.6	5	59.6	6.8	*	*	*	*	—	*	—	—	—	—	—	—
Pavicic Zezelj et al ¹⁴⁴	2010	535	45.6	6	58.79	8.2	*	*	—	—	—	—	—	—	—	—	—	—
Pavlica et al ¹⁴⁵	2013	160	38.87	9.81	58.42	1.01	*	*	—	—	—	—	—	—	—	—	—	—

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(continued)

SUPPLEMENTARY TABLE 2

Table of study characteristics for cross-sectional studies (continued)

Study	Year	Sample size, n	Premeno-pausal women		Postmeno-pausal women		Body mass index	Body-weight	Waist circumference	Waist-to-hip ratio	Total body fat percentage	Hip circumference	Subcutaneous abdominal fat	Visceral fat	Suprailiac skinfold thickness	Trunk fat percentage	Abdominal skinfold thickness	Leg fat percentage
			Mean age, y	Standard deviation	Mean age, y	Standard deviation												
Phillips et al ¹⁴⁶	2008	78	32.9	9.14	61.4	10.73	*	*	*	*	—	—	—	—	—	—	—	—
Polesel et al ¹⁴⁷	2015	311	34.83	8.4	52.63	5.72	*	—	*	—	—	—	—	—	—	—	—	—
Pollan et al ¹⁴⁸	2012	3,574	49	2.9	58	4.5	*	*	*	*	—	*	—	—	—	—	—	—
Portaluppi et al ¹⁴⁹	1997	1,376	48	3.1	53.3	4.2	*	—	—	—	—	—	—	—	—	—	—	—
Priya et al ¹⁵⁰	2013	65	38.65	6.21	55.32	6.32	*	*	*	*	—	*	—	—	—	—	—	—
Rantalainen et al ¹⁵¹	2010	303	23	4.7	57.7	4.2	*	*	—	—	—	—	—	—	—	—	—	—
Reina et al ¹⁵²	2015	192	33	11	58.9	8.9	—	*	—	—	—	—	—	—	—	—	—	—
Revilla et al ¹⁵³	1997	151	37.4	7.2	59.9	9.7	*	*	—	—	—	—	—	—	—	—	—	—
Revilla et al ¹⁵⁴	1997	144	36.1	6.9	60.6	10.5	*	*	—	—	—	—	—	—	—	—	—	—
Rice et al ¹⁵⁵	2015	1,607	43.3	4.1	53.4	5.3	*	—	—	—	—	—	—	—	—	—	—	—
Rico et al ¹⁵⁶	2001	270	35.1	7.7	59.5	9.8	*	*	—	—	—	—	—	—	—	—	—	—
Rico et al ¹⁵⁷	2002	297	34	7	59	9	*	*	—	—	—	—	—	—	—	—	—	—
Roelfsema et al ¹⁵⁸	2016	91	35.83	6.84	59.08	6.81	*	—	—	—	—	—	—	—	—	—	—	—
Rosenbaum et al ¹⁵⁹	1996	41	27	8.94	66	9.17	*	*	—	—	*	—	—	—	—	—	—	—
Salomaa et al ¹⁶⁰	1995	778	47.4	2.4	57.9	4.9	*	—	—	—	—	—	—	—	—	—	—	—
Sarrafzadegan et al ¹⁶¹	2013	4,143	32.15	9.22	59.8	10.39	*	*	*	*	—	—	—	—	—	—	—	—
Schaberg-Lorei et al ¹⁶²	1990	109	42.3	4.8	58.4	5.1	—	*	*	—	*	—	—	—	*	—	*	—
Schwarz et al ¹⁶³	2007	1,119	45.6	4.2	64.6	8	*	—	—	—	—	—	—	—	—	—	—	—
Shakir et al ¹⁶⁴	2004	4,092	53.2	1.6	56.9	2.9	—	—	—	*	—	—	—	—	—	—	—	—
Sherk et al ¹⁶⁵	2011	73	22.8	2.74	64	3.93	—	*	—	—	*	—	—	—	—	—	—	—
Shibata et al ¹⁶⁶	1979	448	46.9	1.4	47.4	1.4	*	—	—	—	—	—	—	—	—	—	—	—
Sieminska et al ¹⁶⁷	2006	131	28.2	4.1	53.9	3.2	*	—	—	*	—	—	—	—	—	—	—	—
Skrzypczak and Szwed ¹⁶⁸	2005	1,647	43.66	4.07	56.01	7.08	*	—	—	—	—	—	—	—	—	—	—	—
Skrzypczak et al ¹⁶⁹	2007	10,216	43.43	4.93	62.87	8.53	*	—	—	—	—	—	—	—	—	—	—	—
Soderberg et al ¹⁷⁰	2002	75	37.9	7.9	60.7	6.1	*	—	*	*	—	*	—	—	*	—	—	—
Son et al ¹⁷¹	2015	1,470	46.8	2.5	52.2	3.1	*	—	*	—	—	—	—	—	—	—	—	—

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(continued)

SUPPLEMENTARY TABLE 2

Table of study characteristics for cross-sectional studies (continued)

Study	Year	Sample size, n	Premeno-pausal women		Postmeno-pausal women		Body mass index	Body-weight	Waist circumference	Waist-to-hip ratio	Total body fat percentage	Hip circumference	Subcutaneous abdominal fat	Visceral fat	Suprailiac skinfold thickness	Trunk fat percentage	Abdominal skinfold thickness	Leg fat percentage
			Mean age, y	Standard deviation	Mean age, y	Standard deviation												
Soriguer et al ¹⁷²	2009	409	36.9	7.5	64.1	5.2	*	—	*	*	—	—	—	—	*	—	—	—
Staessen et al ¹⁷³	1989	462	42.6	5.1	53	5	*	*	—	—	*	—	—	—	—	—	—	—
Suarez-Ortegon et al ¹⁷⁴	2012	123	42.2	5.6	51.8	6.8	*	—	*	—	*	—	—	—	—	—	—	—
Suliga et al ¹⁷⁵	2016	3,636	49.7	3.1	55.2	3	*	—	*	—	*	—	—	—	—	—	—	—
Sumner et al ¹⁷⁶	1998	65	32.6	3.7	57.8	5.9	*	*	—	—	*	—	—	—	—	—	—	—
Tanaka et al ¹⁷⁷	2015	464	41.4	6.5	62.8	6.8	*	*	—	—	*	—	—	—	—	*	—	—
Thomas et al ¹⁷⁸	2000	302	35	8.6	69.8	13.1	*	*	—	—	—	—	—	—	—	—	—	—
Torng et al ¹⁷⁹	2000	1,543	42.7	5.8	61.2	9.5	*	*	—	—	—	—	—	—	—	—	—	—
Toth et al ¹⁸⁰	2000	81	47	3	51	4	*	*	—	—	*	—	*	*	—	—	—	—
Tremollieres et al ¹⁸¹	1996	168	49.3	3.2	53.8	3.1	*	*	—	—	—	—	—	—	—	—	—	—
Trikudanathan et al ¹⁸²	2013	170	49.3	3	49.4	3	*	—	*	—	—	—	*	*	—	—	—	—
Van-Pelt et al ¹⁸³	1998	31	29	4.12	61	4.36	*	*	*	—	*	—	—	—	*	—	*	—
	1998	58	30	5.48	56	5.57	*	*	*	—	*	—	—	—	*	—	*	—
Veldhuis et al ¹⁸⁴	2016	120	34	9.3	64	8.52	*	—	—	—	—	—	*	*	—	—	—	—
Wang et al ¹⁸⁵	2012	1,526	44.2	6.6	56.3	4.6	—	—	—	—	*	—	—	—	—	—	—	—
Wang et al ¹⁸⁶	2006	346	33.36	9.2	66.75	10.75	*	—	—	—	—	—	—	—	—	—	—	—
Wang et al ¹⁸⁷	2012	1,143	49.13	2.72	64.72	7.61	*	—	*	*	—	*	—	—	—	—	—	—
Wee et al ¹⁸⁸	2013	283	45.81	1.12	56.8	1.84	*	—	—	—	—	—	—	—	—	—	—	—
Williams et al ¹⁸⁹	1997	115	32.7	10.9	63.9	11.6	*	—	—	—	—	—	—	—	—	—	—	—
Wing et al ¹⁹⁰	1991	340	NA		NA		*	*	—	—	—	—	—	—	*	—	—	—
Xu et al ¹⁹¹	2010	252	44.7	4.1	70.7	6.3	*	*	—	—	—	—	—	—	—	—	—	—
Yamatani et al ¹⁹²	2013	40	42.6	7.35	60.6	7.5	*	*	—	—	—	—	*	*	—	—	—	—
Yannakoulia et al ¹⁹³	2007	114	38.6	7.7	57.5	6.2	*	*	*	*	*	—	—	—	—	—	—	—
Yoldemir and Erenus ¹⁹⁴	2012	190	45.27	2.93	57.02	6.15	*	*	—	*	—	—	—	—	—	—	—	—
Yoo et al ¹⁹⁵	2012	358	34.2	9.7	61.1	7.7	*	*	*	*	*	—	*	*	—	—	—	—

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(continued)

SUPPLEMENTARY TABLE 2

Table of study characteristics for cross-sectional studies (continued)

Study	Year	Sample size, n	Premeno-pausal women		Postmeno-pausal women		Body mass index	Body-weight	Waist circumference	Waist-to-hip ratio	Total body fat percentage	Hip circumference	Subcutaneous abdominal fat	Visceral fat	Suprailiac skinfold thickness	Trunk fat percentage	Abdominal skinfold thickness	Leg fat percentage
			Mean age, y	Standard deviation	Mean age, y	Standard deviation												
Yoo et al ¹⁹⁶	1998	306	NA		NA		*	*	—	—	—	—	—	—	—	—	—	—
Yoshimoto et al ¹⁹⁷	2011	278	41.8	6.2	62.1	8.2	*	*	—	—	—	—	—	—	—	—	—	—
Zhong et al ¹⁹⁸	2005	676	NA		NA		*	*	—	—	—	—	—	—	—	—	—	—
Zhou et al ¹⁹⁹	2010	729	42.2	3.8	53.8	2.8	*	—	—	—	—	—	—	—	—	—	—	—
Zhou et al ²⁰⁰	2015	6,324	44.1	4.8	60	7.8	*	*	*	*	—	—	—	—	—	—	—	—
Zivkovic et al ²⁰¹	2011	271	37	5.3	54	4.5	*	—	*	—	—	—	—	—	—	—	—	—

NA, not available. The asterisk indicates inclusion of the measure.

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SUPPLEMENTARY TABLE 3

Table of study characteristics for longitudinal studies

Study	Year	Sample Size	Mean age, y (standard deviation)		Body mass index	Bodyweight	Waist circumference	Total body fat percentage	Subcutaneous abdominal fat	Visceral fat
			Premenopausal	Postmenopausal						
Abdulnour et al ²	2012	13	50.65 (2.26)	52.76 (2.16)	—	—	—	—	*	*
Akahoshi et al ²⁰²	2001	48	39.40 (1.60)	45.30 (1.50)	*	—	—	—	—	—
	2001	388	44.20 (1.60)	50.10 (1.50)	*	—	—	—	—	—
	2001	565	48.30 (1.70)	54.20 (1.70)	*	—	—	—	—	—
Ford et al ²⁰³	2005	74	40.07 (4.43)	45.77 (4.62)	*	—	—	—	—	—
Franklin et al ²⁰⁴	2009	8	49.30 (1.70)	57.00 (2.26)	*	*	*	*	—	—
Janssen et al ²⁰⁵	2008	859	46.81 (2.52)	52.29 (2.86)	*	—	*	—	—	—
Lee et al ²⁰⁶	2009	69	50.60 (2.60)	54.70 (2.60)	*	*	—	*	*	*
Liu-Ambrose et al ²⁰⁷	2006	53	40.50 (4.70)	53.20 (4.70)	—	*	—	—	—	—
Lovejoy et al ¹¹⁸	2008	51	48.10 (0.30)	52.10 (0.30)	—	*	—	*	*	*
Macdonald et al ²⁰⁸	2005	248	47.72 (1.40)	54.13 (1.52)	*	*	—	—	—	—
Razmjou et al ²⁰⁹	2018	48	49.77 (1.80)	59.97 (1.78)	*	*	*	*	—	—
Soreca et al ²¹⁰	2009	48	47.98 (1.32)	67.98 (1.32)	*	*	—	—	—	—

The asterisk indicates inclusion of the measure.

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SUPPLEMENTARY TABLE 4
Quality assessment of individual cross-sectional studies

Study	Year	Newcastle-Ottawa quality assessment scale (adapted)									Total score (out of 9)
		Selection			Comparability				Outcome		
		Question 1	Question 2	Question 3	Question 4a	Question 4b	Question 5	Question 6	Question 7	Question 8	
Abate et al ¹	2014	—	*	—	*	*	*	*	*	*	7
Abdulnour et al ²	2012	*	*	—	*	*	*	*	*	*	8
Abildgaard et al ³	2013	*	*	—	*	*	*	*	*	*	8
Adams-Campbell et al ⁴	1996	*	*	*	*	—	—	—	—	*	5
Agrinier et al ⁵	2010	*	*	*	*	—	*	*	*	*	8
Aguado et al ⁶	1996	—	*	—	*	—	—	—	*	*	4
Albanese et al ⁷	2009	*	*	—	*	*	*	*	*	*	8
Allali et al ⁸	2009	*	*	—	*	—	—	—	—	—	3
Aloia et al ⁹	1995	*	*	—	*	—	—	—	—	—	3
Amankwah et al ¹⁰	2013	*	*	*	*	—	*	*	*	*	8
Amarante et al ¹¹	2011	—	—	—	*	*	—	*	—	*	4
Amiri et al ¹²	2014	*	*	*	*	—	—	*	*	*	7
Angsuwanthana et al ¹³	2007	*	*	*	*	*	*	*	*	*	9
Armellini et al ¹⁴	1996	*	*	—	—	—	—	—	*	*	4
Arthur et al ¹⁵	2013	*	*	—	*	—	*	*	*	*	7
Aydin et al ¹⁶	2010	*	*	*	*	*	*	*	*	*	9
Ayub et al ¹⁷	2006	—	—	—	*	*	—	—	*	*	4
Bancroft et al ¹⁸	1996	*	*	*	*	*	*	*	*	*	9
Bednarek-Tupikowska et al ¹⁹	2006	—	—	—	*	*	—	—	*	*	4
Bell et al ²⁰	2007	*	*	—	*	—	*	*	*	*	7
Ben-Ali et al ²¹	2016	*	*	—	*	—	—	*	*	*	6
Ben-Ali et al ²²	2014	*	*	—	*	—	—	*	*	*	6
Ben-Ali et al ²³	2011	*	*	—	*	—	*	*	*	*	7
Berg et al ²⁴	2004	—	—	—	*	—	*	*	*	*	5
Berge et al ²⁵	1994	*	*	*	*	—	*	*	—	—	6
Berger et al ²⁶	1995	—	*	—	*	*	*	*	*	*	7
Berstad et al ²⁷	2010	*	*	*	*	—	*	*	—	*	7

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(continued)

SUPPLEMENTARY TABLE 4

Quality assessment of individual cross-sectional studies (continued)

Study	Year	Newcastle-Ottawa quality assessment scale (adapted)									Total score (out of 9)
		Selection			Comparability				Outcome		
		Question 1	Question 2	Question 3	Question 4a	Question 4b	Question 5	Question 6	Question 7	Question 8	
Bhagat et al ²⁸	2010	*	*	—	*	—	*	*	*	*	7
Bhurosy et al ²⁹	2013	*	*	—	*	—	*	*	*	*	7
Blumenthal et al ³⁰	1991	*	*	*	*	*	*	*	—	—	7
Bonithon-Kopp et al ³¹	1990	*	*	—	*	*	*	*	—	—	6
Caire-Juvera et al ³²	2008	*	*	—	*	—	*	*	*	*	7
Campesi et al ³³	2016	—	—	—	*	—	*	*	—	—	3
Carr et al ³⁴	2000	*	*	—	*	—	*	*	—	—	5
Castracane et al ³⁵	1998	—	—	—	*	—	*	—	—	—	2
Catsburg et al ³⁶	2014	*	*	—	*	—	—	—	—	*	4
Cecchini et al ³⁷	2012	*	*	—	—	—	*	*	*	*	6
Cervellati et al ³⁸	2009	—	—	—	*	—	*	*	*	*	5
Chain et al ³⁹	2017	*	*	—	*	*	—	*	*	*	7
Chang et al ⁴⁰	2000	*	*	—	*	—	*	*	*	*	7
Cho et al ⁴¹	2008	*	*	—	*	—	—	*	*	*	6
Cifkova et al ⁴²	2008	*	*	—	*	*	*	*	*	*	8
Copeland et al ⁴³	2006	*	*	—	*	—	*	*	*	*	7
Cremonini et al ⁴⁴	2013	*	*	—	*	—	*	*	*	*	7
Cui et al ⁴⁵	2007	*	*	—	*	—	*	*	*	*	7
D'haeseleer et al ⁴⁶	2011	—	—	*	*	*	*	*	—	*	6
Da Camara et al ⁴⁷	2015	*	*	*	*	*	*	*	*	*	9
Dallongeville et al ⁴⁸	1995	*	*	—	*	*	—	*	*	*	7
Dancey et al ⁴⁹	2001	*	*	—	*	—	*	*	—	—	5
Davis et al ⁵⁰	1994	*	*	—	*	*	*	*	—	—	6
De Kat et al ⁵¹	2017	*	*	—	*	—	*	*	*	*	7
Den Tonkelaar et al ⁵²	1990	*	*	—	*	—	—	*	*	*	6
Dmitruk et al ⁵³	2018	*	*	—	*	—	*	*	*	*	7
Donato et al ⁵⁴	2006	*	*	*	*	*	*	*	*	*	9

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SUPPLEMENTARY TABLE 4

Quality assessment of individual cross-sectional studies (continued)

Study	Year	Newcastle-Ottawa quality assessment scale (adapted)									Total score (out of 9)
		Selection			Comparability				Outcome		
		Question 1	Question 2	Question 3	Question 4a	Question 4b	Question 5	Question 6	Question 7	Question 8	
Douchi et al ⁵⁵	1997	*	*	—	*	—	*	—	*	*	6
Douchi et al ⁵⁶	2002	*	*	—	*	—	*	*	*	*	7
Douchi et al ⁵⁷	2007	*	*	—	*	—	—	*	*	*	6
Dubois et al ⁵⁸	2001	—	*	—	*	—	*	*	—	—	4
Engmann et al ⁵⁹	2017	*	*	—	*	—	*	*	—	*	6
Ertungealp et al ⁶⁰	1999	*	—	—	—	—	—	—	—	—	1
Feng et al ⁶¹	2008	*	*	*	*	—	*	*	*	*	8
Formica et al ⁶²	1995	*	*	—	*	—	—	—	—	—	3
Friedenreich et al ⁶³	2007	*	*	—	*	—	*	*	*	*	7
Friedenreich et al ⁶⁴	2002	*	*	*	*	—	*	*	*	*	8
Fu et al ⁶⁵	2011	*	*	—	*	—	*	*	*	*	7
Fuh et al ⁶⁶	2003	*	*	—	*	*	*	*	*	*	8
Gambacciani et al ⁶⁷	1999	*	*	—	*	—	*	*	*	*	7
Genazzani et al ⁶⁸	2006	*	*	—	*	—	*	*	*	*	7
Ghosh et al ⁶⁹	2008	*	*	—	*	—	*	*	*	*	7
Ghosh et al ⁷⁰	2010	*	*	—	*	—	*	*	*	*	7
Gram et al ⁷¹	1997	*	*	—	*	*	—	*	*	*	7
Guo et al ⁷²	2015	*	*	—	*	—	*	*	*	*	7
Gurka et al ⁷³	2016	*	*	*	*	*	*	*	—	—	7
Hadji et al ⁷⁴	2000	*	*	—	*	—	*	*	*	*	7
Hagner et al ⁷⁵	2009	*	*	—	*	—	*	*	*	*	7
Han et al ⁷⁶	2006	*	*	—	*	—	—	*	*	*	6
Harting et al ⁷⁷	1984	*	*	—	*	—	*	—	—	—	4
He et al ⁷⁸	2012	*	*	—	*	*	*	*	*	*	8
Hirose et al ⁷⁹	2003	*	*	—	*	—	—	—	—	*	4
Hjartaker et al ⁸⁰	2005	*	*	—	*	*	*	*	—	*	7
Ho et al ⁸¹	2010	*	*	*	—	—	*	*	*	*	7

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(continued)

SUPPLEMENTARY TABLE 4

Quality assessment of individual cross-sectional studies (continued)

Study	Year	Newcastle-Ottawa quality assessment scale (adapted)									Total score (out of 9)
		Selection			Comparability				Outcome		
		Question 1	Question 2	Question 3	Question 4a	Question 4b	Question 5	Question 6	Question 7	Question 8	
Hsu et al ⁸²	2006	*	*	—	*	—	—	—	*	*	5
Hu et al ⁸³	2016	*	*	—	—	—	—	—	*	*	4
Hunter et al ⁸⁴	1996	*	*	—	*	—	—	*	*	*	6
Iida et al ⁸⁵	2011	*	*	—	*	—	—	—	*	*	5
Ilich-Ernst et al ⁸⁶	2002	—	—	—	*	—	—	—	*	*	3
Ito et al ⁸⁷	1994	—	—	—	*	—	*	*	—	—	3
Jaff et al ⁸⁸	2015	*	*	—	*	*	*	*	*	*	8
Jasienska et al ⁸⁹	2005	*	*	—	*	*	—	—	*	*	6
Jeendumang et al ⁹⁰	2014	*	*	—	*	—	—	*	*	*	6
Jeon et al ⁹¹	2011	*	*	—	*	*	*	*	*	*	8
Jurimae et al ⁹²	2007	—	—	—	*	—	*	*	*	*	5
Kadam et al ⁹³	2010	*	*	—	*	*	*	*	*	*	8
Kang et al ⁹⁴	2016	*	*	—	*	—	—	—	*	*	5
Kaufer-Horwitz et al ⁹⁵	2005	*	*	—	*	—	*	*	*	*	7
Kim et al ⁹⁶	2007	*	*	—	*	—	—	*	*	*	6
Kim et al ⁹⁷	2012	*	*	—	*	—	—	—	*	*	5
Kim et al ⁹⁸	2013	*	*	*	*	—	—	*	*	*	7
Kim et al ⁹⁹	2016	*	*	—	*	—	—	—	*	*	5
Kirchengast et al ¹⁰⁰	1996	*	*	*	*	—	*	*	*	*	8
Kirchengast et al ¹⁰¹	1998	*	*	*	*	—	*	*	*	*	8
Knapp et al ¹⁰²	2001	*	—	—	*	—	—	—	—	—	2
Koh et al ¹⁰³	2008	*	*	—	*	—	*	*	*	*	7
Konrad et al ¹⁰⁴	2011	*	*	—	*	*	—	*	*	*	7
Kontogianni et al ¹⁰⁵	2004	*	*	*	*	*	—	*	*	*	8
Konukoglu et al ¹⁰⁶	2000	—	—	*	*	—	—	*	—	—	3
Koskova et al ¹⁰⁷	2007	*	*	*	*	—	*	*	*	*	8
Kotani et al ¹⁰⁸	2011	—	—	—	*	—	—	*	*	*	4

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(continued)

SUPPLEMENTARY TABLE 4

Quality assessment of individual cross-sectional studies (continued)

Study	Year	Newcastle-Ottawa quality assessment scale (adapted)									Total score (out of 9)
		Selection			Comparability				Outcome		
		Question 1	Question 2	Question 3	Question 4a	Question 4b	Question 5	Question 6	Question 7	Question 8	
Kraemer et al ¹⁰⁹	2001	*	*	—	*	—	—	—	—	—	3
Kuk et al ¹¹⁰	2005	*	*	—	*	—	—	—	*	*	5
Laitinen et al ¹¹¹	1991	*	*	—	*	—	—	—	—	—	3
Lejskova et al ¹¹²	2012	*	*	—	*	*	*	*	*	*	8
Leon-Guerrero et al ¹¹³	2017	*	*	—	*	—	*	*	*	*	7
Ley et al ¹¹⁴	1992	*	*	—	*	—	*	*	*	*	7
Lin et al ¹¹⁵	2006	*	*	—	*	*	—	*	*	*	7
Lindquist et al ¹¹⁶	1980	*	*	*	*	*	*	*	*	*	9
Lindsay et al ¹¹⁷	1992	*	*	—	*	—	—	—	*	*	5
Lovejoy et al ¹¹⁸	2008	*	*	*	*	*	—	*	*	*	8
Lyu et al ¹¹⁹	2001	*	*	—	*	*	—	*	*	*	7
Maharlouei et al ¹²⁰	2013	*	*	—	*	—	*	*	*	*	7
Malacara et al ¹²¹	2002	*	*	*	*	*	*	*	—	*	8
Manabe et al ¹²²	1999	—	*	—	*	—	—	—	*	*	4
Manjer et al ¹²³	2001	*	*	—	*	—	*	*	*	*	7
Mannisto et al ¹²⁴	1996	*	*	*	*	—	—	—	*	*	6
Martini et al ¹²⁵	1997	*	*	—	*	—	—	*	*	*	6
Marwaha et al ¹²⁶	2013	*	*	—	*	—	*	*	*	*	7
Matsushita et al ¹²⁷	2003	*	*	—	*	—	*	—	*	*	6
Matsuzaki et al ¹²⁸	2017	*	*	—	*	—	—	—	*	*	5
Matthews et al ¹²⁹	1989	*	*	*	*	*	*	*	—	—	7
Mesch et al ¹³⁰	2006	—	—	—	*	—	*	*	*	*	5
Meza-Munoz et al ¹³¹	2006	*	*	—	*	—	*	*	*	*	7
Minatoya et al ¹³²	2014	*	*	—	—	—	—	—	—	—	2
Mo et al ¹³³	2017	*	*	—	*	—	—	—	*	*	5
Muchanga et al ¹³⁴	2014	*	*	*	*	*	*	*	*	*	9
Muti et al ¹³⁵	2000	*	*	—	*	—	—	*	*	*	6

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(continued)

SUPPLEMENTARY TABLE 4

Quality assessment of individual cross-sectional studies (continued)

Study	Year	Newcastle-Ottawa quality assessment scale (adapted)									Total score (out of 9)
		Selection			Comparability				Outcome		
		Question 1	Question 2	Question 3	Question 4a	Question 4b	Question 5	Question 6	Question 7	Question 8	
Nitta et al ¹³⁶	2016	*	*	—	*	—	—	—	—	—	3
Noh et al ¹³⁷	2013	*	*	*	*	—	*	*	*	*	8
Nordin et al ¹³⁸	1992	—	—	—	*	—	—	—	—	—	1
Ohta et al ¹³⁹	2010	*	*	*	*	—	—	—	*	*	6
Oldroyd et al ¹⁴⁰	1998	—	—	—	*	—	—	—	—	—	1
Pacholczak et al ¹⁴¹	2016	*	*	—	*	—	—	*	*	*	6
Park et al ¹⁴²	2012	*	*	—	*	—	—	—	*	*	5
Park et al ¹⁴³	2017	*	*	—	*	—	*	*	—	*	6
Pavicic et al ¹⁴⁴	2010	*	*	—	*	—	*	*	*	*	7
Pavlica et al ¹⁴⁵	2013	*	*	—	*	—	—	—	*	*	5
Phillips et al ¹⁴⁶	2008	*	*	—	*	—	—	*	*	*	6
Polesel et al ¹⁴⁷	2015	*	*	*	*	—	*	*	*	*	8
Pollan et al ¹⁴⁸	2012	*	*	—	*	*	*	*	*	*	8
Portaluppi et al ¹⁴⁹	1997	—	*	*	*	*	*	*	*	*	8
Priya et al ¹⁵⁰	2013	*	*	—	*	—	—	*	*	*	6
Rantalainen et al ¹⁵¹	2010	—	—	—	*	—	*	—	*	*	4
Reina et al ¹⁵²	2015	—	*	—	*	—	—	—	—	—	2
Revilla et al ¹⁵³	1997	*	—	—	*	—	*	*	*	*	6
Revilla et al ¹⁵⁴	1997	*	*	—	*	—	*	*	*	*	7
Rice et al ¹⁵⁵	2015	*	*	—	*	—	*	*	—	*	6
Rico et al ¹⁵⁶	2001	*	—	*	*	—	*	*	*	*	7
Rico et al ¹⁵⁷	2002	*	—	*	*	—	*	*	*	*	7
Roelfsema et al ¹⁵⁸	2016	*	—	—	*	—	*	*	*	*	6
Rosenbaum et al ¹⁵⁹	1996	—	—	—	*	—	*	*	*	*	5
Salomaa et al ¹⁶⁰	1995	*	*	—	*	—	*	*	*	*	7
Sarrafzadegan et al ¹⁶¹	2013	*	*	—	*	—	—	—	*	*	5
Schaberg-Lorei et al ¹⁶²	1990	—	—	—	*	—	—	—	*	*	3

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(continued)

SUPPLEMENTARY TABLE 4

Quality assessment of individual cross-sectional studies (continued)

Study	Year	Newcastle-Ottawa quality assessment scale (adapted)									Total score (out of 9)
		Selection			Comparability				Outcome		
		Question 1	Question 2	Question 3	Question 4a	Question 4b	Question 5	Question 6	Question 7	Question 8	
Schwarz et al ¹⁶³	2007	*	*	—	*	—	*	*	*	*	7
Shakir et al ¹⁶⁴	2004	*	*	*	*	*	*	*	*	*	9
Sherk et al ¹⁶⁵	2011	—	—	—	*	—	—	—	*	*	3
Shibata et al ¹⁶⁶	1979	—	*	—	*	*	—	—	—	—	3
Sieminska et al ¹⁶⁷	2006	—	—	—	*	—	*	*	—	—	3
Skrzypczak et al ¹⁶⁸	2005	*	*	—	*	—	*	*	*	*	7
Skrzypczak et al ¹⁶⁹	2007	*	*	—	*	—	*	*	*	*	7
Soderberg et al ¹⁷⁰	2002	*	*	—	*	—	*	*	*	*	7
Son et al ¹⁷¹	2015	*	*	—	*	*	*	*	*	*	8
Soriguer et al ¹⁷²	2009	*	*	—	*	—	—	*	*	*	6
Staessen et al ¹⁷³	1989	—	—	—	*	—	—	*	*	*	4
Suarez-Ortegon et al ¹⁷⁴	2012	—	—	—	*	*	—	—	*	*	4
Suliga et al ¹⁷⁵	2016	*	*	—	*	*	—	*	*	*	7
Sumner et al ¹⁷⁶	1998	—	—	—	*	—	—	*	*	*	4
Tanaka et al ¹⁷⁷	2015	—	—	—	*	—	*	*	*	*	5
Thomas et al ¹⁷⁸	2000	*	*	—	*	—	—	*	*	*	6
Torng et al ¹⁷⁹	2000	*	*	—	*	—	—	*	*	*	6
Toth et al ¹⁸⁰	2000	—	*	*	*	*	*	*	*	*	8
Tremollieres et al ¹⁸¹	1996	*	*	*	*	*	—	*	*	*	8
Trikudanathan et al ¹⁸²	2013	*	*	*	*	*	—	*	*	*	8
Van-Pelt et al ¹⁸³	1998	—	—	*	*	—	*	*	*	*	6
Veldhuis et al ¹⁸⁴	2016	*	*	*	*	—	—	*	*	*	7
Wang et al ¹⁸⁵	2012	*	*	—	*	—	—	—	*	*	5
Wang et al ¹⁸⁶	2006	*	*	—	*	—	—	*	*	*	6
Wang et al ¹⁸⁷	2012	*	*	—	*	—	*	*	—	*	6
Wee et al ¹⁸⁸	2013	—	*	—	*	—	*	*	*	*	6
Williams et al ¹⁸⁹	1997	*	*	—	*	—	*	*	*	*	7

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(continued)

SUPPLEMENTARY TABLE 4

Quality assessment of individual cross-sectional studies (continued)

Study	Year	Newcastle-Ottawa quality assessment scale (adapted)									Total score (out of 9)
		Selection			Comparability				Outcome		
		Question 1	Question 2	Question 3	Question 4a	Question 4b	Question 5	Question 6	Question 7	Question 8	
Wing et al ¹⁹⁰	1991	*	*	—	—	—	*	*	*	*	6
Xu et al ¹⁹¹	2010	*	*	*	*	—	*	*	*	*	8
Yamatani et al ¹⁹²	2013	*	*	*	*	—	—	*	*	*	7
Yannakoulia et al ¹⁹³	2007	*	*	*	*	—	*	*	*	*	8
Yoldemir et al ¹⁹⁴	2012	*	*	*	*	—	*	*	*	*	8
Yoo et al ¹⁹⁵	2012	*	*	*	*	—	—	*	*	*	7
Yoo et al ¹⁹⁶	1998	*	*	*	—	—	*	*	*	*	7
Yoshimoto et al ¹⁹⁷	2011	*	*	—	*	—	—	—	—	—	3
Zhong et al ¹⁹⁸	2005	*	*	—	—	—	—	—	*	*	4
Zhou et al ¹⁹⁹	2010	*	*	*	*	—	*	*	*	*	8
Zhou et al ²⁰⁰	2015	*	*	—	*	—	—	*	*	*	6
Zivkovic et al ²⁰¹	2011	*	*	—	*	—	—	*	*	*	6

The *asterisk* indicates inclusion of the measure.

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SUPPLEMENTARY TABLE 5

Quality assessment of individual longitudinal studies

Study	Year	Newcastle-Ottawa quality assessment scale (adapted)									Total score (of 9)
		Selection			Comparability				Outcome		
		Question 1	Question 2	Question 3	Question 4a	Question 4b	Question 5	Question 6	Question 7	Question 8	
Abdulnour et al ²	2012	*	*	—	*	*	*	*	*	*	8
Akahoshi et al ²⁰²	2001	*	*	*	*	*	*	*	*	*	9
Ford et al ²⁰³	2005	*	—	*	*	*	*	*	*	*	8
Franklin et al ²⁰⁴	2009	—	—	—	*	*	—	*	*	—	4
Janssen et al ²⁰⁵	2008	*	*	—	*	*	*	*	*	*	8
Lee et al ²⁰⁶	2009	*	*	—	*	*	*	*	*	*	8
Liu-Ambrose et al ²⁰⁷	2006	*	*	—	*	*	*	*	*	*	8
Lovejoy et al ¹¹⁸	2008	*	*	*	*	*	—	*	*	*	8
Macdonald et al ²⁰⁸	2005	*	*	—	*	*	*	*	*	*	8
Razmjou et al ²⁰⁹	2018	*	*	—	*	*	*	*	*	*	8
Soreca et al ²¹⁰	2009	*	*	—	*	*	*	—	*	*	7

The *asterisk* indicates the study met the criterion for the question.

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SUPPLEMENTARY TABLE 6
Output for cross-sectional studies

Data element name	Studies, n (samples)	Total sample size, n		Mean age, y (standard deviation) ^a		Mean fat mass, % (standard deviation) ^a		Estimate, % (95% confidence interval)	P value	Standardized	P value
		Premenopausal	Postmenopausal	Premenopausal	Postmenopausal	Premenopausal	Postmenopausal	Unstandardized			
Body mass index	171 (181)	453,036	523,796	41.96 (3.69)	59.42 (3.06)	24.75 (1.60)	26.64 (1.25)	1.14 (0.95–1.32) ^b	<.0001	0.28 (0.23–0.33) ^b	<.0001
Bodyweight	109 (122)	113,603	204,845	43.36 (4.71)	59.55 (3.27)	64.82 (7.91)	66.12 (9.17)	1.00 (0.44–1.57) ^b	.0005	0.08 (0.03–0.14) ^b	.0040
Waist circumference	70 (72)	214,712	326,639	42.28 (3.65)	59.07 (1.91)	78.58 (4.24)	83.61 (3.19)	4.63 (3.90–5.35) ^b	<.0001	0.45 (0.37–0.52) ^b	<.0001
Waist-to-hip ratio	47 (50)	199,140	309,797	42.39 (3.44)	59.09 (1.42)	0.78 (0.03)	0.81 (0.03)	0.04 (0.03–0.05) ^b	<.0001	0.65 (0.52–0.77) ^b	<.0001
Total body fat percentage	46 (52)	58,605	113,226	43.81 (4.67)	59.55 (3.81)	32.44 (3.47)	35.69 (3.84)	2.88 (2.13–3.63) ^b	<.0001	0.90 (0.09–1.71) ^b	.0292
Hip circumference	25 (25)	185,885	297,189	42.48 (3.08)	59.15 (0.95)	100.30 (2.66)	102.73 (2.25)	2.01 (1.36–2.65) ^b	<.0001	0.20 (0.13–0.27) ^b	<.0001
Subcutaneous abdominal fat	10 (10)	696	833	41.01 (6.96)	57.48 (5.36)	194.05 (23.65)	221.21 (32.09)	28.73 (8.56–48.91) ^b	.0053	0.85 (–0.50–2.21)	.2176
Visceral fat	10 (10)	696	833	41.01 (6.96)	57.48 (5.36)	69.22 (15.75)	104.36 (13.92)	26.90 (13.12–40.68) ^b	.0001	0.59 (0.20–0.98) ^b	.0028
Suprailiac skinfold thickness	9 (10)	1,103	745	39.76 (4.41)	61.89 (4.77)	22.16 (7.04)	24.55 (9.90)	2.65 (0.45–4.85) ^b	.0181	0.28 (0.05–0.50) ^b	.0149
Trunk fat percentage	7 (7)	39,335	95,756	45.28 (6.61)	59.68 (3.41)	31.27 (4.78)	33.74 (5.36)	5.49 (3.91–7.06) ^b	<.0001	0.68 (0.52–0.83) ^b	<.0001
Abdominal skinfold thickness	4 (5)	199	359	40.64 (6.32)	62.99 (5.16)	26.65 (8.14)	29.43 (9.82)	6.46 (0.51–12.42) ^b	.0335	0.61 (0.05–1.18) ^b	.0338
Total leg fat percentage	3 (3)	991	524	36.96 (1.13)	55.18 (5.17)	36.33 (5.47)	36.00 (2.62)	–3.19 (–5.98 to –0.41) ^b	.0246	–0.51 (–0.95 to –0.07) ^b	.0227

^a Computed as weighted means and weighted standard deviations, taking into account sample size; ^b Indicates significance at the $P < .05$ level.

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SUPPLEMENTARY TABLE 7
Output for longitudinal studies

Data element name	Studies, n (samples)	Total sample size, n	Mean age, y (standard deviation) ^a		Mean fat mass, ●●●● (standard deviation) ^a		Estimate, ●●●● (95% confidence interval)	P value	Standardized	P value
			Premenopausal	Postmenopausal	Premenopausal	Postmenopausal	Unstandardized			
Body mass index	8 (10)	2355	46.67 (2.53)	52.80 (3.71)	24.30 (1.97)	25.03 (2.37)	0.93 (0.26–1.59) ^b	.0061	0.21 (0.07–0.35) ^b	.0036
Bodyweight	7 (7)	525	47.64 (3.06)	55.76 (5.08)	66.11 (3.89)	69.19 (3.71)	2.99 (1.36–4.63) ^b	.0003	0.39 (0.12–0.66) ^b	.0049
Total body fat percentage	4 (4)	176	49.59 (1.24)	55.49 (3.65)	36.29 (4.88)	37.84 (3.33)	2.18 (0.21–4.16) ^b	.0299	0.28 (0.13–0.42) ^b	.0001
Waist circumference	3 (3)	915	46.99 (2.04)	52.73 (5.17)	80.79 (3.62)	84.06 (2.61)	3.82 (0.87–6.77) ^b	.0111	0.38 (–0.07–0.84)	.1004
Subcutaneous abdominal fat	3 (3)	133	49.65 (1.61)	53.51 (1.64)	215.14 (66.15)	242.28 (77.34)	18.53 (–3.64–40.69)	.1014	0.52 (–0.31–1.35)	.2168
Visceral fat	3 (3)	133	49.65 (1.61)	53.51 (1.64)	78.63 (14.45)	92.23 (12.77)	12.95 (8.65–17.25) ^b	<.0001	0.49 (–0.03–1.01)	.0629

^a Computed as weighted means and weighted standard deviations, taking into account sample size; ^b Indicates significance at the $P < .05$ level.

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