Review

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Serum lipid levels serve as predictors for osteoporosis or osteopenia in postmenopausal women: A meta-analysis of observational studies

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SUMMARY: This meta-analysis summarizes the differences in serum lipid levels among postmenopausal women with osteopenia, osteoporosis, and normal bone mass, aiming to establish reliable lipid markers for predicting bone loss in postmenopausal women. Relevant literature published up to March 21, 2024, was sourced from databases including PubMed, Embase, Web of Science, and the Cochrane Library. Following a thorough evaluation in accordance with established inclusion and exclusion criteria, the meta-analysis incorporated 14 studies, involving a total of 12,974 postmenopausal women. The weighted mean deviation (WMD) and 95% confidence intervals (CIs) were conducted by RevMan 5.4 software. The findings indicated that serum triglyceride (TG) concentrations were significantly lower in osteopenia (WMD = -6.82, 95% CI: -9.80 to -3.83, $P = 0.05$, $I^2 = 42\%$) and osteoporosis (WMD = -10.28, 95% CI: -14.51 to -6.04, $P < 0.001$, $I^2 = 45\%$) women compared to their normal counterparts. In addition, serum high-density lipoprotein cholesterol (HDL-C) levels were notably elevated in osteoporosis women (WMD = 1.66, 95% CI: 0.75 to 2.57, $P = 0.0004$, $I^2 = 43\%$). However, no significant discrepancies were found in total cholesterol and low-density lipoprotein cholesterol levels among postmenopausal women with bone loss. Sensitivity analysis showed that the results of the meta-analysis were reliable. Egger's test showed no publication bias in the included studies. Consequently, our meta-analysis shows that low serum TG levels predict the onset of osteopenia in postmenopausal women, while high serum HDL-C levels suggest a potential risk for osteoporosis.

Keywords: perimenopausal women, osteopenia, serum lipid levels, meta-analysis

1. Introduction

Postmenopausal osteoporosis represents the predominant type of osteoporosis among women. Epidemiological studies indicate that more than 50% of individuals aged over 50 are affected by osteoporosis, with approximately 70% of these cases occurring in postmenopausal women (*1*), which is responsible for a globally higher incidence of vertebral fractures in women over 50 than in men of the same age (*2*). The higher prevalence of osteoporosis in postmenopausal women is mainly attributed to an increase in bone turnover rate caused by elevated follicle-stimulating hormone, estrogen deficiency, elevated osteocalcin levels, and disorders in lipid metabolism (*3-6*). Osteoporotic vertebral fractures bring high societal costs and mortality; however, currently, available therapeutic options are primarily confined to either suppressing bone resorption or enhancing bone formation, with both strategies being associated with specific side effects (*7,8*). Therefore, the prevention of postmenopausal osteoporosis and osteoporotic fractures remains promising approaches for reducing both incidence and morbidity.

It is well known that bone metabolic balance is the relative balance between osteoclast-mediated bone resorption and osteoblast-mediated bone formation

(*9*). Lipid utilization of osteoblast is necessary for normal skeletal homeostasis. However, dyslipidemia may impair osteoblast function and contribute to bone remodeling imbalances, particularly postmenopausal osteoporosis (*10*). This condition is characterized by an exaggerated rate of bone resorption and a predominant loss of trabecular bone compared to cortical bone (*8*). The change in lipid metabolism may be a key initiating factor of osteoporosis and play a double-edged role. For example, low-density lipoprotein (LDL) can significantly improve the viability of osteoclasts by inducing cholesterol delivery. In contrast, high-density lipoprotein (HDL) can suppress the fusion and survival of osteoclasts by promoting cholesterol efflux (*11,12*). Research has indicated that cholesterol metabolism, adipocytokine, and sphingolipid signaling pathways were significantly enriched on the fifth day following surgery in a murine model of postmenopausal osteoporosis (*13*). These findings further underscore the critical role of lipid metabolism during the early stages of osteoporosis.

Compared to bone mineral density (BMD) values, serum lipid levels are more accessible health information for most postmenopausal women. However, how serum lipid levels affect bone loss in postmenopausal women has not been determined. Gu *et al.* (*14*) found no notable connection between BMD and lipid levels in postmenopausal women. Alfahal *et al*. (*15*) reported postmenopausal women with osteoporosis tend to perform higher total cholesterol (TC), triglyceride (TG), and serum LDL cholesterol (LDL-C) than those with normal bone mass. In contrast, Li *et al.* (*16*) concluded that postmenopausal women with high serum HDL cholesterol (HDL-C) levels were more likely to develop osteoporosis in China. Consequently, the present study summarizes the differences in lipid levels among postmenopausal women with osteopenia, osteoporosis, and normal bone mass, aiming to establish reliable lipid markers for predicting bone loss in postmenopausal women.

2. Materials and Methods

2.1. Search strategy

A comprehensive literature search of the databases PubMed, Embase, Web of Science, and the Cochrane Library was conducted from their inception until March 21, 2024. The search utilized the keywords "Osteoporosis, Postmenopausal" AND ["Lipoproteins" OR "Cholesterol" OR "Triglycerides" OR "Lipoproteins, HDL" OR "Lipoproteins, LDL"] AND ["Case-Control Studies" OR "Cohort Studies" OR "Cross-Sectional Studies"]. The search strategies for each database are detailed in Table S1 (*https://www.ddtjournal.com/action/getSupplementalData.php?ID=270*).

2.2. Inclusion criteria

Inclusion criteria include: (a) Participants were required to be postmenopausal women; (b) all included studies were observational, comprising case-control, cohort, or cross-sectional designs; (c) studies need to provide bone T-value and corresponding lipid data; (d) studies need to be classified strictly according to the criteria set by the World Health Organization (WHO) (*17*): Women with a T-value ≥ -1 of BMD were classified as normal controls; those with -1 > T-value > -2.5 were categorized as having osteopenia; those with T-value ≤ -2.5 were identified as having osteoporosis.

Exclusion criteria include: (a) Subjects were not postmenopausal women; (b) data failed to present the relationship between serum lipid levels and bone T scores; (c) studies did not conform to the established inclusion criteria; (d) participants accepted treatment with bone-active medications, lipid-lowering agents, or corticosteroids; (e) participants underwent severe metabolic disorders or unexplained osteoporosis; (f) research was not published in English; (g) duplicate publications; (h) articles were not classified as observational studies; (i) Studies lacked original text or complete data.

2.3. Data extraction

The evaluation process was conducted using EndNote software. Citations obtained from various database searches were consolidated, and duplicates were eliminated. Two reviewers independently evaluated the literature abstract to determine adherence to the inclusion criteria. Review the full text of studies deemed potentially relevant. Any disagreements were resolved through joint deliberation, with the participation of a third reviewer as necessary. The following items were extracted from all, including research: author, publication date, research type, country, basis for grouping, sample size, age, body mass index (BMI), and BMD evaluation.

2.4. Quality assessment of studies

The Newcastle-Ottawa Quality Assessment Scale (NOS) was employed to evaluate the quality of included studies (*18*). Scores ranging from 0 to 3, 4 to 6, and 7 to 9 correspond to low, medium, and high quality of included studies, respectively. Any disagreements between the two reviewers, Chen ZQ and Zhou J, were addressed through discussion.

2.5. Statistical analysis

2.5.1. Meta-analysis statistics

The weighted mean deviation (WMD) and 95% confidence intervals (CIs) were conducted by RevMan 5.4 software. A significance level of P-value < 0.05 was predetermined. The heterogeneity of studies was evaluated using I^2 statistics. A fixed-effects model

was used if heterogeneity was slight (I^2 < 40%), and a random-effects model was used otherwise. Sensitivity analyses and Egger's tests were performed by Stata 16.0 software. Additionally, if more than 10 articles were pooled for analysis, funnel plots were conducted to assess potential publication bias.

2.5.2. Subgroup analyses

We performed a subgroup analysis of the high heterogeneity results based on the following factors: The level of country development (developed *vs.* developing), dietary pattern of residents (mediterranean *vs.* western *vs.* eastern), BMD evaluation methods (lumbar spine *vs.* lumbar spine and others), sample size (≥ 200 *vs.* < 200), literature quality (high *vs.* median), and mean age of patients (≤ 55 *vs.* > 55). Instances where data were not reported in the studies were noted as "not provided." A *P*-value < 0.05 was set as statistically significant.

3. Results

3.1. Study selection

The initial search identified 276 potentially relevant studies. Sixty-one duplicate studies were removed. Following the predetermined inclusion and exclusion criteria, 179 studies were excluded based on an evaluation of their abstracts, while 22 studies were excluded after a thorough review of their full texts. Ultimately, 14 studies (*14,19-31*) were deemed suitable for inclusion in this meta-analysis. The flowchart of this study is shown in Figure 1.

3.2. Study characteristics

The studies included in this analysis were sourced from four databases and published prior to March 21, 2024. Table 1 provides a comprehensive overview of the characteristics of all included studies, which comprises 8 studies that adopted a case-control design, a cohort study design, and 5 cross-sectional studies. Our meta-analysis involved 12,974 postmenopausal women from 9 countries, including 2,772 osteoporosis patients, 4,552 osteopenia patients, and 5,650 women with normal bone mass. The NOS was adopted to assess the non-randomized studies' methodological quality. All studies were assessed as having median or high quality, as shown in Table 2.

3.3. Pooled findings

Initially, we compared the serum lipid concentrations in postmenopausal women with osteopenia versus those with normal bone mass. Utilizing a random-effects model, we found a significant reduction in TG levels (WMD = -6.82, 95% CI: -9.80 to -3.83, P = 0.05, I^2 = 42%) in osteopenia women. No significant differences were noted in TC (P = 0.91, I^2 = 24%), HDL-C (P = 0.43, I^2 = 82%), and LDL-C (P = 0.81, I^2 = 0%) between the two groups (Figures 2A-2D).

To further investigate the differences in serum

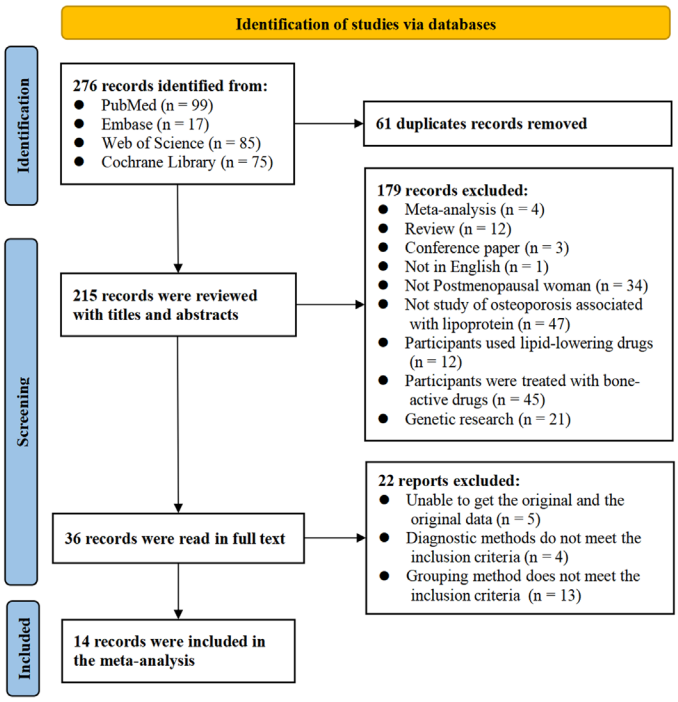

Figure 1. A flowchart of the study.

Table 1. Main characteristics of included studies

Author, year (reference)	Country	Study design	Groups	Grouping standard	Participant	BMD test site (instrument)	Age (years)[a]	BMI (kg/m^2)[a]
Abbasi M 2016 (*24*)	Iran	Cross-sectional	Osteoporosis	T ≤ -2.5	80	Lumbar spine and femoral neck (DEXA)	60.03 ± 8.21	33.64 ± 9.22
			Normal	T ≥ -1	63		53.47 ± 7.33	31.61 ± 7.95
Alay I 2020 (*22*)	Turkey	Case-control	Osteoporosis	T ≤ -2.5	176	Lumbar spine (L1-L4) and the femoral neck (DEXA)	54.54 ± 7.37	28.02 ± 4.58
			Osteopenia	-2.5 < T < -1	179		54.43 ± 6.22	29.42 ± 4.87
			Normal	T ≥ -1	97		51.67 ± 6.06	29.56 ± 5.01
Cui R 2016 (*26*)	Germany	Case-control	Osteoporosis	T ≤ -2.5	253	Lumbar spine (L1-L4) (DEXA)	65.00 ± 9.63	24.09 ± 3.70
			Osteopenia	-2.5 < T < -1	1602		60.00 ± 7.41	25.15 ± 3.30
			Normal	T ≥ -1	2098		57.00 ± 5.93	25.80 ± 3.43
D'Amelio P 2001 (*19*)	Italy	Case-control	Osteoporosis	T ≤ -2.5	37	Lumbar spine (DEXA)	53.40 ± 3.10	Not provided
			Normal	T ≥ -1	43		61.00 ± 6.80	Not provided
Demir B 2008 (*20*)	Turkey	Case-control	Osteoporosis	T ≤ -2.5	1085	Lumbar spine (L1-L4) (DEXA)	47.70 ± 4.80	27.60 ± 4.30
			Osteopenia	-2.5 < T < -1	449		48.30 ± 4.40	28.40 ± 4.50
			Normal	T ≥ -1	1235		48.60 ± 4.10	29.80 ± 4.80
Erden E 2023 (*23*)	Turkey	Cross-sectional	Osteoporosis	T ≤ -2.5	60	Lumbar spine (L1-L4) and femur neck (DEXA)	56.50 ± 3.70	28.55 ± 5.04
			Osteopenia	-2.5 < T < -1	60		56.00 ± 5.78	29.7 ± 4.52
			Normal	T ≥ -1	60		56.00 ± 5.19	29.45 ± 2.15
Gu LJ 2019 (*14*)	China	Case-control	Osteoporosis	T ≤ -2.5	529	Left calcaneus (ultrasound BMD analyzer)	65.49 ± 8.18	23.54 ± 3.20
			Osteopenia	-2.5 < T < -1	1616		59.64 ± 7.28	23.67 ± 3.16
			Normal	T ≥ -1	1400		57.15 ± 7.19	23.63 ± 3.28
Naguib M 2022 (*29*)	Egypt	Cross-sectional	Osteoporosis	T ≤ -2.5	25	Lumbar spine and the total hip (DEXA)	56.00 ± 5.45	34.09 ± 3.85
			Osteopenia	-2.5 < T < -1	25		56.75 ± 6.29	31.42 ± 3.43
			Normal	T ≥ -1	25		52.77 ± 3.55	33.18 ± 6.02
Pliatsika P 2012 (*25*)	Greece	Cross-sectional	Osteoporosis	T ≤ -2.5	71	Lumbar spine (L2-L4) (DEXA)	Not provided	Not provided
			Osteopenia	-2.5 < T < -1	248		Not provided	Not provided
			Normal	T ≥ -1	272		Not provided	Not provided
Pontes TA 2019 (*30*)	Brazil	Case-control	Osteoporosis	T ≤ -2.5	24	Lumbar spine (L1-L4), femoral neck, and total femur (Hologic Bone	60.80 ± 6.00	25.58 ± 4.80
			Osteopenia	-2.5 < T < -1	26	Densitometer Discovery Ci)	61.88 ± 7.90	27.20 ± 5.20
			Normal	T ≥ -1	28		60.38 ± 6.20	25.35 ± 3.40
Safari A 2019 (*27*)	Iran	Case-control	Osteoporosis	T ≤ -2.5	44	Lumbar spine and hip (DEXA)	64.22 ± 13.85	30.47 ± 5.77
			Normal	T ≥ -1	44		63.67 ± 6.40	27.52 ± 4.75
Tamaki J 2009 (*21*)	Japan	Cohort studies	Osteoporosis	T ≤ -2.5	78	Lumbar spine (L2-L4), total hip, and the distal forearm (DEXA)	65.91 ± 7.36	23.40 ± 3.55
			Osteopenia	-2.5 < T < -1	133		61.34 ± 6.83	23.35 ± 2.55
			Normal	T ≥ -1	92		55.98 ± 5.59	25.40 ± 3.36
Yaprak EÜ 2016 (*31*)	Turkey	Cross-sectional	Osteoporosis	T ≤ -2.5	88	Lumbar spine (L1-L4) and hip (femoral neck) (DEXA)	55.00 ± 10.25	31.00 ± 4.40
			Normal	T ≥ -1	88		56.00 ± 9.50	31.40 ± 4.80
Zhao X 2023 (*28*)	China	Case-control	Osteoporosis	T ≤ -2.5	222	Lumbar spine (L1-L4) and the bilateral hip (DEXA)	68.09 ± 7.32	24.60 ± 3.47
			Osteopenia	-2.5 < T < -1	214		62.87 ± 7.44	25.47 ± 3.17
			Normal	T ≥ -1	105		60.37 ± 6.51	26.49 ± 3.80

Note: BMD: bone mineral density; BMI: body mass index; DEXA: dual-energy X-ray absorptiometry. [a]Data are shown as mean ± SD.

lipid levels among postmenopausal women with varying degrees of bone loss, we compared the lipid concentrations of osteoporosis and normal women. Our study revealed a significant decrease in TG (WMD = -10.28, 95% CI: -14.51 to -6.04, $P < 0.001$, $I^2 = 45\%$) and an increase in HDL-C (WMD = 1.66, 95% CI: 0.75 to 2.57, $P = 0.0004$, $I^2 = 43\%$) levels in osteoporosis women. No significant differences were found in TC ($P = 0.84$, $I^2 = 9\%$) and LDL-C ($P = 0.59$, $I^2 = 18\%$) levels between the two groups (Figures 3A-3D).

3.4. Subgroup analyses

Focusing on various study characteristics, we conducted a subgroup analysis of research on HDL-C levels in osteopenia and normal women to uncover potential sources of heterogeneity (Figures 4A-4F). The findings remained consistent regardless of the BMD evaluation ($P = 0.15$), sample size ($P = 0.51$), quality of the literature ($P = 0.67$), and mean age of patients ($P = 0.80$). Among postmenopausal women in developed nations, levels of HDL-C are significantly elevated in those with osteopenia (WMD = 2.24, 95% CI: 1.56 to 2.93, $P < 0.001$, $I^2 = 0\%$). Conversely, this disparity is not observed in developing countries (WMD = -0.11, 95% CI: -1.29 to 1.07, $P = 0.83$, $I^2 = 62\%$) (Figure 4A). Stratification analysis based on the national development level markedly reduced heterogeneity within each subgroup, and the difference in effect size between the two subgroups was statistically significant ($P < 0.001$).

To rule out the possibility of chance, we performed subgroup analyses based on the dietary patterns of postmenopausal women. The results showed that across all three dietary pattern subgroups, there were no statistically significant differences in HDL-C levels between women with osteopenia and normal bone mass ($P > 0.05$) (Figure 4B). Nonetheless, the effect size differences among the three dietary subgroups were statistically significant ($P = 0.001$). These findings suggest that national development level and dietary structure may contribute to the high heterogeneity observed in HDL-C comparisons between postmenopausal women with osteopenia and normal bone mass. However, these factors did not affect the

Table 2. Quality evaluation of included studies

Reference	Selection	Comparability	Exposure/Outcome	Core	Quality
Abbasi M 2016 (*24*)	**	*	***	6	Median
Alay I 2020 (*22*)	****	**	**	8	High
Cui R 2016 (*26*)	****	*	**	7	High
D'Amelio P 2001 (*19*)	***	*	**	6	Median
Demir B 2008 (*20*)	***	*	**	6	Median
Erden E 2023 (*23*)	**	*	**	5	Median
Gu L.J. 2019 (*14*)	***	*	**	6	Median
Naguib M 2022 (*29*)	***	**	**	7	High
Pliatsika P 2012 (*25*)	**	*	**	5	Median
Pontes T.A. 2019 (*30*)	**	*	**	5	Median
Safari A 2019 (*27*)	****	**	**	8	High
Tamaki J 2009 (*21*)	***	**	**	7	High
Yaprak E.Ü. 2016 (*31*)	**	**	**	6	Median
Zhao X 2023 (*28*)	***	**	**	7	High

Note: The number of stars indicates the score of the item.

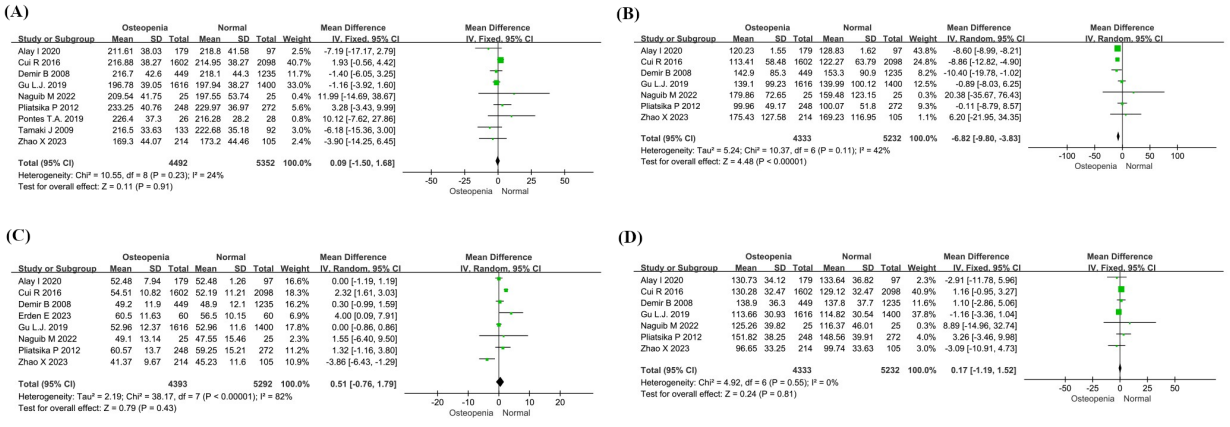

Figure 2. Forest plots of the comparison of serum lipid levels in postmenopausal women with osteopenia and normal bone mass. TC **(A)**, TG **(B)**, HDL-C **(C)**, and LDL-C **(D)**. Abbreviations: SD: standard deviation; 95% CI: 95% confidence interval.

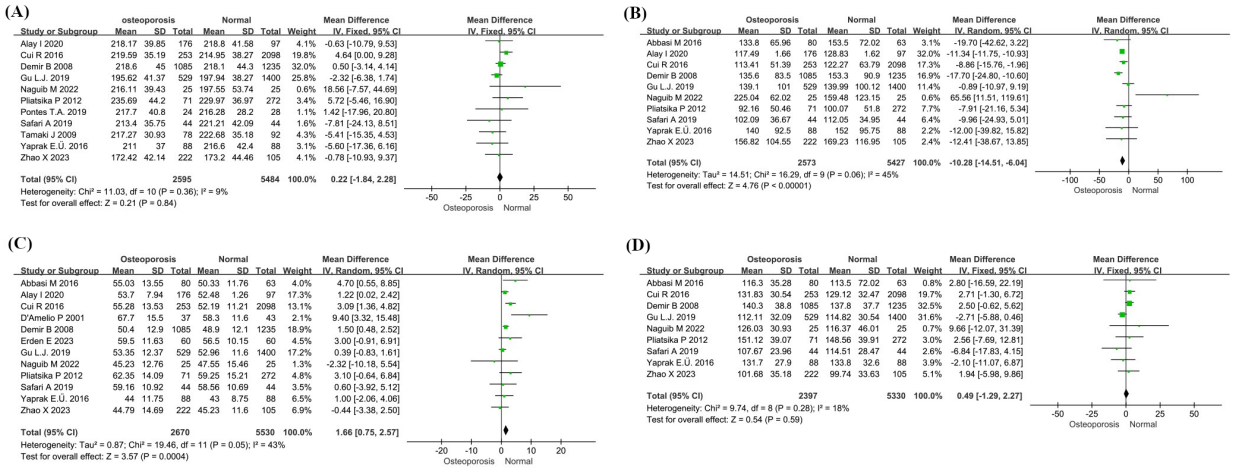

Figure 3. Forest plots of the comparison of serum lipid levels in postmenopausal women with osteoporosis and normal bone mass. TC **(A)**, TG **(B)**, HDL-C **(C)**, and LDL-C **(D)**. Abbreviations: SD: standard deviation; 95% CI: 95% confidence interval.

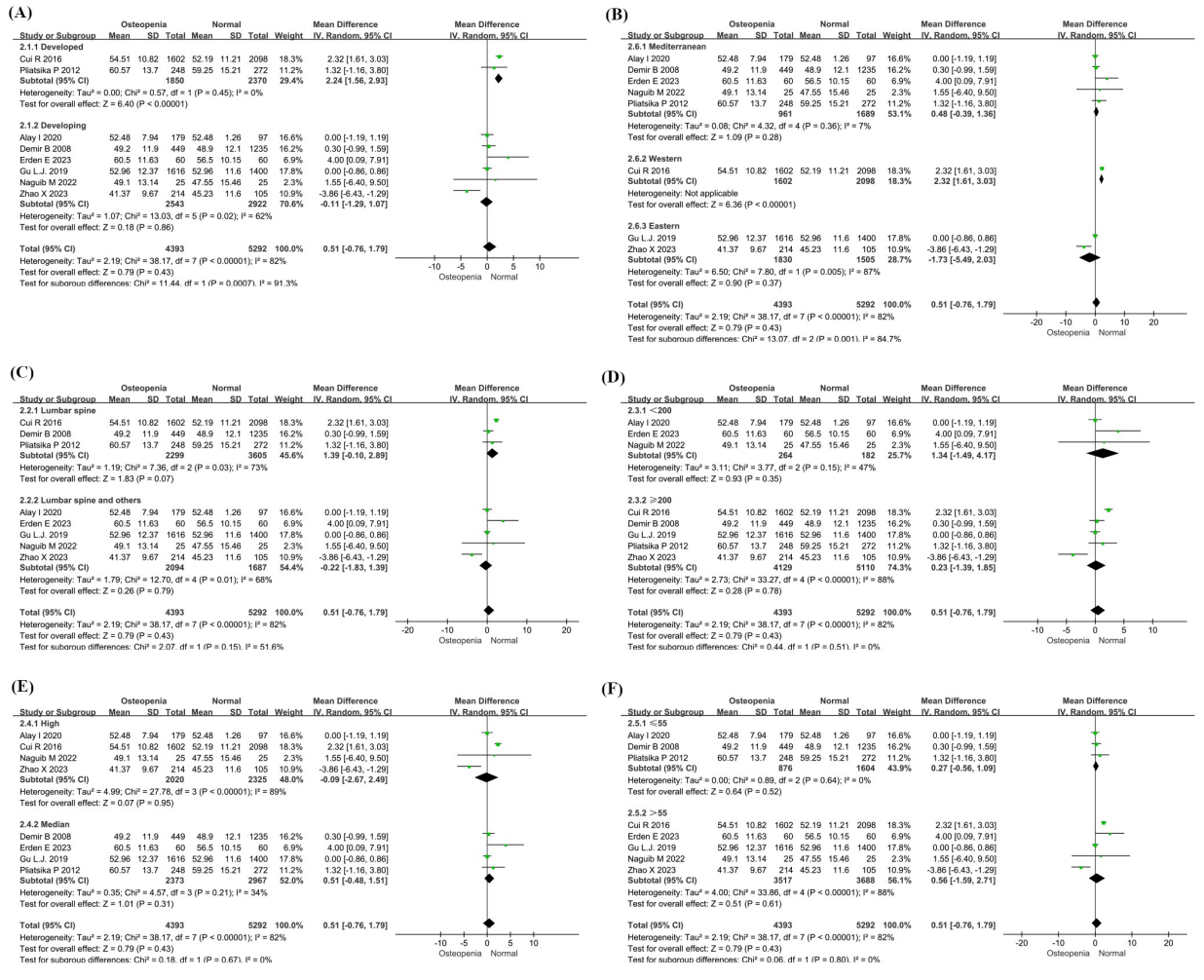

Figure 4. Forest plots of the subgroup analysis of the serum HDL-C levels in postmenopausal women with osteopenia and normal bone mass based on different study characteristics. Country development level **(A)**, dietary pattern of residents**(B)**, BMD evaluation **(C)**, sample size **(D)**, literature quality **(E)**, and mean age of patients **(F)**. Abbreviations: SD: standard deviation; 95% CI: 95% confidence interval.

main analysis results.

3.5. Sensitivity analysis

We found no significant discrepancies between pre-sensitivity and post-sensitivity pooled effect sizes when systematically removing individual studies related to serum lipid concentration—regardless of bone loss severity among postmenopausal women (Figure S1, *https://www.ddtjournal.com/action/getSupplementalData.php?ID=270*). Therefore, the results of our meta-analysis are reliable.

3.6. Publication bias

A funnel plot (applicable if ≥ 10 studies were included) and Egger's test were implemented using Stata software to assess potential publication bias for included studies. The Egger's test indicated that our research showed no signs of publication bias, both in postmenopausal women with osteopenia (P = 0.78 for TC, P = 0.49 for TG, P = 0.53 for HDL-C, and P = 0.95 for LDL-C) and in those with osteoporosis (P = 0.95 for TC, P = 0.62 for TG, P = 0.35 for HDL-C, and P = 0.91 for LDL-C). In addition, the funnel plot of the study on the connection between serum lipid concentration and bone T score in osteoporosis women showed symmetry (Figure S2, *https://www.ddtjournal.com/action/getSupplementalData.php?ID=270*).

4. Discussion

4.1. Main findings

This meta-analysis aimed to explore the relationship between bone health and lipid levels in postmenopausal women. It examined three bone conditions (normal, osteopenia, and osteoporosis) and four lipid parameters (TC, TG, HDL-C, and LDL-C), incorporating data from 14 studies involving 12,974 participants. The findings indicated that TG levels in postmenopausal women with osteopenia and osteoporosis are significantly lower than those in women with normal bone mass, suggesting that low serum TG levels may be indicative of bone loss in the population. Additionally, serum HDL-C concentrations were found to be significantly greater in osteoporosis women, implying that elevated HDL-C may serve as an indicator of osteoporosis in postmenopausal women. However, our analysis indicated that variations in TC and LDL-C did not correlate with bone mass in postmenopausal women. This implies that TC and LDL-C might not be reliable serological markers for forecasting bone loss in this population. Our subgroup analysis determined that national development level and dietary structure may contribute to the high heterogeneity observed in HDL-C comparisons between postmenopausal women with osteopenia and normal bone mass. However, these factors did not affect the main analysis results.

4.2. Implications

The level of bone mass in mammals relies on a delicate balance between bone formation and resorption—two critical processes carried out by osteoblasts and osteoclasts, respectively. Continuous communication between these two cell types is meticulously coordinated through bone remodeling, which is essential for maintaining bone homeostasis. Disruption in this coupling can lead to significant issues related to various bone diseases, including osteoporosis (*32*). Indeed, it has been demonstrated that disturbances within lipid metabolic pathways can differentially impact bone cells, contributing to the development of skeletal pathologies.

The association between serum TG levels and osteoporosis has been a contentious topic in the literature. For instance, while some studies have established a strong association between fasting serum TG concentrations and lumbar bone density (*33*), others have found no relationship (*34*). In our investigation, low serum TG levels indicated diminished bone mass, aligning with previous findings that suggest elevated TG levels may reflect a favorable nutritional status for bone health (*35*). Serum TG levels are intricately linked to BMD. For instance, adipocytes and osteoblasts originate from pluripotent mesenchymal stem cells, and a range of cytokines released by adipose tissue can influence bone remodeling *via* the central nervous system and autonomic innervation (*36,37*). Furthermore, research indicates that TG can create a protective barrier between collagen fibers and mineral crystals, which facilitates the adhesion of the protein matrix and contributes to the stability of bone (*38*). In summary, serum TG levels serve as reliable indicators of early bone loss, and low serum TG concentrations should prompt postmenopausal women to be vigilant regarding their bone health.

Apolipoprotein E (ApoE) and apolipoprotein A1 (ApoA1), two key molecules that regulate HDL biogenesis, are related to protect against atherosclerosis and maintain plasma lipid homeostasis (*39*). Studies have shown that a lack of ApoE may prevent bone marrow mesenchymal stem cells from maturing at an early stage, thereby affecting lipoblast and osteoblast lineages through unknown mechanisms (*40*). Alterations in ApoA1 may contribute to the pathogenesis of bone metastases by affecting signaling cascades and molecular pathways (*32*). In essence, disturbances in HDL metabolic pathways seem to encourage the transformation of cells into fat-storing adipocytes and hinder the development of bone-forming osteoblasts. Changes influence the intriguing interplay in certain bone-related chemokines and signaling routes. Our meta-analysis indicates that elevated HDL-C levels may be linked to severe bone loss, known as osteoporosis in

postmenopausal women. Additionally, high HDL-C levels in healthy older adults also predict an increased fracture risk (*41*). Consequently, elevated serum HDL-C levels warrant significant attention in postmenopausal women.

The enzymes and molecules that govern cholesterol balance are intricately intertwined with the process of bone formation. When TC levels soar, they may pave the way for osteoporosis, as cholesterol and its byproducts play a pivotal role in maintaining bone health by modulating the growth and function of osteoblasts and osteoclasts (*42*). LDL-C-induced cholesterol delivery can significantly increase osteoclast activity, while LDL-C consumption can inhibit osteoclast formation (*43,44*). However, our study did not find elevated TC and LDL-C levels in postmenopausal women with osteopenia and osteoporosis. In line with our discoveries, a comprehensive study involving 667 postmenopausal women revealed no noteworthy link between TC and LDL-C concentration and BMD in the spine and femoral neck, as determined through multifactor analysis (*45*). In addition, studies have shown that compared with natural menopause, the variety of TC, TG, and other lipid markers in women undergoing surgical menopause are more significant (*46*). However, our study could not determine the cause of menopause in our subjects. Further observational studies are needed to determine the predictive power of TC and LDL-C on bone status in postmenopausal women.

4.3. Limitations

There are several limitations to this review. First, we could not stratify participants by race, diet, exercise, smoking history, *etc*., because that information was unavailable in the original literature. Second, the included literature on lipid levels in women with osteopenia is limited, comprising fewer than ten studies, several of which involved small sample sizes. This may restrict the generalizability of our findings. To mitigate potential bias, several rigorous methodologies were employed. These included an extensive literature review, the establishment of strict guidelines for data extraction, the formulation of explicit inclusion and exclusion criteria, the use of a random effects model for estimation, and the execution of subgroup analyses. Despite certain limitations, this meta-analysis provides valuable insights into the relevance of serum lipid levels and bone status in postmenopausal women.

5. Conclusion

This study suggests that bone loss in postmenopausal women is associated with serum lipid levels. Our meta-analysis shows that low serum TG levels predict the onset of osteopenia in postmenopausal women, while high serum HDL-C levels suggest a potential risk for osteoporosis. These findings may assist clinicians in assessing the bone health of postmenopausal women and contribute to the early prevention and diagnosis of osteopenia and osteoporosis.

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Conflict of Interest: The authors have no conflicts of interest to disclose.

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