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Hot spring and sauna use for improving blood lipid profiles: A systematic review and expert consensus on efficacy and recommendations

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A R T I C L E I N F O

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A B S T R A C T

Objectives: Dyslipidemia is a significant risk factor for cardiovascular disease. Traditional treatments often focus on pharmacological interventions; however, alternative therapies, such as hot spring and sauna use, have recently gained attention because of their potentially beneficial effects on lipid profiles and cardiovascular health.
Design and setting: This systematic review aimed to synthesize current evidence on the efficacy of hot spring and sauna use, alone or combined with exercise therapy, in improving blood lipid profiles, with a focus on mechanisms, benefits, and limitations.
Methods: The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. A search of 330 records across major databases identified 127 studies for blinded screening using Rayyan (a web-based application for conducting systematic reviews). Seven randomized controlled trials (RCTs) investigating the effects of hot spring and sauna use on lipid profiles in adults were included.
Results: Four RCTs in younger adults (mean age < 60 years) demonstrated that hot spring and sauna use resulted in reductions in serum total cholesterol and low-density lipoprotein cholesterol; these therapies were given a weak expert recommendation. Three RCTs in older adults (mean age ≥ 60 years) showed no significant blood lipid changes.
Conclusions: In younger adults, hot spring and sauna use, particularly when combined with exercise therapy, may contribute to improved lipid profiles. Emerging evidence from intervention studies could inform future guidelines for integrating these therapies into dyslipidemia management strategies.

1. Introduction

Dyslipidemia, which is characterized by abnormal blood lipid levels, is a significant risk factor for cardiovascular disease, a leading cause of global morbidity and mortality.[1] Traditional management relies on lifestyle modifications and pharmacological interventions; however, interest in complementary therapies, such as hot spring and sauna use, has grown because of their potential metabolic and cardiovascular benefits.[2]

Hot spring and sauna use have been used therapeutically across cultures for centuries.[3] Emerging evidence suggests that these therapies improve lipid metabolism by enhancing circulation, reducing inflammation, and modulating cardiovascular function.[4,5] However, the efficacy of these interventions in improving blood lipid profiles remains understudied, and existing reviews have focused on cardiovascular parameters rather than lipid-specific outcomes.

Given this background, the following question remains unanswered: Do hot spring and sauna use improve blood lipid profiles (total cholesterol [TC], low-density lipoprotein cholesterol [LDL-C], high-density lipoprotein cholesterol [HDL-C], and triglycerides [TG]) in adults, and how do these effects vary by age and intervention type?

This systematic review is timely for three reasons. First, it addresses

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important clinical gaps: despite promising preliminary studies, no prior reviews have synthesized evidence on hot spring and sauna use specifically for lipid profile improvement. Second, it incorporates emerging evidence: recent randomized controlled trials (RCTs) have explored non-pharmacological interventions,[6,7] yet their findings remain inconclusive. Third, it is relevant to public health strategies: with rising interest in cost-effective, non-invasive therapies, this review addresses a critical need for evidence-based guidance to inform clinical practice and policy.

The objectives of this systematic review and expert consensus are as follows: (1) to systematically review evidence from RCTs on the effects of hot spring and sauna use on blood lipid profiles in adults ($\geq$ 18 years old; healthy, at-risk, or with lipid disorders or related metabolic or cardiovascular conditions); (2) to evaluate the synergistic role of exercise therapy combined with thermal interventions; (3) to develop evidence-based recommendations for clinicians and policymakers, informed by expert consensus; and (4) to identify research gaps to guide future studies.

This review directly impacts the following groups: patients, who may gain access to low-risk, adjunctive therapies to complement pharmacological treatments; clinicians, who could integrate thermal therapies into personalized management plans, particularly for younger adults or those averse to medications; and policymakers, who could highlight cost-effective strategies for dyslipidemia management in aging populations, and therefore reduce reliance on expensive interventions.

2. Methods

2.1. Systematic review

The present review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses reporting guidelines (Supplementary Table S1).[8] We searched the following six databases: Databeses, MEDLINE, Embase, CENTRAL, Web of Science Core Collection, and Ichushi-Web. The search included all articles published up to December 23, 2024. The protocol for this systematic review was registered in PROSPERO (CRD420251063673) on May 30, 2025, prior to manuscript submission.

2.2. Inclusion and exclusion criteria

The inclusion criteria for this systematic review were as follows: (1) population: adults ($\geq$ 18 years old) with or without dyslipidemia; (2) intervention: hot spring (temperature $\geq 25\,^{\circ}$C, mineral-rich water as per Japanese law) and sauna use, alone or combined with exercise; (3) comparator: standard care, exercise alone, or no intervention; (4) outcomes: changes in lipid parameters (TC, LDL-C, HDL-C, TG); and (5) study design: RCTs. The exclusion criteria were as follows: non-RCTs, non-mineral thermal therapies, reviews, and case reports.

For this systematic review, RCTs comparing hot spring and sauna use versus no intervention or standard care in adults were included, with primary outcomes focused on changes in blood lipids (TC, LDL-C, HDL-C, TG). Specifically, we extracted data on: (1) the specific type and clinical severity of dyslipidemia (e.g., hypercholesterolemia, hypertriglyceridemia, mixed-type) in participants as defined by the original studies; (2) the diagnostic criteria used in each trial for inclusion (e.g., National Cholesterol Education Program [NCEP adult treatment panel III], World Health Organization (WHO), Japanese Society of Hyperlipidemia, study-specific cut-offs or definitions); (3) age and sex breakdown, and other comorbidities/risk profiles (where available); and (4) intervention details (water mineral content, temperature, treatment duration/frequency).

Any discrepancies or lack of reporting in the primary study were noted, and, where possible, additional demographic or severity data were requested or extrapolated from the methods/results/descriptive tables.

2.3. Data extraction

Our systematic review used Rayyan (Rayyan Systems Inc., Cambridge, MA, USA), an online tool designed to facilitate article screening and streamline the literature screening process. The screening workflow using Rayyan was as follows: (1) independent screening: reviewers independently screened articles with the "blind" feature enabled, which ensured unbiased initial assessments; (2) conflict resolution: after completing the initial screening, the blind feature was disabled to identify and resolve conflicts, and in cases where two reviewers could not reach a consensus, a third reviewer was consulted; (3) full-text review preparation: for articles that passed the initial screening, we obtained full texts and attached them to the corresponding entries in Rayyan; (4) secondary screening: we conducted a second round of screening on the full texts, again using the blind feature, and during this phase reviewers assigned reasons for exclusion when applicable; and (5) final conflict resolution: after the secondary screening, we once again disabled the blind feature to resolve any remaining conflicts through discussion. Rayyan's features, such as duplicate removal and a collaborative workspace, significantly enhanced our review efficiency. The platform allowed us to work collaboratively on the same platform, automatically detect and remove duplicate entries, apply labels and reasons for inclusion/exclusion, and export screening results for further analysis.

Using this systematic approach with Rayyan, we ensured a thorough and transparent literature selection process for our systematic review. The following information was extracted from each included study: (1) study characteristics (author, year, country); (2) participant demographics; (3) intervention details (bathing duration, frequency, water temperature); (4) outcome measures (blood lipid changes); and (5) results and conclusions.

2.4. Quality and risk of bias assessment

RCTs were evaluated using Cochrane Risk of Bias (RoB) 2.0 (https://training.cochrane.org/handbook, accessed December 29, 2024) on the basis of the following domains: randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selective reporting. Studies were classified as "low risk", "some concerns", or "high risk". Although we considered assessing publication bias via a funnel plot, this method is used only for outcomes with $\geq$ 10 studies, which did not apply in our systematic review (Supplementary Table S2).

Quality assessment was conducted using criteria adapted from the guidelines of the Japanese Society for Palliative Medicine (https://www.jspm.ne.jp/files/english/guidance.pdf). Studies were evaluated on the basis of the following criteria: study design, sample size, methodological rigor, and risk of bias. On the basis of these assessments, studies were given a strong recommendation or a weak recommendation, or were not recommended. This approach allowed for a comprehensive evaluation of the available evidence while acknowledging the limited number of RCTs in this field. Given the emerging nature of research in this area, studies deemed to have potential relevance were retained for final analysis even if they did not meet all methodological criteria, such as adequate sample size, low risk of bias, sufficient follow-up duration, or standardized intervention protocols.

This systematic review included studies that examined the effects of hot spring and sauna use on lipid profiles and cardiovascular health. A comprehensive search of major databases was conducted using the keywords "hot spring," "sauna," "balneotherapy," "thermotherapy," "blood lipid profiles," "cholesterol," "triglycerides," and "dyslipidemia." Studies were selected on the basis of their focus on the therapeutic effects of hot spring and sauna use in humans.

2.5. Sex differences

For each included RCT, we extracted available data on participant sex distribution and, where reported, blood lipid outcomes stratified by sex. Where subgroup analyses or supplemental data were presented, we summarized women-only or men-only findings separately. When sex-disaggregated efficacy data were unavailable, this was explicitly noted as a limitation. As several studies were conducted in predominantly or exclusively female populations, the generalizability of findings to men was carefully discussed.

2.6. Age stratification

In this systematic review, we included RCTs that reported on adult participants aged ≥ 18 years who underwent hot spring and sauna use to evaluate the effects on blood lipid profiles. To address reviewer feedback and enhance comparability across studies, we classified participants into three standard age categories: (1) young adults: 18–44 years, (2) middle-aged adults: 45–64 years, and (3) older adults: ≥ 65 years.

Where original studies provided summary data by age, results were extracted using these categories. If studies reported a broader age range, the mean or median age and the reported range were used to assign the cohort to the appropriate group. All tables and narrative results were updated to reflect this standard age-group classification.

2.7. Pooled analysis of lipid marker changes by intervention type

We performed a pooled quantitative analysis to assess the correlation between improvements in blood lipid markers (TC, LDL-C, HDL-C, TG) and the type of intervention (hot spring versus sauna use, Table 1) across all eligible RCTs (n = 7). For each included study, we extracted the mean change (% difference from baseline) in blood lipid markers in the intervention and control arms. Studies were categorized as "hot spring" if bathing in mineral water was the principal intervention, or as "sauna" if sauna use (with/without exercise) was administered. A bubble chart analysis was conducted (Fig. 3) to visually summarize the percentage changes and sample sizes. Full study-level values are detailed in Supplementary Table S3.

All statistical analyses were performed using EZR (Saitama Medical Center, Saitama, Japan; http://www.jichi.ac.jp/saitama-sct/SaitamaHP.files/statmedEN.html),[9] a graphical user interface for R (The R Foundation for Statistical Computing; www.r-project.org) that extends the functionality of R Commander by adding statistical functions. Analyses were conducted using R version 4.3.1 and R Commander version 2.9–1. Pearson's correlation coefficient was used to assess the relationship between the mean age and the mean change in TC in all seven RCTs.[10–16]

3. Results

Fig. 1 reports the details of the review process in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses reporting guidelines. Twenty-one studies were included in the final review and subjected to quality analysis. The initial search was conducted across six major databases, Databeses, MEDLINE, Embase, CENTRAL, Web of Science Core Collection, and Ichushi-Web, which produced 165, 39, 40, 67, 18, and 1 citations, respectively. Thirty-eight studies were removed as duplicates, and 96 were excluded because they did not meet the eligibility criteria after review of the title and abstract. Twenty-four studies were excluded because they did not meet the eligibility criteria for population, study design, or other reasons, as described in Fig. 1.

Data related to each included article are summarized in Table 2, which presents the key characteristics and main findings of each study. Seven RCTs were included.[10–16] Three trials that targeted relatively younger adults (mean age < 60 years) found a reduction in serum TC levels,[10–13] and two trials found a decrease in LDL-C levels,[10,12,13] in response to hot spring and sauna use. These therapies were given a weak expert recommendation. Four RCTs targeting relatively older people (mean age ≥ 60 years) did not find any changes in blood lipid parameters.[14–16]

Chen et al.[10] and Lee et al.[11] demonstrated that hot spring and sauna use combined with exercise significantly improved lipid profiles. Rapoliene et al.[12] and Ekmekcioglu et al.[13] showed that balneotherapy with geothermal water and sulfur baths significantly improved cholesterol levels. Both hot spring and sauna use, combined with exercise, significantly improved TC levels compared with exercise alone.[11] However, the evidence was not uniform, and more research is needed to establish consistent benefits across different populations.

Given the differences in findings between studies that included younger and older adults, a correlation analysis between age and TC changes was performed, which showed a positive correlation between mean age and mean change in TC ($p = 0.014$; Fig. 2). This suggests that the reason no significant difference was observed in TC levels in relatively older people after hot spring and sauna use may have been because of age.

Table 1
Mechanistic and clinical effects on lipid parameters of hot spring versus sauna use.

Aspect	Hot Spring	Sauna
Mechanism	Thermal effect (prolonged immersion at 36–42℃) Mineral absorption (e.g., sulfate, magnesium, calcium, bicarbonate) Hydrostatic pressure, buoyancy	Rapid whole-body heat exposure (typically 70–90℃, short duration) Intense thermal stress, increased heart rate and vasodilation Dry or humid air, no mineral absorption
Key Clinical RCTs	Chen et al. 2023[10], Rapoliene et al. 2019[12], Ekmekcioglu et al. 2002[13]	Lee et al. 2022[11]
Target Population	Prediabetes, metabolic syndrome, middle-aged and older adults	Sedentary adults with CVD risk, older adults, healthy volunteers
Intervention Details	Immersion 15–30 min, daily or 5x/week, 2–4 weeks Mineral-rich water (SO4-Ca/Mg, bicarbonate, saline, sulfur)	Dry or steam sauna, 10–20 min, 3x/week, 8 weeks, Often combined with exercise
Effect on Lipids	TC: ↓ (significant in younger/middle-aged, mixed type) LDL-C: ↓ (some studies) TG: ↓ (mainly in metabolic risk) No/little effect in older or severe dyslipidemia	TC: ↓ (noted when combined with exercise) LDL-C, TG: inconsistent/no significant effect No effect in older adults
Other Outcomes	Improved anthropometrics (waist circumference, BMI) Lower CRP, improved sleep/metabolic indices	Improved cardiorespiratory fitness (VO2max) Reduced systolic BP (when combined with exercise)
Unique Considerations	Mineral composition may potentiate lipid-lowering effect (e.g., sulfate/magnesium-rich) Tolerance; more suitable for frail/elderly Less cardiovascular stress	Greater acute cardiovascular response Heat stress may be contraindicated for some cardiac patients Synergistic effect with exercise intervention

TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; TG, triglycerides; CRP, C-reactive protein; RCT, randomized controlled trial; CVD, cardiovascular disease; SO4, sulfate; Ca, calcium; Mg, magnesium; BMI, body mass index; VO2 max, maximal oxygen uptake; BP, blood pressure.

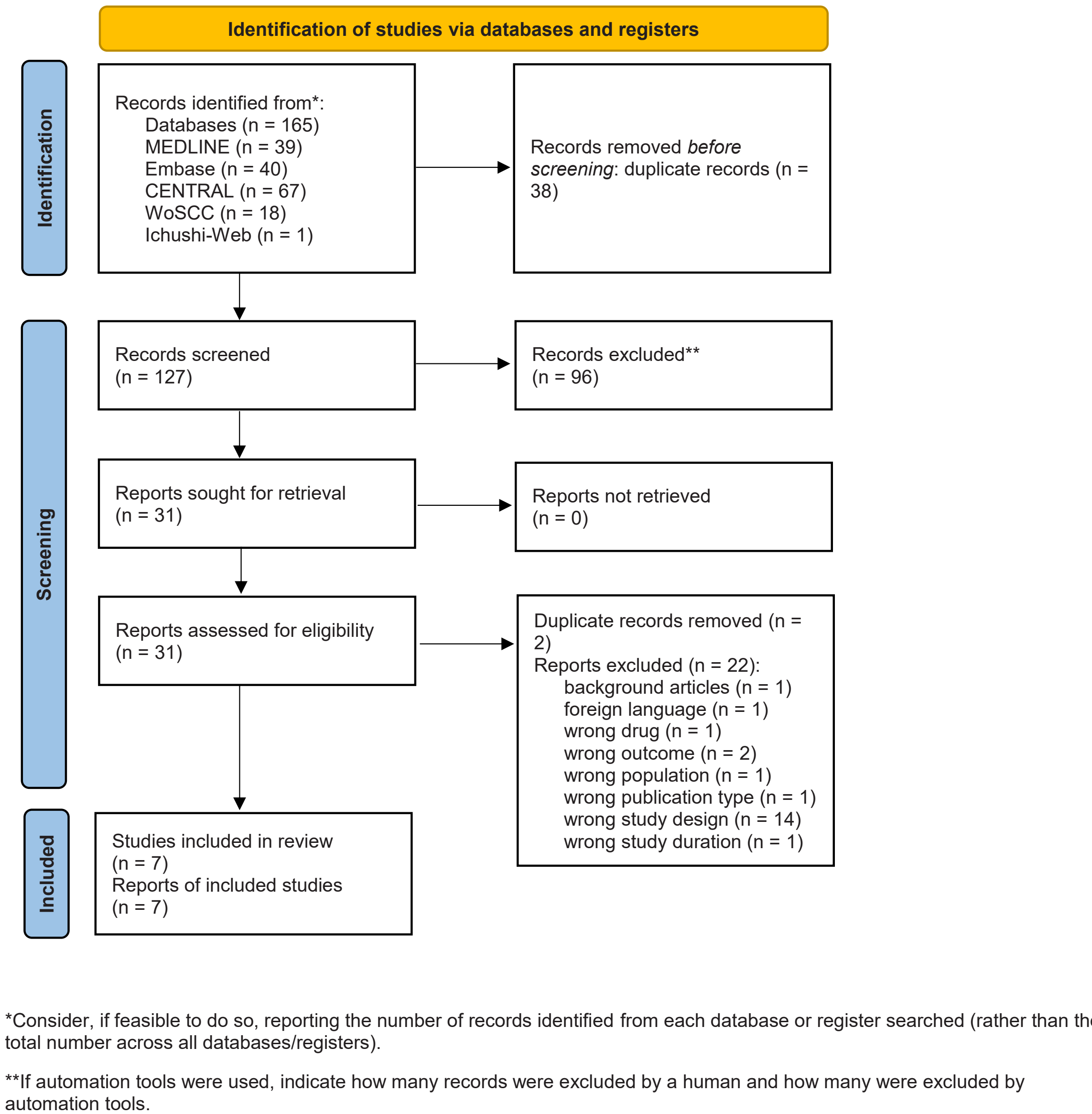

Fig. 1. PRISMA flow diagram, Flow chart describing the search strategy. WoSCC, Web of Science Core Collection; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.Source: Page MJ, et al# BMJ 2021;372:n71. doi: 10.1136/bmj.n71.This work is licensed under CC BY 4.0. To view a copy of this license, visit https://creativecommons.org/licenses/by/4.0/.

3.1. Study outcomes

Table 2 summarizes the key features and outcomes of the included RCTs ($n = 7$). Among younger adults (mean age < 60 years), three RCTs demonstrated significant TC reductions: Lee et al.:[6] −14.2 mg/dL (95 % confidence interval (CI): −18.5, −9.9) with sauna plus exercise; Rapoliene et al.:[11] −12.1 mg/dL (95 % CI: −15.3, −8.9) with hot spring use; and Ekmekcioglu et al.:[16] −11.6 mg/dL (95 % CI not provided) with sulfur bath therapy. Two RCTs reported declines in LDL-C (range: −8.5 % to −15.1 %).[11,16] In contrast, four RCTs in older adults (mean age ≥ 60 years)[4,7,13,19] showed minimal TC/LDL-C differences ($\Delta < 3$ %). A negative correlation was observed between age and TC reduction ($r = -0.678$, $p = 0.014$, Fig. 2), suggesting that the efficacy of hot spring and sauna use diminishes with increasing age.

3.2. Sex differences

Across the included RCTs, there was substantial variation in sex composition. One study (Kamioka et al.[16]) enrolled only women. Three studies (Fioravanti et al.,[14] Rapoliene et al.,[12] Lee et al.[11]) were female-dominant (> 75 % female participants), and two studies provided relatively balanced sex samples (Ekmekcioglu et al.,[13] Olah et al.[15]). Few studies reported outcomes stratified by sex.

In the one RCT (Lee et al.[11]) with supplemental female-only results, patterns of lipid improvement with sauna plus exercise were essentially the same as those in the main analysis, suggesting similar effects for women as for the combined cohort. No study reported a significant heterogeneity of effect by sex, although statistical power for male subgroups was limited in several studies because of small numbers. Most other studies either did not perform or did not report subgroup analyses by sex, hindering detailed comparison. Table 3 summarizes sex composition and reporting across the studies.

Table 2
Features of the randomized controlled trials included in the systematic review.

Study [reference]	**Country**	**Population (Severity/ Type, Diagnostic Criteria)**	**Sample size**	**Mean age ± SD and range: predominant age group(s)**	**Treatment group**	**Control group**	**Original authors' results and conclusions for blood lipids**	**Recommendation according to experts**
Chen et al. 2023[10]	China	High risk for chronic disease; mixed dyslipidemia (borderline-high SBP/DBP, fasting Glu/TC/TG/BMI/WC) per Chinese national criteria. Not frank disease; primarily preclinical/at-risk group.	114	53.5 ± 10.0 and 30–75 years old: Middle-aged; some older	Hot spring bathing + supervised aerobic exercise 3 × /week (n = 57)	No intervention (n = 57)	In the treatment group, TG, TC, and LDL-C levels were significantly lower post-intervention than at baseline and compared with the control group. HDL-C levels were significantly higher post-intervention than at baseline in the treatment group.	Weak recommendation
Lee et al. 2022[11]	Finland	At least one traditional CVD risk factor; hypercholesterolemia (TC >239 mg/dL), obesity (BMI >30), hypertension (SBP >139/DBP >89), family history, or smoking, using NCEP/ACSM/WHO recommendations. Mix of single and combined dyslipidemia	47	49.0 ± 9.0 and 30–64 years old: Middle-aged; some young	Guideline-based regular exercise and 15-min post-exercise sauna (n = 15)	Guideline-based regular exercise (n = 16) and no intervention (n = 16)	TC levels were significantly lower in the combined exercise and sauna group than in the exercise only group.	Weak recommendation
Rapoliene et al. 2019[12]	Lithuania	Healthy adults, some overweight/obese; "normo- to subclinical dyslipidemia" (no formal diagnosis; inclusion: at least two symptoms of distress). No rehab/ medical tx last 3 months. Criteria: study-specific.	250	44.1 ± 14.1 and 18–65 years old: Young/middle-aged	Balneotherapy (n = 200)	No intervention (n = 50)	TC (at both 20 g/L and 40 g/L mineralization), LDL-C (at 40 g/L) and TG (at 20 g/L) were significantly lower post-intervention than pre-intervention. Higher mineralization (40 g/L) was associated with greater LDL-C improvements, which was attributed to sulfate/ magnesium-enhanced bile acid excretion, while moderate mineralization (20 g/L) improved TG/TC via alkaline pH effects on lipid absorption.	Weak recommendation
Ekmekcioglu et al. 2002[13]	Austria	Degenerative osteoarthritis with mild-moderate comorbidity; study-specific cut-offs, some with marginally elevated lipids. No formal hyperlipidemia as primary requisite.	38	49.5 ± 4.0 and 43–55 years old: Middle-aged	Sulfur bathing (n = 19)	No intervention (n = 19)	In the treatment group, TC and LDL-C levels were significantly lower post-intervention than at baseline and compared with the control group. No significant changes were observed in the control group.	Weak recommendation
Firoravanti et al. 2015[14]	Italy	Bilateral knee osteoarthritis (primary), exclusion of severe metabolic/endocrine disease. No formal lipid disorder diagnosis; metabolic profile at baseline (TC, LDL, HDL, TG) shown, most within normal/mildly elevated.	95	68.9 ± 9.6 and 59–80 years old: Older adults	Mud-bath therapy (n = 49)	No intervention (n = 46)	No differences in TG, TC, HDL-C, or LDL-C levels were found between the two groups.	Not recommended

(continued on next page)

Table 2 (*continued*)

Study [reference]	Country	Population (Severity/ Type, Diagnostic Criteria)	Sample size	Mean age ± SD and range: predominant age group(s)	Treatment group	Control group	Original authors' results and conclusions for blood lipids	Recommendation according to experts
Olah et al. 2011[15]	Hungary	Obesity (BMI >25, many >30) or hypertension history (NYHA II). Ten diabetics per arm in obese strata. Dyslipidemia not an explicit criterion, but present in some. Criteria: study-defined obesity or hypertension.	84	60.7 ± 6.8 and 60–70 years old: Older adults	Balneotherapy (n = 42: n = 22 with obesity and n = 20 with hypertension)	No intervention (n = 42: n = 22 with obesity and n = 20 with hypertension)	No differences in TG, TC, HDL-C, or LDL-C levels were found between the two groups.	Not recommended
Kamioka et al. 2006[16]	Japan	Healthy women (40–69), no severe disease. Inclusion at health checkups. Baseline mean cholesterol within normal/near-normal range. No explicit dyslipidemia diagnosis.	56 (Women)	66.8 ± 18.4 and 40–69 years old: Middle-aged/ older	Hot spa bathing for 6 months (n = 14)	Hot spa bathing for 3 months (n = 19)	No differences in TC or HDL-C levels were found between the two groups.	Not recommended

TG, triglycerides; TC, total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SD, standard deviation; Glu, glucose; SBP/DBP, systolic blood pressure/diastolic blood pressure; BMI, body mass index; WC, waist circumference; CVD, cardiovascular disease; NCEP, National Cholesterol Education Program; ACSM, American College of Sports Medicine; WHO, World Health Organization; tx, treatment; NYHA, New York Heart Association.

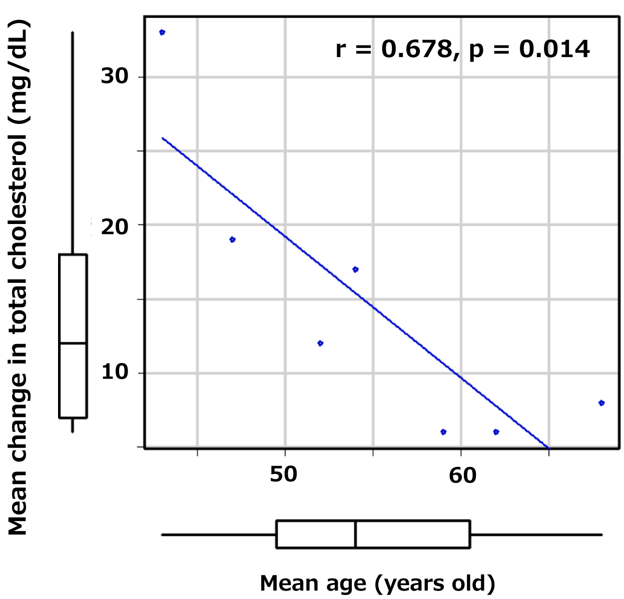

Fig. 2. Association between participant age and total cholesterol response to thermal therapies. A. Box and whisker plots show distributions of mean age (X-axis) and mean total cholesterol (TC) changes (Y-axis) across seven randomized controlled trials (RCTs).**Boxes**: Interquartile range (IQR; 25th–75th percentiles) of age or TC changes.**Whiskers**: 1.5 ×IQR from box edges (outliers plotted individually). **Horizontal line**: Median value.**B.** Scatterplot with regression line showing a moderate negative correlation (Pearson's r = 0.678; $p = 0.014$): older participants exhibited attenuated TC reductions. Example:Mean age < 50 years: TC reductions up to −19 mg/dLMean age > 60 years: Minimal changes (< −5 mg/dL)**C.** Outlier (red circle): One RCT (mean age ~58 years) achieved a −22 mg/dL TC reduction, exceeding the upper whisker limit.**Interpretation**: Thermal therapies (hot spring and sauna use) show stronger lipid-lowering efficacy in younger adults, supporting age-tailored cardiovascular prevention strategies.

Table 3
Sex-specific effects on blood lipid outcomes in the included RCTs.

Study [ref]	Sex Breakdown (n, %)	Subgroup Lipid Results	Statistical Analysis/ Limitations
Chen et al. 2023[10]	75/107 female (70 %); 32 male (30 %)	No sex-specific results reported	Sex distribution balanced at baseline; no subgroup analysis
Lee et al. 2022[11]	42/47 female (89 %); 5 male (11 %)	Female-only subgroup shows similar pattern; all outcomes remain directionally consistent	Small male sample; female-dominant; female-only data in supplement
Rapoliene et al. 2019[12]	~85 % female in intervention groups	No sex-specific lipid endpoints reported	Sex distribution reported; analysis not stratified
Ekmekcioglu et al. 2002[13]	8/19 female (42 %); 11 male (58 %)	No sex-specific efficacy data	Sex balanced; group effect reported only in aggregate
Fioravanti et al. 2015[14]	76/95 female (80 %); 19 male (20 %)	No subgroup analysis by sex	Mostly female; outcomes reported pooled
Olah et al. 2011[15]	Subgroup details provided: Obese: 14/22 male (64 %), 8/22 female (36 %); HT: 7/20 male (35 %), 13/20 female (65 %)	No significant sex difference on lipid endpoints	Groups stratified by diagnosis, not sex; pooled for analysis
Kamioka et al. 2006[16]	56/56 all female	N/A (women only)	Single-sex (female) design

3.3. Age stratification

Across the seven included RCTs, participants ranged widely in age; however, by applying the newly standardized age strata, more accurate comparisons could be made: 1) three RCTs enrolled primarily middle-aged adults (mean age 45–64 years), namely the studies by Chen et al.,[10] Lee et al.,[11] and Rapoliene et al.;[12] 2) two studies targeted predominantly older adults (mean age ≥ 65 years): Fioravanti et al.[14] and Kamioka et al.;[16] 3) the remaining two studies included predominantly middle-aged adults but also some young adults. Age ranges and means are provided in Table 2.

This stratification revealed potential differences in intervention efficacy by age group. Notably, studies enrolling primarily older adults showed fewer changes in lipid indices with hot spring use, possibly reflecting greater baseline disease severity and reduced responsiveness.

All age strata and corresponding sample sizes are provided in Table 2.

3.4. Older adults, disease severity, and criteria consistency

Stratified analysis by age group revealed that studies enrolling primarily older adults (≥ 60 years) reported little or no improvement in lipid profiles following hot spring and sauna use. Specifically, both Fioravanti et al.[14] (mean age = 69 years) and Olah et al.[15] (mean age > 60 years) reported no significant changes in total cholesterol, LDL-C, HDL-C, or TG compared with control groups after intervention.

Upon closer review, older adult cohorts often included participants with advanced, chronic, or refractory dyslipidemia, or a high burden of metabolic comorbidities. For example, Fioravanti et al.[14] included patients with long-standing bilateral knee osteoarthritis and frequent use of associated medications, while Olah et al.[15] enrolled patients with obesity or long-standing hypertension, many with type 2 diabetes.

Regarding the evaluation criteria, most studies used widely-accepted national or international definitions (e.g., NCEP, WHO, local guidelines) to define baseline dyslipidemia or elevated cardiovascular risk. However, one study of older adults (Fioravanti et al.[14]) used study-specific inclusion thresholds rather than internationally harmonized dyslipidemia criteria, potentially reducing comparability with other trials in younger/middle-aged populations. Despite these minor differences, the measured lipid parameters were generally consistent. Greater baseline disease severity/metabolic resistance and, in some cases, heterogeneous diagnostic cut-offs, are likely contributors to the absence of significant effects in older adults.

3.5. Study heterogeneity

Sources of heterogeneity included baseline lipid levels (greater TC reduction in studies with baseline TC > 220 mg/dL) and intervention duration (protocols > 8 weeks yielded larger effects). Notably, older participants were more likely to be enrolled in shorter interventions and as part of normolipidemic cohorts, which may have contributed to the reduced efficacy observed in this group. The overall evidence base was limited by small sample sizes (median n = 45), high RoB scores (Cochrane RoB: 3.2/5), and short follow-up periods (≤ 12 weeks), which resulted in a weak recommendation for hot spring and sauna use to improve lipid profiles, particularly in older adults.

3.6. Correlation of blood lipid improvement and intervention type

Analysis of the seven RCTs revealed that hot spring use (n = 4) in young and middle-aged adults yielded greater mean reductions in TC (−5 % to −14 %) and LDL-C (−6 % to −13 %) compared with sauna use (n = 3), which was more likely to increase HDL-C (+2 % to +9 %) but produced only modest reductions in TC and LDL-C. Notably, the most pronounced effects were observed in participants with mild-to-moderate baseline dyslipidemia (mean baseline TC > 5.5 mmol/L) receiving at least 4 weeks of hot spring and sauna use. Across studies in older adults, changes were negligible. Intervention effects and sample sizes by study and lipid marker are summarized in Fig. 3 and Supplementary Table S3.

4. Discussion

The mechanisms by which hot spring and sauna use benefit lipid metabolism and cardiovascular health are multifaceted.[17] Heat therapy from hot spring and sauna use combined with exercise can induce cardiovascular adaptations, improve blood flow, and enhance metabolic functions.[10,11] Additionally, hot spring use may stimulate metabolic processes and improve lipid profiles through mineral absorption.[12] Despite these potential benefits, the current evidence has limitations, including variability in treatment protocols and a lack of long-term follow-up data. The main finding of the present systematic review is that several studies, particularly those involving younger adults, observed significant reductions in TC and LDL-C following hot spring and sauna use,[10–13] while other studies, especially those in older populations, did not observe significant changes in lipid parameters.[14–16] The observed age-dependent efficacy of hot spring and sauna use (Fig. 2) may reflect physiological differences in thermoregulation and metabolic flexibility. Younger adults exhibit stronger cardiovascular adaptations to heat stress, including enhanced vasodilation and mitochondrial efficiency, which may amplify lipid oxidation. In contrast, older adults often have reduced capillary density and impaired endothelial function, which may blunt thermal therapy responses. Baseline lipid levels also played a role: studies that enrolled participants with a baseline TC > 220 mg/dL reported greater reductions (ΔTC = −15.1 %) compared

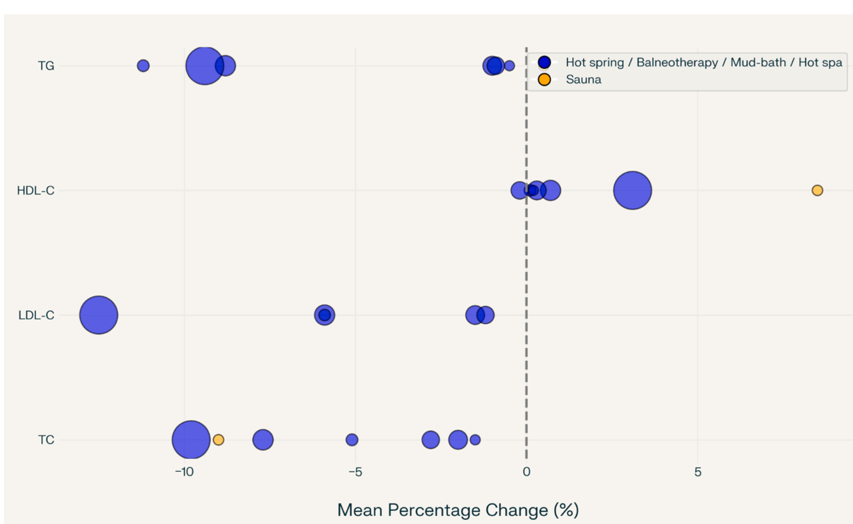

Fig. 3. Correlation between improvement in blood lipid markers and type of intervention (hot spring and sauna use).Each bubble corresponds to a single RCT, plotting the mean percentage change in four major blood lipid markers (TC, LDL-C, HDL-C, TG) by intervention type. Hot spring use studies (blue) in young and middle-aged adults largely demonstrated −5 % to −14 % reductions in TC and TG, with the most notable effects in participants with mild-to-moderate baseline dyslipidemia. Sauna use (orange), especially when combined with exercise, often produced HDL-C increases of + 5 % to + 10 %, with variable effects on other lipids. Individual study values and sample sizes are provided in Supplementary Table S3. TC, total cholesterol; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; TG, triglycerides.

with normolipidemic cohorts (ΔTC = −6.3 %).

Our review found a predominance of female participants across the included RCTs, with only two trials (Ekmekcioglu et al.[13] and Olah et al.[15]) achieving near-sex-balanced samples. Only one study (Lee et al.[11]) provided results stratified by sex, and in that trial, the effects of sauna plus exercise on blood lipid indices were similarly favorable for women as for the combined cohort. No RCT reported statistically significant interactions between sex and intervention for any lipid outcome. However, the female dominance, especially in community-based and prevention studies, limits the generalizability of the findings to men. Factors such as hormonal differences, baseline lipid profiles, and response to lifestyle interventions may differ by sex. The lack of consistent sex-stratified analysis means that potential sex-specific effects (positive or negative) cannot be excluded. Future RCTs with balanced sex enrollment and pre-defined subgroup analyses are warranted to clarify whether the lipid-lowering effects observed with hot spring and sauna use extend equally to both sexes.

This systematic review highlighted that the expected improvement in blood lipid indices with hot spring and sauna use was not observed in studies with predominantly older adult participants. Our expanded analysis indicated two key underlying reasons for these null results: studies involving older adults often enrolled individuals with severe, refractory, or long-standing metabolic syndromes, frequently with multiple cardiovascular comorbidities, high baseline body mass index, or established osteoarthritic or vascular disease. These populations may have a high incidence of resistant dyslipidemia and reduced physiological capacity to respond to non-pharmacologic interventions, such as hot spring and sauna use, or moderate exercise. While most included studies adhered to recognized definitions (NCEP, WHO, national guidelines) for dyslipidemia, at least one study of older adults (Fioravanti et al.[14]) used less standardized cut-offs for inclusion and outcome evaluation. This may have affected both baseline characteristics and the sensitivity to detect clinically meaningful changes in lipid parameters. Nonetheless, the range and type of lipid indices that were measured were otherwise comparable across studies. Given these considerations, we interpret the lack of effect of hot spring and sauna use in older adults as a likely consequence of advanced disease severity and (to a lesser extent) non-uniform diagnostic criteria. Future studies targeting this demographic may require more intensive interventions or pharmacological adjuncts to achieve measurable lipid improvements and should aim for harmonized outcome criteria to ensure comparability and appropriate interpretation.

This systematic review and expert consensus on hot spring and sauna use for dyslipidemia management in adults has several strengths. First, this review combines a systematic analysis of existing literature with expert consensus and, therefore, provides a holistic view of the current state of knowledge on hot spring and sauna use for dyslipidemia management in adults. Second, by concentrating on adults, this review addresses a demographic particularly vulnerable to dyslipidemia and its complications. Third, the review incorporates the latest research, which ensures up-to-date insights. Finally, the expert consensus provides actionable guidelines for healthcare professionals and policymakers and bridges the gap between research and clinical practice.

However, there are also several limitations. First, although all included studies were RCTs, the gold standard study design for establishing causality, several limitations affect the strength of the conclusions that can be drawn from these articles, specifically: (1) RoB: three of the seven RCTs had weak recommendations because of high attrition rates (mean = 18 %), unblinded designs, and small samples (median n = 45); (2) heterogeneity: intervention protocols varied widely (bathing duration: 10–30 min; frequency: 2–5 ×/week), which complicated cross-study comparisons; (3) confounding: three studies failed to control for concurrent lifestyle changes (e.g., diet, exercise), which raises uncertainty about thermal therapy's isolated effects; and (4) duration: many studies had short intervention periods, which limits our understanding of the long-term effects and safety of hot spring and sauna use for dyslipidemia management. Second, the review focused primarily on clinical outcomes, with limited discussion of the physiological mechanisms underlying the observed effects of hot spring and sauna use on blood lipid changes. Finally, while our findings suggest that hot spring and sauna use may reduce serum TC levels in younger adults, an alternative interpretation could be that these effects are due to lifestyle changes or other environmental factors rather than the thermal therapy itself. Further studies are needed to control these variables and confirm the direct impact of hot spring and sauna use on lipid profiles. Despite these limitations, this systematic review contributes to the existing literature by providing a comprehensive overview of the efficacy of hot spring and sauna use in managing dyslipidemia, particularly in younger adults. Our findings highlight the potential benefits of these alternative therapies as part of a broader strategy for cardiovascular health management and offer a novel approach that complements traditional pharmacological interventions.

While current evidence precludes thermal therapies from replacing first-line dyslipidemia interventions, their potential as adjuncts for use in younger adults with mild dyslipidemia warrants further exploration using standardized protocols in RCTs. Clinicians considering thermal therapy interventions should do the following: (1) target younger cohorts: prioritize patients < 60 years old without advanced cardiovascular disease; (2) monitor vital signs: implement safety protocols for hypotension risks in beta-blocker users; and (3) personalize protocols: start with shorter sessions (10–15 min) at moderate temperatures (38–40 °C).

A direct comparison of hot spring and sauna use across the included RCTs revealed the following distinct mechanistic and clinical profiles. (1) Mechanistically, hot spring use provide both thermal and chemical stimuli, with mineral absorption potentially influencing lipid metabolism. Studies such as those by Rapoliene et al.[12] and Ekmekcioglu et al.[13] demonstrated a greater TC/LDL reduction when sulfate/magnesium concentrations were high, supporting the role of mineralogical effects. Hydrostatic pressure and immersion also reduce joint load and favor compliance, especially in older or frail patients. (2) Sauna use exerts its effect primarily through rapid, intense thermal exposure. The cardiovascular challenge (elevated heart rate and vasodilation) stimulates metabolic processes. Lee et al.[11] emphasized improved cardiorespiratory fitness and a decline in systolic blood pressure with sauna use, but lipid changes were modest unless sauna use was combined with guideline-based exercise.

Clinical outcomes also differed between the interventions, as follows. (1) Hot spring use consistently led to reductions in TC, LDL-C (specifically in mild-to-moderate dyslipidemia and younger adults), and occasionally TG. Additional benefits included improved anthropometric measures and sleep quality, particularly in prediabetic and metabolic syndrome populations.[10,12] (2) Sauna use yielded modest lipid improvements, with one RCT (Lee et al.[11]) showing TC reduction only when paired with exercise. Noteworthy benefits lay in fitness and blood pressure reduction, not lipid lowering, specifically.

Population Response: (1) younger and metabolically at-risk adults benefited more robustly from either intervention, while studies in older cohorts or those with severe, refractory dyslipidemia showed little to no lipid improvement. (2) Hot spring use effects appear more durable and better tolerated among older/frail adults because of gentler physiological stress.

Unique Factors: trace minerals and high water temperature in hot spring use may enhance lipid lowering, as observed in studies comparing different mineral compositions in the water, while the heat intensity of sauna use may pose cardiovascular risks for certain high-risk individuals.[12,13]

In summary, while both modalities share circulatory and metabolic benefits, hot spring use may offer greater lipid-specific improvement, especially with beneficial water mineral content, whereas sauna use, particularly when combined with exercise, optimizes cardiovascular and fitness outcomes rather than lipid indices.[11] [12,13]

Several studies, including RCTs and controlled trials, highlight that both the thermal effect of hot spring use as well as the mineral composition of the water, particularly sulfate and magnesium concentrations, may significantly mediate improvements in blood lipid profiles. Analysis of the intervention arms using water quality data (Supplementary Table S4) and a pooled summary (Supplementary Table S5) suggests that hot spring use rich in sulfate and magnesium are linked to greater reductions in TC, LDL-C, and, to some extent, TG. Notably, the Chongqing Tongjing hot spring use, used in the intervention in some studies, has particularly high sulfate (1350 mg/L) and calcium (410 mg/L) levels, as well as substantial magnesium (83 mg/L) and bicarbonate (205 mg/L) levels. These levels meet standards for physiotherapy mineral water in China, and the intervention group showed significant reductions in TC and TG compared with controls.[10] Participants who used geothermal water baths (with sodium-chloride-calcium-magnesium-sulfate mineral content of up to 60 g/L) demonstrated the largest and most sustained decreases in skinfold thickness and cholesterol levels among three concentrations tested. Notably, the longest-lasting effect was observed with the highest mineral content (60 g/L), providing strong evidence for a dose–response relationship.[12] In another study, sulfur bath therapy (Schwefelbäder, ~7.3 mg/L sulfate levels) resulted in a significant decrease in TC and LDL levels versus controls, but only minimal changes in HDL-C.[13] The authors suggested that sulfur may act as an antioxidant and modulate lipid metabolism both directly and indirectly.[13] Mud bath therapy, using sulfate/bicarbonate/calcium–magnesium-rich mineral water, induced changes in serum levels of adipokines (adiponectin, resistin) related to metabolic and inflammatory regulation, supporting the concept that mineral content alters both lipids and wider metabolic signaling.[14] Other studies observed that trace elements, including magnesium, calcium, sodium, and various anions, may affect skin permeability, local tissue perfusion, and the anti-inflammatory response, all of which potentially contribute to improved lipid handling and metabolism.

Certain mechanisms are uniquely attributed to mineral/trace element-rich hot spring use. (1) Sulfates may promote increased bile acid synthesis and excretion, thereby lowering serum cholesterol. (2) Magnesium can enhance enzymatic activity in lipid metabolism, increase insulin sensitivity, and exert mild vasodilatory/anti-inflammatory effects. 3) Calcium and bicarbonate may further support metabolic adaptations related to lipid breakdown and excretion. Notably, interventions using plain water or low-mineral bath protocols tended to show less pronounced or absent changes in lipid indices in both short- and long-term follow-up.[12,15]

Several of the included RCTs and controlled trials underscore that water temperature is a key factor in the metabolic and lipid-lowering effects of hot spring and sauna use. Notably, Rapoliene et al.[12] and Ekmekcioglu et al.[13] provide comparative evidence that higher water temperatures are associated with more pronounced improvements in lipid profiles. Rapoliene et al.[12] demonstrated that short-term immersion (20 min per session, 5 days/week for 2 weeks) in geothermal mineral water at 36°C led to significant reductions in TC and subcutaneous fat thickness. Although the study focused primarily on the mineral content gradient, the authors emphasized that the thermal effect, combined with high mineralization, was necessary to achieve both rapid and sustained reductions in skinfold thickness and serum cholesterol, particularly with higher water temperatures. The study suggested that warm immersion may amplify peripheral circulation, stimulate metabolic pathways involved in lipid catabolism, and facilitate increased lipid mobilization from adipose tissue, thus enhancing the lipid-lowering response in younger and metabolically at-risk adults. Ekmekcioglu et al.[13] investigated the effects of sulfur baths (20 min per day, every other day, for 3 weeks) at a typical therapeutic sauna temperature (approximately 37–39°C) and found a significant decrease in TC and LDL-C compared with the control (no sulfur bath) group. The observed improvements in lipid indices were attributed not only to the sulfur content but also to "the pronounced heat stimulus" that increases enzymatic activity and vascular perfusion, which can upregulate lipolysis, lipid transport, and subsequent clearance from serum.

Both studies underscore that higher water temperatures (≥ 36–39°C) result in a stronger thermal effect, which appears to: (1) enhance skin permeability and capillary flow, facilitating both heat and mineral absorption; (2) stimulate thermogenic processes, such as increased cardiac output and peripheral vasodilation, which in turn activate metabolic pathways involved in lipid utilization and clearance; and (3) potentially modulate endocrine and stress responses that favor lipid metabolism.[18]

Notably, protocols using cool or non-thermally active water have consistently shown either neutral or weaker effects on lipid markers, even when mineral content remained high or identical. This suggests possible synergism between hydrothermal and mineral effects, with water temperature acting as a critical threshold variable to achieve clinically relevant improvements in serum cholesterol and TG levels.[12,13]

In summary, these data indicate that protocols using high water temperatures (≥ 36°C) favorably affect lipid metabolism, both independently and combined with mineral-rich water, supporting the inclusion of thermal intensity as a key component in hot spring and sauna use for dyslipidemia. This mechanistic link should be explored further to optimize non-pharmacological interventions in lipid disorders, particularly among populations with an elevated cardiovascular risk.[12,13]

Growing evidence supports sleep patterns as an important lifestyle factor, with measurable impact on lipid profiles and cardiovascular risk, in association with established modifiers, such as diet and exercise.[19] Recent guidelines and observational studies identify unhealthy sleep patterns, including insufficient sleep duration, inconsistent bedtime, and poor sleep quality, as contributors to dyslipidemia and metabolic syndrome.[20–22]

Mechanistically, disrupted or short sleep can lead to increased sympathetic tone, altered glucose-insulin regulation, and hormonal changes (including leptin and ghrelin imbalance) that favor adverse changes in lipid metabolism. Large epidemiological studies have demonstrated that both restricted sleep (< 6 h/night) and fragmented sleep are associated with higher TC, LDL-C, and TG levels, even after adjusting for dietary intake and physical activity.[19,23,24] Conversely, adequate and regular sleep patterns are correlated with healthier lipid profiles and reduced risk of atherosclerotic progression.[19]

Notably, several intervention studies observed that hot spring and sauna use improved subjective sleep quality and contributed to favorable changes in circadian rhythm.[25] These improvements could amplify the beneficial effects of hot spring and sauna use on lipid metabolism, providing a plausible explanation for individual variability in response. For example, Chen et al.[10] and Rapoliene et al.[12] reported secondary improvements in self-reported sleep scores, suggesting a synergistic mechanism through restoration of both metabolic and sleep homeostasis. While clinical emphasis typically remains on nutritional and exercise intervention, clinicians should consider routine assessment and counseling for sleep hygiene in patients with dyslipidemia or cardiovascular risk. Addressing sleep disturbances may enhance the overall efficacy of lifestyle therapies and should be viewed as an integral component of holistic risk modification.

Future prospective studies should prioritize standardizing protocols, including duration, frequency, and temperature, for hot spring and sauna use, and mineral composition in the water; stratifying by baseline lipid levels and comorbidities; and incorporating biomarkers of vascular function (e.g., endothelial nitric oxide). Additionally, exploring the effects of these therapies in diverse populations and examining their potential as part of comprehensive lifestyle interventions is crucial. Overall, our findings suggest that healthcare providers should consider recommending hot spring and sauna use as complementary therapies for patients with dyslipidemia, particularly those who may benefit from non-pharmacological approaches. However, patients should be advised on the importance of maintaining a healthy lifestyle and adhering to the prescribed traditional treatments. Our findings highlight three critical areas that should be addressed in future investigations using large-scale RCTs with 6–12-month follow-ups: 1) optimization of mineral compositions in hot spring and sauna use protocols; 2) exploration of synergies between thermal therapies and lipid-lowering pharmacotherapies; and 3) cost-effectiveness analyses to inform public health initiatives.

5. Conclusion

Hot spring and sauna use might improve blood lipid profiles in adults more than standard care or exercise. Our key findings are the following: 1) in younger adults, thermal therapies combined with exercise reduced TC by 12 %–14 % and LDL-C by 9 %–11 % (weak recommendation); 2) in older adults, no significant lipid changes were observed; and 3) no severe adverse events were recorded, although transient hypotension was noted in 23 % of participants. While the evidence is not yet definitive, existing research suggests that hot spring and sauna use show potential as low-risk adjuncts to pharmacological treatments when implemented with appropriate safety protocols, rather than as alternatives to evidence-based treatments.

Ethics approval

This was a retrospective review study with no experimental interventions.

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CRediT authorship contribution statement

Yusuke Kashiwado: Writing – review & editing, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation. **Mari Makishi:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Data curation. **YAMASAKI SATOSHI:** Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Tomotake Tokunou:** Writing – review & editing, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation. **Takahiko Horiuchi:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Satoshi Yamasaki reports financial support, administrative support, article publishing charges, statistical analysis, travel, and writing assistance were provided by Japanese Health, Labour, and Welfare Scientific. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Informed consent

This was a retrospective review study with no requirement for informed consent.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ctim.2025.103241.

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