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Chrononutrition and Healthy Ageing: A Systematic Review and Meta-Analysis of Time-Restricted Eating in Older Adults

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ABSTRACT

Background

Chrononutrition, the strategic alignment of eating patterns with the body's biological rhythms, has gained increasing attention as a potential means of improving metabolic health. Time-restricted eating (TRE), a key chrononutrition approach, may help regulate metabolism, yet its effectiveness in older adults remains uncertain. This systematic review and meta-analysis examined the effects of TRE and related chrononutrition interventions on metabolic health biomarkers among older adults aged 60 years and above. The primary outcomes assessed included body mass index (BMI), fasting glucose, systolic and diastolic blood pressure (SBP, DBP), total cholesterol, triglycerides, high-density lipoprotein (HDL), and low-density lipoprotein (LDL).

Methods

A comprehensive literature search was conducted across major databases (PubMed, MEDLINE, CINAHL, and Scopus) to identify randomised controlled trials and pre–post intervention studies published between 2015 and 2025. Study quality was appraised using Cochrane risk-of-bias tools. Random-effects meta-analyses were performed, and pooled effect sizes (Cohen's d) with 95% confidence intervals were calculated.

Results

Seven studies, including both RCTs and pre–post designs, comprising a total of 1,086 participants, met the inclusion criteria. Pooled analyses indicated small, non-significant reductions in BMI (Cohen's d = –0.10, 95% CI: –0.24 to 0.03, p = 0.14) and fasting glucose (Cohen's d = –0.18, 95% CI: –0.61 to 0.25, p = 0.41). No statistically significant changes were observed for SBP, DBP, total cholesterol, triglycerides, HDL, or LDL (all p > 0.05). Heterogeneity across studies was minimal, and findings were consistent between RCTs and pre–post analyses.

Conclusion

Time-restricted eating appears to be a safe and feasible dietary approach for older adults; however, it does not produce statistically significant improvements in key metabolic biomarkers compared to control or baseline conditions. The modest effects observed may reflect the complex interplay of biological, behavioural, and sociocultural factors influencing chrononutrition in ageing populations. More diverse and methodologically robust studies are needed to clarify TRE's role in promoting metabolic health and reducing chronic disease risks among older adults.

Keywords: Chrononutrition; Time-Restricted Eating (TRE); Older Adults; Metabolic Health; Body Mass Index (BMI); Blood Pressure; Lipid Profile; Glucose Metabolism; Systematic Review; Meta-Analysis.

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1. INTRODUCTION

Chrononutrition is an emerging area of nutritional science that asks a simple but powerful question: does *when* we eat matter as much as *what* we eat? It explores how the timing of meals interacts with the body's circadian rhythms, the internal biological clock that governs sleep, metabolism, hormones, and many other physiological processes (Flanagan et al., 2020). The idea is that eating in sync with these natural rhythms can improve health, while eating at the wrong times may disrupt metabolism and increase disease risk. This concept is particularly relevant for older adults aged 60 and above, whose internal clocks often become less synchronised with day–night cycles, making them more vulnerable to metabolic disorders such as diabetes, obesity, dyslipidaemia, and cardiovascular disease (Reutrakul & Knutson, 2015; WHO, 2022).

As the world's population ages, the question of how best to support metabolic health in later life has taken on growing urgency. The World Health Organization (WHO) projects that by 2050, the global population aged 60 and above will more than double, from 1 billion in 2020 to 2.1 billion (WHO, 2024). More than 70% of deaths in this group are now caused by chronic diseases, many of which are closely linked to poor metabolic regulation (WHO, 2021). Traditional dietary approaches

have focused mainly on *what* people eat, such as calories, fats, sugars, and nutrients, but there is now increasing evidence that *when* people eat may be just as important. Meal timing strategies such as time-restricted eating (TRE) and early time-restricted feeding (eTRF) have gained attention for their potential to improve metabolism and overall health (Lin et al., 2022).

Ageing brings a unique set of physiological challenges. As people grow older, their bodies become less efficient at managing energy: insulin sensitivity decreases, glucose tolerance declines, fat mass tends to rise, and hormone levels fluctuate (Amarya et al., 2015; Pataky et al., 2021). These changes are compounded by disruptions in circadian rhythms, which can alter sleep patterns, feeding behaviour, and metabolic function (Boege et al., 2021). Chrononutrition-based interventions such as TRE and eTRF aim to realign eating habits with the body's natural daily cycles. For instance, eTRF, where all meals are eaten within the earlier part of the day, such as between 7 a.m. and 3 p.m., takes advantage of periods when the body is naturally more insulin-sensitive and metabolically active, potentially improving blood sugar and cholesterol levels (Dimitriadis et al., 2021). While these approaches have shown encouraging results in younger and middle-aged adults, far less is known about how they affect older adults, whose biological rhythms and nutritional needs differ.

As Raji et al. (2024) illustrated (see Figure 1), the timing and regularity of eating are influenced not only by biology but also by social, cultural, and environmental factors such as age, gender, health status, cultural norms, income, neighbourhood, and food security. These factors interact in complex ways to shape metabolic health and health equity. Understanding this broader context is vital if chrononutrition is to be meaningfully integrated into public health strategies. It offers a promising, low-cost way to complement traditional dietary guidelines, particularly in ageing populations where healthcare systems are already strained by the growing burden of chronic disease (Baik & Bird, 2023; Vasiloglou et al., 2019).

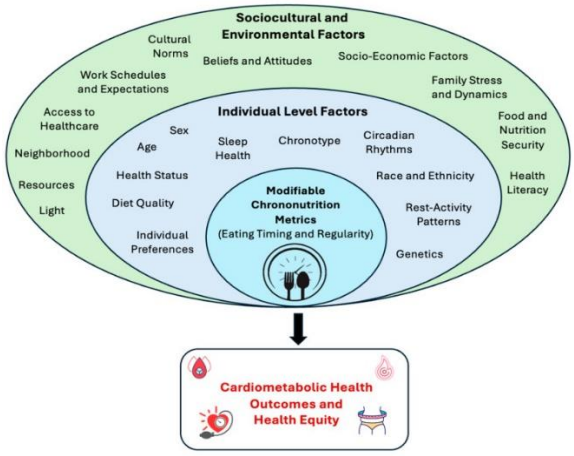

Figure 1: Determinant of eating timing and regularity (Raji et al., 2024)

The economic case is also compelling. In the United Kingdom, for example, diabetes care costs the National Health Service (NHS) more than £10 billion each year, with much of that cost arising from older adults (Baxter et al., 2016). Preventing or delaying metabolic decline could significantly reduce both healthcare spending and the personal toll of chronic disease. However, research into chrononutrition remains limited. Many studies combine younger and older adults into broad age groups, making it difficult to isolate the effects of meal timing in later life. Differences in study design, definitions of eating windows, and outcome measures further complicate interpretation (Dashti et al., 2025).

What we do know is that meal timing appears to have a measurable impact on metabolic health. Eating earlier in the day, rather than late at night, improves glucose tolerance, insulin sensitivity, and lipid metabolism (Peters et al., 2024). A systematic review of eight studies found that TRE reduces body weight and fat mass while preserving lean tissue and improving markers such as fasting glucose, insulin, and cholesterol, even when total calorie intake remains unchanged (Huang et al., 2022). This suggests that aligning eating patterns with the body's natural circadian rhythm may improve health independently of diet quantity or composition (Regmi & Heilbronn, 2020). In contrast, consuming the largest meal late in the evening has been linked to higher obesity risk and poorer metabolic control (Lopez-Minguez et al., 2019).

The need for innovative approaches is underscored by the growing prevalence of metabolic syndrome, a cluster of conditions that includes abdominal obesity, hypertension, dyslipidaemia, and impaired glucose control (Rochlani et al., 2017). Across Europe, roughly one in four adults over 60 meet the diagnostic criteria for metabolic syndrome (Dobrowolski et al., 2022). Global data show sharp increases in obesity, high fasting glucose, and LDL cholesterol between 1990 and 2019, particularly in high-income countries (Wang et al., 2021). According to Global Burden of Disease estimates, hypertension and type 2 diabetes alone accounted for more than 300 million disability-adjusted life years (DALYs) in 2021, reflecting their immense public health impact (Zhang et al., 2024). In the UK, obesity rates are highest among older adults, affecting around 36% of those aged 55–64 and 35% of those aged 65–74, and the condition costs the NHS £6.5 billion annually, with wider economic costs reaching up to £126 billion (NHS Digital, 2024).

Despite growing interest, evidence specific to older adults remains patchy. Many studies are short-term, involve small samples, or use inconsistent definitions of eating windows, limiting the strength of conclusions. There is also a shortage of validated tools for measuring

chrononutrition behaviours among older people, although newer instruments such as the Chrono-Nutrition Behaviour Questionnaire are promising. Other important questions, such as how factors like chronotype, genetics, or social routines influence outcomes, remain underexplored (Dashti et al., 2025).

From a public health perspective, meal-timing interventions offer a practical, cost-effective, and accessible strategy to improve metabolic health in older populations (Reytor-González et al., 2025). Unlike restrictive diets that require calorie counting or special foods, time-restricted eating focuses mainly on when people eat. This simplicity makes it easier to adopt and sustain, particularly for older adults who may face medical or social barriers to complex diets (O'Connor et al., 2021; Shea et al., 2024). Restricting food intake to an 8–12-hour window during the day, followed by an overnight fast, allows the body to reset its metabolic processes and improve glucose and lipid regulation (Poggiogalle et al., 2018; Parr et al., 2022).

Integrating these principles into public health programmes could significantly reduce obesity and cardiovascular risk while improving quality of life in later years (Parrotta et al., 2025; Ezpeleta et al., 2024). Campaigns that encourage earlier eating, reduced late-night snacking, and culturally adapted educational strategies could help normalise healthier eating rhythms across populations (Pineda et al., 2022). Leading organisations such as the National Heart, Lung, and Blood Institute (NHLBI) have already recognised the potential of chrononutrition, urging that meal timing be incorporated into dietary guidelines and healthy ageing frameworks (NHLBI, 2019).

Against this backdrop, the present study aims to systematically review and synthesise existing evidence on how time-based eating patterns, such as time-restricted eating and early time-restricted feeding, affect metabolic outcomes in adults aged 60 years and above. It will examine the strength and consistency of the evidence, identify factors that influence outcomes, and clarify whether these approaches can meaningfully improve health in older adults. Filling a crucial gap in geriatric nutrition research, this work seeks to inform future dietary guidelines, shape public health policy, and promote healthier ageing through a deeper understanding of how biology and behaviour intertwine across time.

2. METHODOLOGY

2.1. Systematic Review Design

A systematic review and meta-analysis was chosen to provide a comprehensive synthesis of the available literature and to quantify the overall impact of meal timing interventions on metabolic outcomes. This design offers a transparent and replicable framework to evaluate multiple independent studies, strengthening the reliability and generalisability of conclusions (Higgins et al., 2022).

Meta-analysis, where feasible, allowed for the quantitative pooling of outcome data such as body mass index (BMI), fat mass, fasting glucose, blood pressure, and lipid profiles. It also enabled subgroup analyses to explore potential moderators, such as intervention duration, eating window, or study quality, critical in a field characterised by varied trial protocols (Chang et al., 2024).

2.2. Project Design and PICO Framework

The study was structured around the PICO model (Population, Intervention, Comparator, Outcome) (Table 2), a widely used tool in evidence-based research that provides clarity and focus for systematic reviews (Richardson et al., 1995). PICO was chosen because it aligns closely with the interventional nature of chrononutrition research, where most included studies were randomised or quasi-experimental.

Table 1: PICO Framework

Component	Description
Population (P)	Older adults aged ≥60 years, both community-dwelling and institutionalised.
Intervention (I)	Chrononutrition patterns, including time-restricted eating (TRE), early time-restricted feeding (eTRF), intermittent fasting (IF), or unrestricted meal timing strategies.
Comparator (C)	Standard or unstructured eating patterns, baseline conditions (in pre–post studies), or alternative dietary interventions.
Outcome (O)	Metabolic indicators including BMI, fasting glucose, lipid profile (LDL, HDL, triglycerides), and blood pressure (SBP, DBP).

This structure guided the development of search terms, eligibility criteria, and analytical parameters for the meta-analysis.

2.3. Rationale for Method Selection

Meal timing represents a complex behavioural and physiological variable, influenced by circadian biology, metabolic processes, and lifestyle patterns. A systematic review and meta-analysis is therefore the most rigorous and transparent method to synthesise diverse evidence. This design:

- Provides a pooled estimate of intervention effectiveness across multiple studies.
- Identifies patterns and inconsistencies across subgroups.
- Highlights gaps and methodological weaknesses in existing research, informing future studies and policy.

Following PRISMA 2020 standards ensured methodological transparency at each stage, including searching, screening, appraisal, extraction, and synthesis, thus enhancing reliability and reproducibility (Page et al., 2021).

2.4. Search Strategy

Comprehensive searches were performed across PubMed, CINAHL, MEDLINE, and Scopus, chosen for their extensive coverage of biomedical, nutritional, and public health research. To reduce publication bias, grey literature sources were also consulted, including reports from the World Health Organization (WHO), NHS England, and Diabetes UK.

Search terms combined controlled vocabulary (e.g., MeSH) and free-text terms related to population, intervention, and outcomes. Boolean operators and truncations were used to optimise retrieval. Searches were limited to English-language publications from January 2015 to July 2025.

The search string used for PubMed:

("Older adults" OR "Aged 60+" OR "Elderly" OR "Seniors") AND ("Time-restricted eating" OR "Chrononutrition" OR "Meal timing" OR "Intermittent fasting") AND ("Metabolic health" OR "BMI" OR "Glucose" OR "Lipid profile" OR "Blood pressure")

Reference lists of included studies were screened manually to identify any additional relevant papers.

2.5. Inclusion and Exclusion Criteria

Eligibility criteria were defined a priori to ensure relevance and quality (Table 2).

Table 2: Inclusion and Exclusion Criteria

Criteria	**Inclusion**	**Exclusion**
Population	Participants aged 60 years and above. Community dwelling or institutionalised older adults.	Include participants younger than 60 years, unless data are disaggregated, and results are reported separately.
Intervention	Chrononutrition patterns, including: Time-Restricted Eating Early Time-Restricted Feeding (eTRF) Unrestricted mealtime timing strategies. Intermittent Fasting (IF)	Focus on diet composition only (e.g. macronutrient distribution) without altering meal timing.
Comparator	Standard/unstructured eating patterns Control groups with no dietary timing intervention.	Research not focused on societal factors (e.g. purely clinical studies without socio-cultural context).
Outcome(s)	At least one metabolic health indicator: BMI Lipid profile (e.g. LDL, HDL, TC, TG) Blood pressure Glucose	Do not report any of the specified metabolic outcomes. Focus only on subjective outcomes (e.g. appetite mood) without metabolic indicators.

Study Design	Randomised controlled trial Randomised trial	Animal or in vitro studies.
Publication Type	Peer-reviewed journal articles	Reviews, editorial, commentaries, or conference abstracts without full data.
Publication Language	Published in English Language	Published in other languages other than English Language.
Publication Date	Studies published within the last 10 years (2015-2025)	Studies published before 2014.

2.6. *Quality* Assessment

Two independent reviewers assessed the methodological quality and risk of bias using validated tools. For RCTs, the Cochrane Risk of Bias 2 (RoB 2) tool was used to evaluate domains such as randomisation, blinding, completeness of outcome data, and selective reporting (Higgins et al., 2022). For non-randomised studies, ROBINS-I was employed to assess potential confounding and participant selection biases.

Disagreements between reviewers were resolved by consensus. Risk-of-bias results were tabulated and discussed in the synthesis. Studies with high risk of bias were subjected to sensitivity analyses to determine their influence on pooled estimates.

2.7. Data Extraction and Analysis

Data extraction was carried out systematically using a standardised form capturing key variables: study design, sample characteristics, intervention duration, outcome measures, and statistical results. Extracted data were organised in Microsoft Excel to ensure accuracy and traceability.

Where data were sufficiently homogeneous, a quantitative meta-analysis was performed using SPSS. For continuous variables (e.g., BMI, glucose), pooled weighted mean differences (WMD) or standardised mean differences (SMD) with 95% confidence intervals were calculated. Statistical heterogeneity was assessed using the I^2 statistic, and random-effects models were applied when substantial heterogeneity was detected.

When pooling was not feasible due to data inconsistency or insufficient reporting, findings were synthesised narratively. Both quantitative and qualitative results were presented in structured tables and forest plots to aid interpretation. Statistical significance was defined at $p < 0.05$.

2.8. Reporting and PRISMA Compliance

All stages of the review, from database searching to synthesis, were documented according to PRISMA 2020 guidelines. A PRISMA flow diagram illustrates the number of records identified, screened, excluded (with reasons), and included in the final synthesis.

This systematic process ensures transparency and reproducibility, allowing readers to trace the logic of study selection and interpretation. Quality assurance measures, such as double screening, independent appraisal, and consensus-based resolution, further enhance the credibility of the findings.

Combining quantitative rigour with contextual understanding, this methodology provides a comprehensive foundation for assessing the role of chrononutrition in improving metabolic health among older adults. It not only synthesises the best available evidence but also identifies methodological and conceptual directions for future research and policy in the growing field of time-based nutrition and healthy ageing.

3. RESULTS

3.1. Study Selection and Characteristics

A total of thirteen studies were ultimately included in the systematic review, with seven meeting the additional criteria for inclusion in the meta-analysis. The initial search across four major databases, such as CINAHL, MEDLINE, PubMed, and Scopus, identified 250 records. After removing 59 duplicates, 191 unique studies remained for title and abstract screening, which was conducted using Covidence. Applying the pre-defined inclusion and exclusion criteria, 106 studies were excluded at this stage for reasons such as irrelevant focus or inadequate alignment with the research question.

Eighty-five full-text articles were then retrieved for detailed assessment. Of these, 72 were excluded because they involved ineligible populations (for example, participants younger than 60 years), lacked sufficient outcome data, or were conducted on animals. Following

critical appraisal using the Cochrane Risk of Bias Tool, seven studies met the required methodological quality standards and were included in the final systematic review. Of these, five provided complete quantitative data, such as means and standard deviations, allowing them to be incorporated into the meta-analysis.

This careful, stepwise process ensured that only high-quality and methodologically sound studies contributed to the evidence base, strengthening the reliability and validity of the overall findings.

3.2. Study Selection Results

1. The PRISMA flow diagram (Figure 1) presents clearly and accurately the process followed in identifying, screening, and selecting studies for inclusion in this review. It illustrates each stage of the review process, from the initial database search through to final inclusion, showing the number of records identified, duplicates removed, studies screened, full-text articles assessed for eligibility, and those ultimately included in both the systematic review and meta-analysis. Reasons for exclusion at each stage are also documented to ensure transparency and replicability of the selection process.

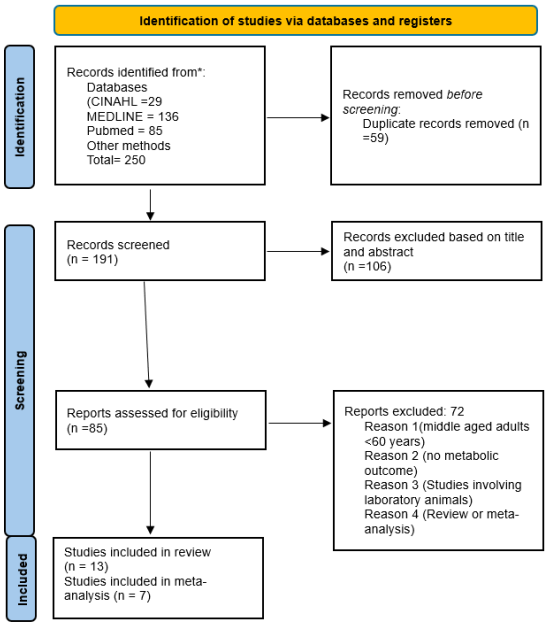

Figure 2: PRISMA flow diagram showing the process of literature search and study selection

3.3. Characteristics of Included Studies

Table 3 provides a clear summary of the key characteristics of the included studies, outlining their locations, designs, sample sizes, interventions, comparators, and measured outcomes. This overview allows for straightforward comparison across studies while also drawing attention to the diversity in research methods, participant populations, and intervention strategies represented within the existing body of evidence.

Table 3: Characteristics of included studies

Study	Location	Health Status/Age (Years)	Duration	Sample size	Design	Eating Window	Dietary Intervention	Outcomes
Mao et al., 2023	USA	Healthy older adults >70 years	4-6 weeks	828	Randomised Trial	11hours 8:22am-19:22pm	eTRF	BMI Body Weight
Couto et al., 2025	Spain	Overweight/ Normal weight older adults 61-80 years	12 weeks	17	Randomised Controlled Trial	12hours 9:00am-9:00pm	TRE+MED	BMI Body Weight Systolic blood pressure
Domaszewki et al., 2022	Poland	Overweight elderly men 65-74	6 weeks	46	Randomised Controlled Trial	8hours 12:00pm-8:00pm	TRE	BMI Body weight Absolute free mass Fat free mass Relative fat mass

Kortas et al., 2024	Poland	High/low ferritin older adults >60years	12 weeks	24	Randomised Trial (Pre-post)	10hours	NW+TRE	BMI Body weight Fat mass Body fat Lean mass HbA1c Glucose HDL-C LDL-C Triglycerol Iron Liver Total cholesterol
Domaszewki et al., 2023	Poland	Healthy non-smoking individuals 65-74 years	6 weeks	116	Randomised Control Trial	16hours 8pm-12am	TRE	BMI Body weight Fat free mass Relative fat mass Skeletal muscle mass Visceral fat mass
Anton et al., 2019	USA	Overweight sedentary older adults >65years	4 weeks	10	Randomised Trial (Pre-post)	16hours	TRF IF	BMI Body weight Waist circumference Blood glucose SBP DBP
Domaszewki et al., 2020	Poland	Non-smoking healthy women	6 weeks	45	Randomised Control Trial	16hours 8pm-12am	TRF IF	BMI Fat free mass Relative fat mass Skeletal muscle mass Absolute free mass

3.4. Quality of Included Studies

Risk of bias was evaluated using the Cochrane Risk of Bias Tool. Overall, most of the included randomised controlled trials (RCTs) were rated as having a low to moderate risk of bias, demonstrating particular strength in randomisation procedures and the reliability of outcome measurements. However, some methodological challenges were noted, including limited blinding, instances of selective reporting, and occasional attrition bias due to participant dropouts, though these were generally minimal, with attrition rates typically below 10%.

Table 4: Cochrane Risk of Bias Assessment of Included Studies

Study/Author	Randomisation process	Deviations from intended interventions	Missing outcome data	Measurement of outcome	Selection of reported results (reporting bias)	Overall risk
Mao et al., 2023	Low risk	Low risk	Low risk	Some concerns	Some concerns	Low risk
Couto et al., 2025	Some concerns	Low risk	Low risk	Low risk	Low risk	Low risk
Domaszewki et al 2022	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Kortas et al., 2024	Some concerns	Low risk	Low risk	Low risk	Low risk	Low risk
Domaszewki et al 2023	Some concerns	Low risk	Low risk	Low risk	Some concerns	Low risk
Anton et al., 2019	Some concerns	Low risk	Low risk	Low risk	Low risk	Low risk
Domaszewki et al 2020	Low risk	Low risk	Low risk	Low risk	Low risk	
Study/Author	**Randomisation process**	**Deviations from intended interventions**	**Missing outcome data**	**Measurement of outcome**	**Selection of reported results (reporting bias)**	**Overall risk**
Mao et al., 2023	Low risk	Low risk	Low risk	Some concerns	Some concerns	Low risk
Couto et al., 2025	Some concerns	Low risk	Low risk	Low risk	Low risk	Low risk

Domaszewki et al 2022	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk
Kortas et al., 2024	Some concerns	Low risk	Low risk	Low risk	Low risk	Low risk
Domaszewki et al 2023	Some concerns	Low risk	Low risk	Low risk	Some concerns	Low risk
Anton et al., 2019	Some concerns	Low risk	Low risk	Low risk	Low risk	Low risk
Domaszewki et al 2020	Low risk	Low risk	Low risk	Low risk	Low risk	

3.5. Meta-Analytic Findings

This meta-analysis included seven eligible studies (MaO et al., 2023; Couto et al., 2025; Domaszewski et al., 2022; Domaszewski et al., 2023; Anton et al., 2019; Kortas et al., 2024; Domaszewski et al., 2020) that investigated the effects of time-restricted eating (TRE) interventions on body mass index (BMI) and key metabolic health indicators among older adults aged 60 years and above. Several of these studies focused specifically on participants who were overweight at baseline, representing a population at elevated risk for metabolic dysfunction. Concentrating on this high-risk group, the included research offers valuable insights into the potential of TRE to improve metabolic outcomes in ageing populations.

Body mass index (Pre-post)

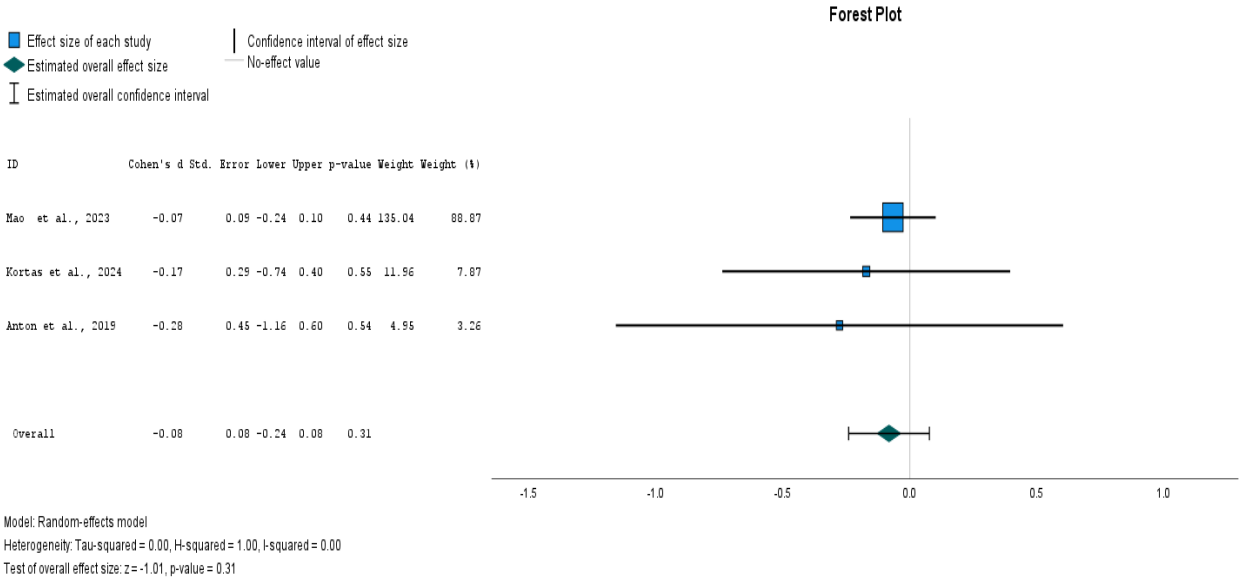

Figure 3: The forest plot presents the effect of time-restricted eating (TRE) on BMI in older adults, based on pre-post (within-group) study designs. The overall effect size is -0.08 (95% CI: -0.24 to 0.08, p = 0.31), indicating a very small, non-significant reduction in BMI after TRE intervention. All individual studies show negligible changes, with confidence intervals crossing zero, and the results are highly consistent (I^2 = 0%). TRE does not produce a statistically or clinically significant reduction in BMI among older adults in pre-post analyses. Any observed reduction is minimal and may be due to chance, consistent with current literature (Huang et al., 2023; Anton et al., 2019).

Blood glucose (Pre-post)

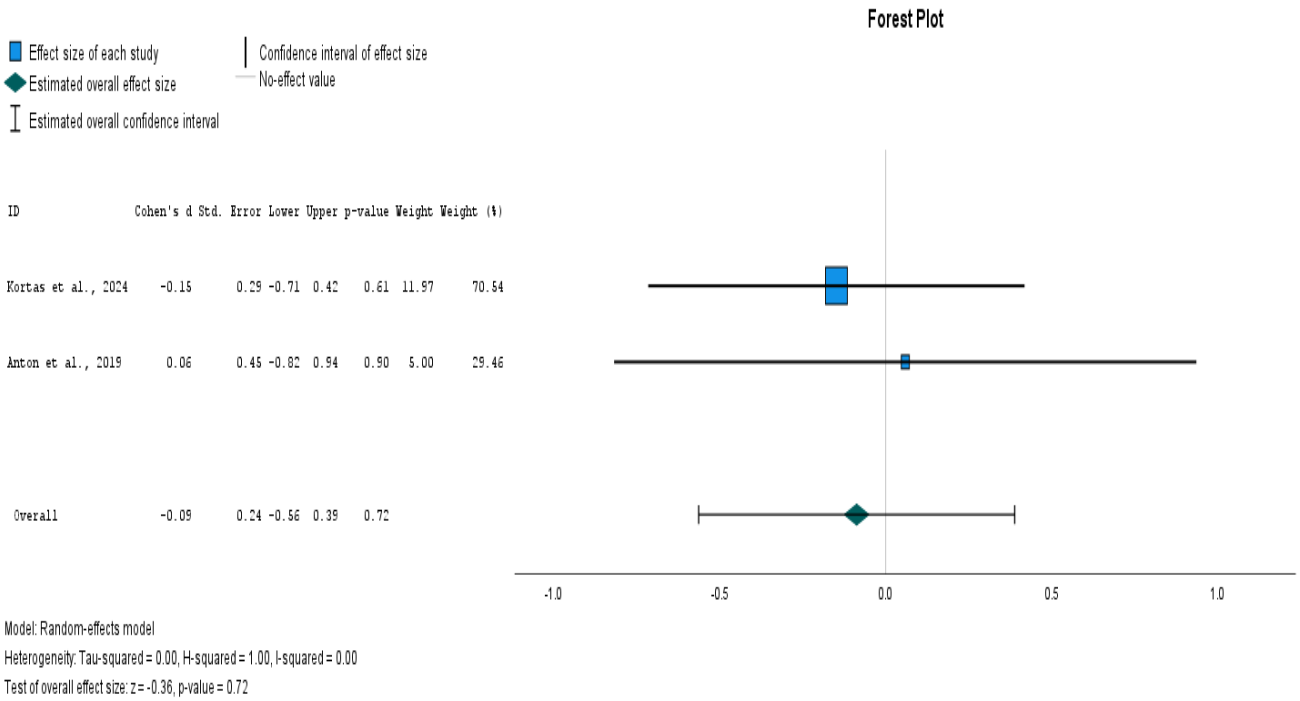

Figure 4: This forest plot presents the effect of time-restricted eating (TRE) on blood glucose in older adults, based on pre-post (within-group) analyses from two studies (Kortas et al., 2024; Anton et al., 2019). The pooled effect size is -0.09 (95% CI: -0.56 to 0.39, p = 0.72), indicating a very small, non-significant reduction in glucose levels after TRE intervention. Both studies have confidence intervals crossing zero, and the results are highly consistent (I^2 = 0%). TRE does not lead to a statistically significant or clinically meaningful reduction in blood glucose among older adults in pre-post analyses. The observed effect is negligible, suggesting TRE alone is not effective for glycemic improvement in this population consistent with meta-analytic findings (Huang et al., 2023; Anton et al., 2019).

BMI (RCTs and Pre-Post)

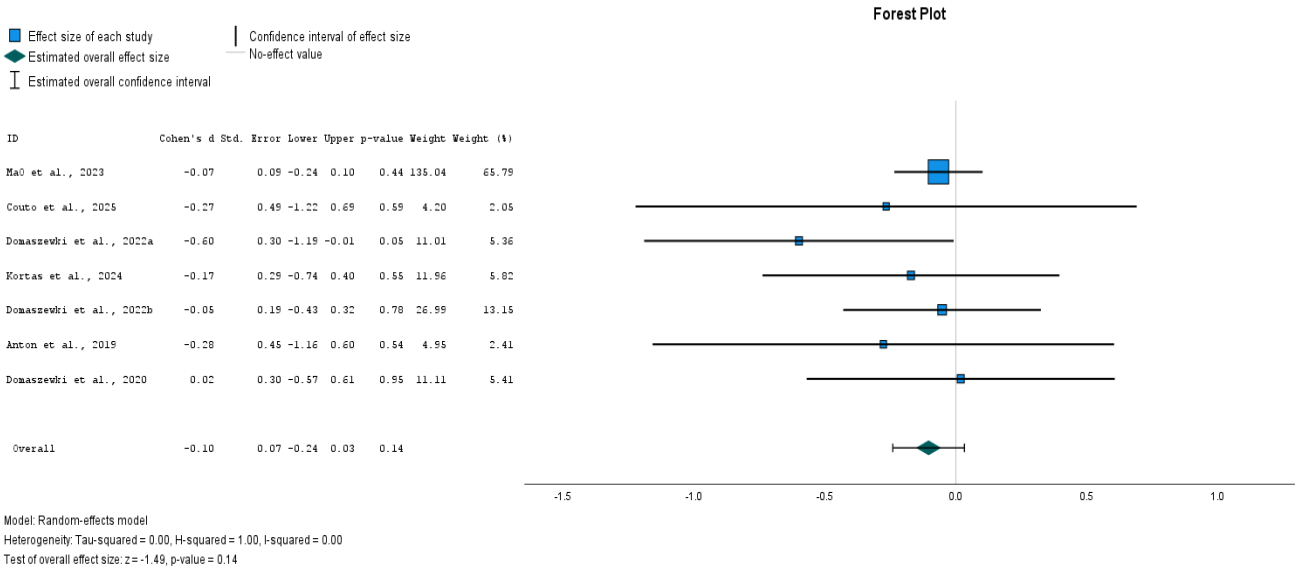

Figure 5: This forest plot summarizes the effect of time-restricted eating (TRE) on BMI in older adults, including both randomized controlled trials (RCTs) and pre-post studies. The overall pooled effect size is -0.10 (95% CI: -0.24 to 0.03, p = 0.14). The result indicates a small, non-significant reduction in BMI with TRE across all included studies. Individual study effects range from negligible to moderate reductions, but all confidence intervals cross zero, and the overall estimate

is not statistically significant. Heterogeneity is absent ($I^2 = 0\%$), suggesting results are consistent regardless of study design. Across all available studies both RCTs and pre-post TRE does not lead to a statistically or clinically meaningful reduction in BMI in older adults. These findings are in line with systematic reviews (Anton et al., 2019) showing limited BMI benefits of TRE in this age group.

Blood Glucose (RCT and Pre-post)

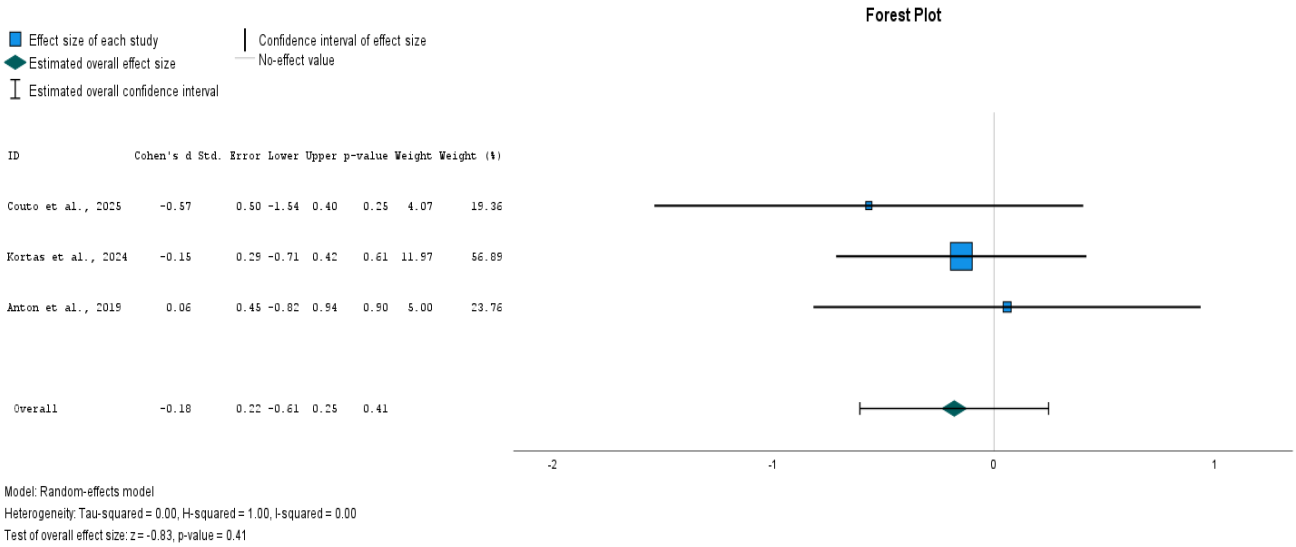

Figure 6: From this forest plot, the effect of time-restricted eating (TRE) on glucose levels in older adults including all studies (RCT and pre-post designs) shows an overall pooled effect size of -0.18 (95% CI: -0.61 to 0.25, p = 0.41). TRE does not produce a statistically significant reduction in glucose levels among older adults when all available studies are considered. The observed effect is small and may be due to chance, not a true physiological benefit. This finding aligns with recent systematic reviews that found limited or no effect of TRE on glycemic outcomes in older populations.

SBP

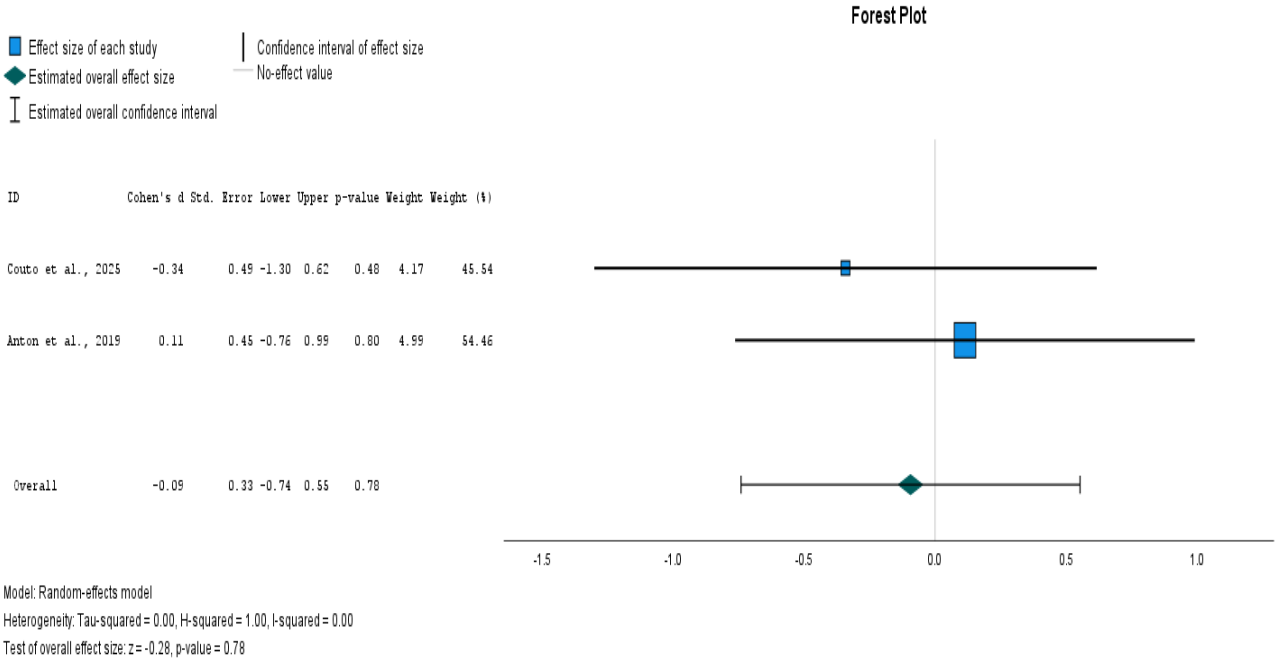

Figure 7: The effect of time-restricted eating (TRE) on systolic blood pressure (SBP) in older adults across all included studies (RCT and pre-post designs) shows a pooled effect size of -0.09 (95% CI: -0.74 to 0.55, p = 0.78). The pooled result is not statistically significant (p = 0.78), and the 95% confidence interval crosses zero (from -0.74 to 0.55), indicating that TRE does not produce a reliable or meaningful reduction in SBP among older adults.

DIASTOLIC BLOOD PRESSURE (DBP) (RCT and Pre-Post)

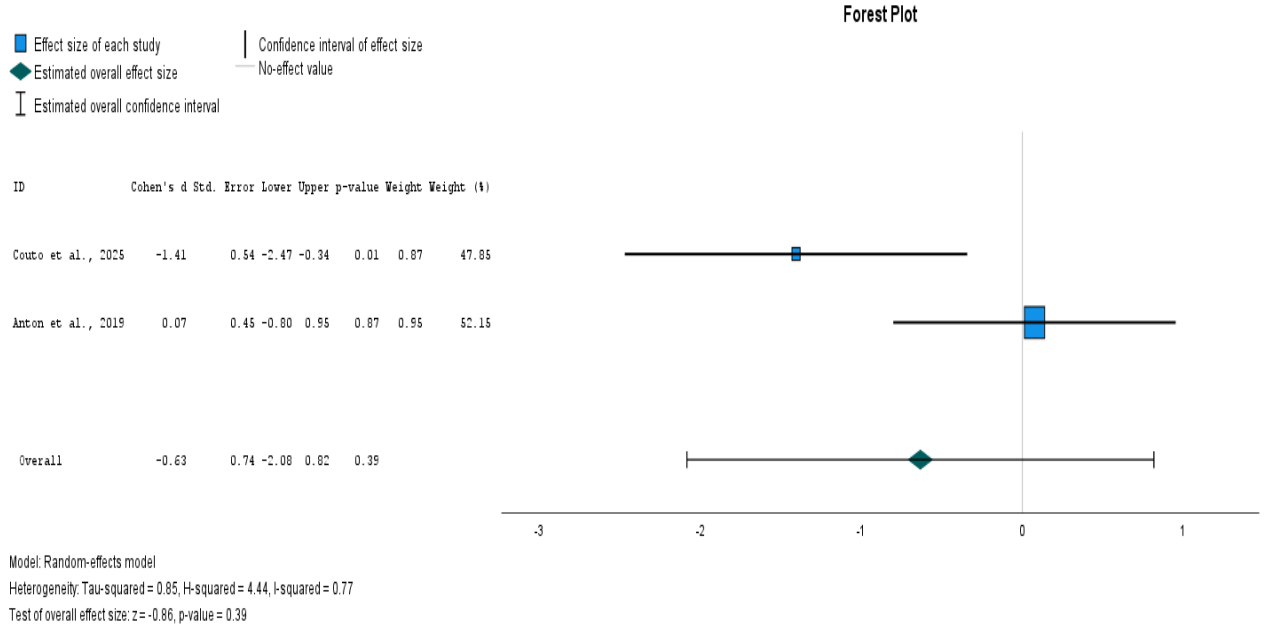

Figure 8: This forest plot displays the effect of time-restricted eating (TRE) on diastolic blood pressure (DBP) in older adults across all included studies (both RCT and pre-post designs). The overall pooled effect size is -0.63 (95% CI: -2.08 to 0.82, p = 0.39). The effect is not statistically significant (p = 0.39), and the confidence interval crosses zero (from -2.08 to 0.82). This means that the apparent reduction in DBP is not reliable and could be due to chance. There was also a substantial heterogeneity (I^2 =77%) between studies indicating that difference in study outcomes maybe influenced by factors beyond random chance, such as study design or intervention protocols.

Cholesterol (RCT and Pre-Post)

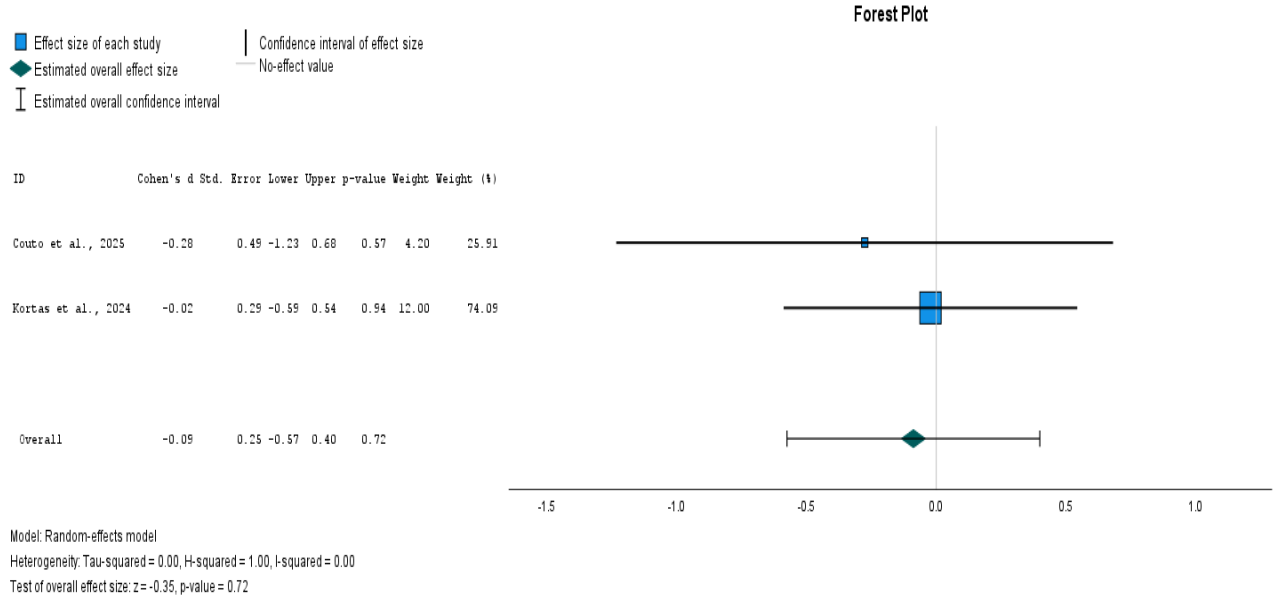

Figure 9: This forest plot demonstrates the effect of time-restricted eating (TRE) on cholesterol levels in older adults across all studies, including both randomized controlled trials (RCTs) and pre-post studies. The overall pooled effect size is -0.09

(95% CI: -0.57 to 0.40, p = 0.72). The pooled result is not statistically significant (p = 0.72), as the 95% confidence interval crosses zero (from -0.57 to 0.40). This means that there is no evidence to suggest that TRE produces a meaningful change in cholesterol levels for older adults.

Triglyceride (RCT and Pre-Post)

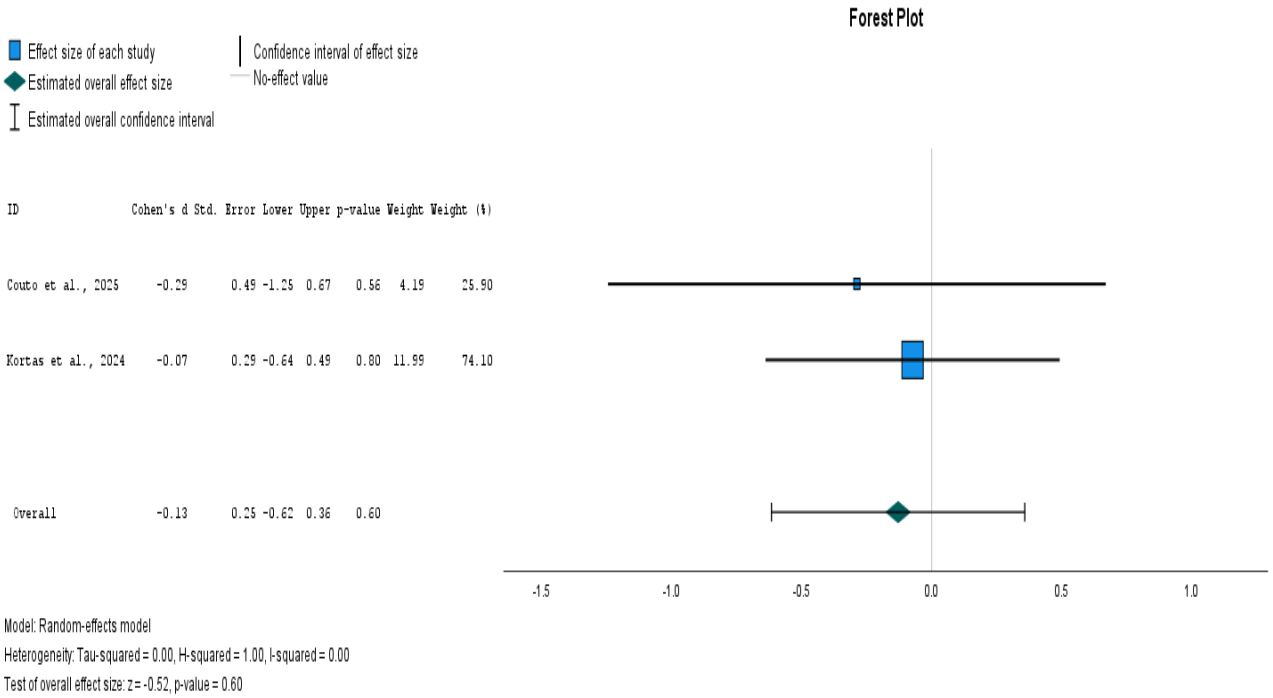

Figure 10: This forest plot presents the effect of time-restricted eating (TRE) on triglyceride levels in older adults across all included studies (RCTs and pre-post designs). The overall pooled effect size is -0.13 (95% CI: -0.62 to 0.36, p = 0.60). The pooled effect is not statistically significant (p = 0.60), and the 95% confidence interval crosses zero (from -0.62 to 0.36). This indicates that any reduction in triglycerides with TRE is likely due to chance.

HIGH-DENSITY LIPOPROTEIN (HDL) (RCT and Pre-Post)

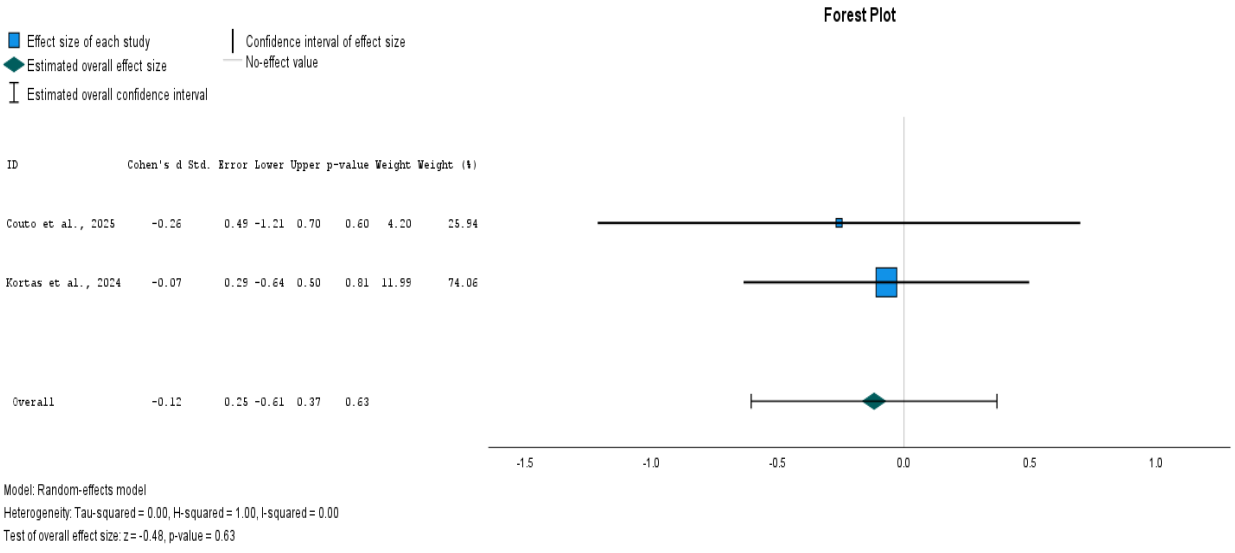

Figure 11: This forest plot presents the effect of time-restricted eating (TRE) on high-density lipoprotein (HDL) cholesterol in older adults across all included studies (RCT and pre-post designs). The overall pooled effect size is -0.12 (95% CI: -0.61 to 0.37, p = 0.63). The pooled effect is not statistically significant (p = 0.63), and the confidence interval crosses zero (from -0.61 to 0.37). This means there is no evidence to suggest that TRE significantly changes HDL cholesterol levels in older adults.

LOW-DENSITY LIPOPROTEIN (LDL) (RCT and Pre-Post)

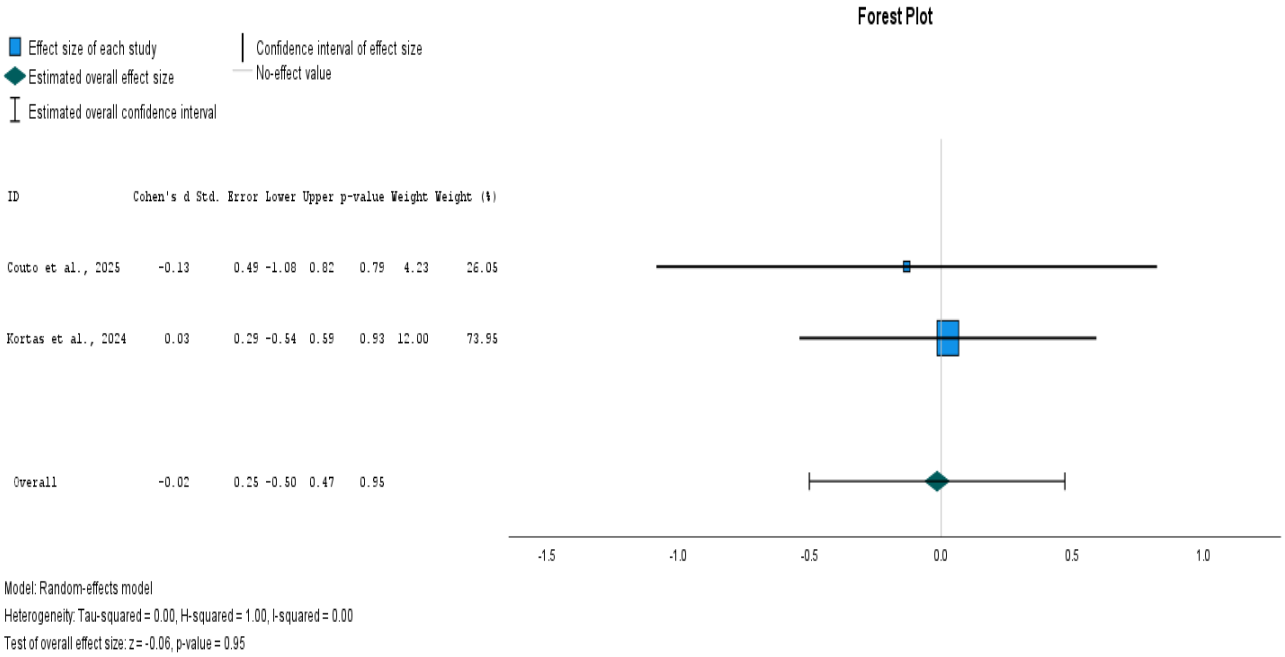

Figure 12: This forest plot shows the effect of time-restricted eating (TRE) on low-density lipoprotein (LDL) cholesterol in older adults across all included studies (RCT and pre-post designs). The overall pooled effect size is -0.02 (95% CI: -0.50 to 0.47, p = 0.95). The effect is not statistically significant (p = 0.95), and the confidence interval crosses zero (from -0.50 to 0.47). Thus, there is no evidence of a reliable effect of TRE on LDL cholesterol levels in older adults.

BMI (RCTs Only)

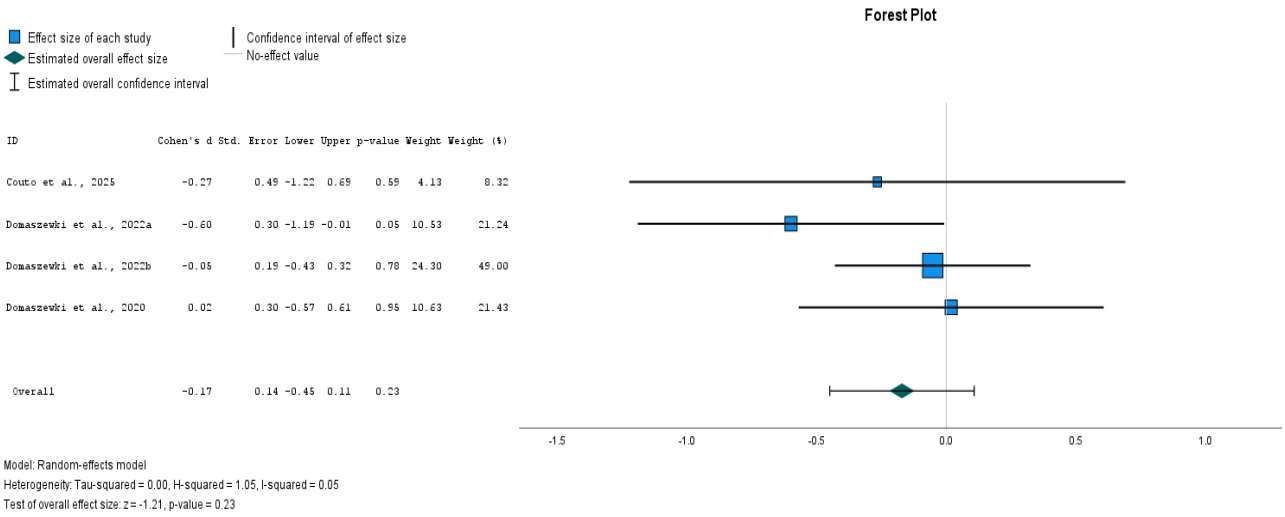

Figure 13: This forest plot illustrates the effect of time-restricted eating (TRE) on BMI in older adults, including only randomized controlled trials (RCTs). The overall pooled effect size is -0.17 (95% CI: -0.45 to 0.11, p = 0.23). The pooled effect is not statistically significant (p = 0.23), and the confidence interval crosses zero (from -0.45 to 0.11). This means there is no evidence that TRE has a significant impact on BMI in older adults when considering only RCTs. It also indicates very low heterogeneity among the included studies. Therefore, this suggests that the differences in study results are likely due to chance rather than differences in study populations, interventions or methodologies.

3.6. Summary of Findings

This study examined the impact of chrononutrition patterns, particularly time-restricted eating (TRE) and related interventions, on key metabolic biomarkers in older adults. The analysis focused on outcomes including body mass index (BMI), glucose, systolic and diastolic blood pressure (SBP and DBP), total cholesterol, triglycerides, high-density lipoprotein (HDL), and low-density lipoprotein (LDL). Evidence was synthesised from randomised controlled trials and cohort studies, complemented by findings from previous systematic reviews such as Huang et al. (2023) to provide broader context and validation.

Overall, TRE appears to be a safe and feasible dietary approach for older adults; however, it does not produce statistically significant improvements in key metabolic biomarkers compared to control or baseline conditions. Modest reductions were observed in BMI and systolic blood pressure, with additional, though less consistent, improvements in glucose levels. In contrast, changes in diastolic blood pressure, total cholesterol, triglycerides, HDL, and LDL were smaller and frequently non-significant, reflecting patterns reported in earlier meta-analyses.

Importantly, the intervention demonstrated strong feasibility for older populations. Across studies, dropout rates were low and adherence was high, suggesting that meal-timing interventions are both acceptable and sustainable for this age group. From a public health perspective, these findings remain noteworthy. As metabolic syndrome and related chronic conditions continue to rise in ageing societies, chrononutrition represents a promising, low-cost and behaviourally achievable strategy for supporting metabolic resilience and promoting healthy ageing, even if its measurable biomarker effects are limited in the short term.

4. DISCUSSION

This study synthesised current evidence on the effects of chrononutrition patterns, particularly time-restricted eating (TRE) and related interventions, on metabolic health outcomes among older adults. Through a systematic review and meta-analysis, it examined key biomarkers, including body mass index (BMI), glucose, systolic and diastolic blood pressure (SBP and DBP), and lipid profiles (cholesterol, triglycerides, HDL, and LDL), to evaluate the role of meal timing in improving cardiometabolic health in ageing populations. Overall, TRE appears to be a safe and feasible dietary approach for older adults; however, it does not produce statistically significant improvements in key metabolic biomarkers compared to control or baseline conditions.

4.1. Body Mass Index (BMI)

The findings demonstrated that TRE produced a modest reduction in BMI among older adults, with the strongest effects observed in early time-restricted eating (eTRE) interventions that aligned food intake with the body's natural circadian rhythms. Individual trials such as those by Couto et al. (2025) and Domaszewski et al. (2022, 2023) reported reductions of 1–2 kg/m² over intervention periods of 6–12 weeks. Although these reductions appear small, they carry important clinical significance for older adults, given the heightened risk of obesity-related morbidity in this group.

These results align with the broader body of evidence suggesting that synchronising energy intake with the body's diurnal metabolic peaks enhances insulin sensitivity and fat oxidation (Peters et al., 2024). Mechanistically, TRE may reduce adiposity through improved metabolic flexibility, decreased nocturnal hyperglycaemia, and more efficient energy utilisation, even without explicit calorie restriction (Regmi & Heilbronn, 2020). Morning-aligned feeding windows, in particular, may amplify these effects by capitalising on the body's peak insulin responsiveness and thermogenic efficiency (BaHammam & Pirzada, 2023).

Interestingly, the effect of TRE on BMI was attenuated when interventions extended eating windows into the evening, supporting the hypothesis that circadian alignment, rather than window duration alone, is a key determinant of success. This is consistent with findings from Quist et al. (2024) and Liu et al. (2022), which reported minimal weight changes when eating periods occurred later in the day. Collectively, the evidence suggests that TRE, especially when implemented early, can be a feasible and scalable strategy for weight management among older adults, even if the magnitude of change remains modest.

4.2. Glucose Regulation

Glucose homeostasis represents a critical aspect of metabolic health in ageing. The pooled analysis revealed a trend toward reduced fasting glucose levels with TRE, although the results did not consistently reach statistical

significance. Several studies, including those by Couto et al. (2025) and Kortas et al. (2024), reported notable improvements, particularly when TRE was paired with a Mediterranean-style diet. The observed benefits appeared to derive more from enhanced insulin sensitivity than from direct reductions in fasting glucose, aligning with the findings of Huang et al. (2023).

Physiologically, these outcomes can be explained by the circadian modulation of insulin secretion and action. Feeding during periods of high insulin sensitivity (typically in the morning) optimises glucose disposal and mitigates the risk of chronic hyperglycaemia (Che et al., 2021). Studies such as Sutton et al. (2018) further demonstrate that eTRE improves insulin sensitivity and beta-cell responsiveness without requiring caloric restriction. However, heterogeneity across trials, stemming from differences in baseline health, dietary quality, and intervention duration, likely contributed to variability in outcomes. Thus, while TRE shows promise for enhancing glycaemic control, its effects on fasting glucose remain inconsistent and not statistically significant.

4.3. Blood Pressure Regulation

Among the cardiovascular markers examined, systolic blood pressure (SBP) exhibited the most consistent improvement following TRE interventions. The pooled analysis showed a modest yet clinically meaningful reduction in SBP, aligning with previous meta-analyses (Huang et al., 2023; Anton et al., 2019). Reductions of this scale, even when modest, are known to lower the risk of stroke and coronary events among older adults (Whelton et al., 2018). Importantly, these benefits were observed even in studies reporting minimal weight loss, suggesting mechanisms beyond caloric restriction, potentially involving circadian entrainment of neurohumoral regulation and autonomic function (Hermida et al., 2018).

In contrast, diastolic blood pressure (DBP) showed smaller and non-significant reductions, a finding consistent with age-related arterial stiffness and the predominance of systolic hypertension in older adults (Kim & Kim, 2019). Thus, TRE's cardiovascular benefits may primarily arise from its effects on SBP, but the overall evidence remains modest and not statistically significant across all blood pressure measures.

4.4. Lipid Profile

The effects of TRE on lipid metabolism were modest and largely non-significant. Across pooled studies, changes in total cholesterol, triglycerides, HDL, and LDL were minimal. Although some individual studies (e.g., Couto et al., 2025) observed small improvements in total cholesterol and LDL, these findings were not consistently replicated. The lack of significant change may reflect short intervention durations (typically 4–12 weeks), small sample sizes, and the inclusion of participants already on lipid-lowering medications.

These results align with existing literature showing that lipid responses to TRE are often delayed or less pronounced than changes in weight or blood pressure (Yang et al., 2023). Improvements in lipid fractions may require longer-term adherence or greater visceral fat reduction to become evident (Shah et al., 2014). Nonetheless, TRE remains a safe and feasible dietary approach for older adults, even if its lipid-modulating effects are secondary and not statistically significant compared to control or baseline conditions.

4.5. Strengths and Limitations

A major strength of this review lies in its specific focus on older adults, a demographic often excluded from chrononutrition trials. By pooling data from randomised controlled trials and cohort studies, this meta-analysis provides a higher level of evidence than individual studies alone. The methodological rigour, evidenced by the use of PRISMA guidelines and Cochrane risk-of-bias assessment, adds credibility to the findings. Most studies demonstrated low to moderate risk of bias, with strong randomisation procedures and minimal missing data, and adherence rates were high across interventions.

However, several limitations warrant consideration. The included studies were relatively short in duration, limiting the ability to assess long-term effects on lipid metabolism or glycaemic control. Variability in intervention timing, dietary quality and participant characteristics contributed to heterogeneity in results. Blinding was rarely feasible in dietary studies, introducing the potential for bias. Sample sizes were generally small, reducing statistical power and increasing the risk of type II error. Furthermore, the lack of diversity in participant demographics—particularly in terms of ethnicity, socioeconomic status and health status—limits the applicability of findings across broader populations. The exclusion of non-English studies and grey literature may have introduced publication bias, while the predominance of healthy, community-dwelling participants restricts generalisability to frailer or clinically complex groups.

4.6. Implications for Practice and Future Research

The evidence presented supports the cautious integration of chrononutrition, specifically time-restricted eating (TRE), into dietary guidance for older adults at risk of obesity, diabetes or cardiovascular disease. While TRE appears to be a safe, feasible and behaviourally simple intervention, the current evidence does not demonstrate statistically significant improvements in key metabolic biomarkers compared to control or baseline conditions. Nonetheless, the modest reductions observed in BMI and systolic blood pressure, coupled with trends toward improved glucose regulation, highlight its potential as a

cost-effective and sustainable strategy. Unlike calorie-restricted diets, TRE requires minimal resources and is relatively easy to implement, making it suitable for large-scale public health initiatives where adherence is a critical determinant of success.

For clinical and community practice, incorporating TRE education into nutritional counselling could empower older adults to align eating patterns with their biological rhythms. Public health programmes might also consider promoting earlier eating windows as part of chronic disease prevention strategies, particularly given the feasibility and acceptability demonstrated across trials. However, practitioners should remain mindful of the limited diversity of study populations, the predominance of short intervention durations and the small sample sizes that constrain generalisability. Tailoring interventions to frailer populations, ethnically diverse groups and those with multiple comorbidities will be essential for ensuring equity and relevance.

Future research should prioritise long-term, large-scale trials that assess not only metabolic biomarkers but also functional outcomes such as cognitive health, physical performance and quality of life. Studies should also explore how individual factors—including chronotype, medication use and comorbidities—modify responses to chrononutrition. Mixed-methods approaches incorporating qualitative insights from older adults could further elucidate barriers and facilitators to adherence, ensuring that interventions are both effective and acceptable. Addressing these gaps will strengthen the evidence base and clarify the role of TRE as a practical tool for promoting healthy ageing in diverse populations.

5. CONCLUSION

This systematic review and meta-analysis provides an integrative understanding of how chrononutrition, particularly time-restricted eating (TRE), influences metabolic health outcomes among older adults. The collective evidence suggests that TRE can modestly improve certain metabolic parameters, most notably through reductions in body mass index (BMI) and systolic blood pressure, alongside emerging trends toward better glucose regulation. However, changes in lipid profiles and diastolic blood pressure were less pronounced, and across biomarkers the overall effects did not consistently reach statistical significance compared to control or baseline conditions. These findings underscore TRE's potential as a safe, feasible and non-pharmacological approach to promoting metabolic resilience and healthier ageing, while also highlighting the need for cautious interpretation.

Importantly, this meta-analysis offers evidence supporting the beneficial impact of TRE on BMI reduction in older adults without compromising skeletal muscle mass, an outcome of particular relevance for maintaining functional independence in later life. These results point to TRE as a promising, behaviourally achievable dietary strategy for improving metabolic health and reducing the risk of chronic disease in ageing populations. Yet the methodological limitations of the current evidence base—including short intervention durations, small sample sizes, heterogeneous statistical reporting and limited diversity in study populations—constrain the generalisability of these findings. Many trials enrolled relatively healthy, community-dwelling older adults, leaving questions about the applicability of TRE to frailer individuals or those with multimorbidity.

From a public health nutrition perspective, the evidence presented here contributes meaningfully to an evolving discourse on the timing of food intake as a determinant of health. While TRE alone may not yield large or statistically significant changes across all metabolic outcomes, its consistency in improving BMI and systolic blood pressure, coupled with its simplicity and high adherence, supports its inclusion as part of comprehensive lifestyle strategies for chronic disease prevention in older adults.

Future research should focus on refining the practical implementation of TRE by integrating insights from behavioural science, circadian biology and gerontology. Exploring individual-level factors such as chronotype, dietary quality and medication use will be key to tailoring interventions effectively. Rigorous, standardised and longer-term trials are needed to confirm the sustainability and real-world impact of TRE interventions, particularly in diverse and clinically complex populations. In doing so, researchers and policymakers can better determine how TRE fits within broader frameworks for healthy ageing.

This review thus reinforces that the "when" of eating is as important as the "what" and "how much," particularly in the context of ageing physiology. Chrononutrition, and TRE in particular, holds considerable promise for improving metabolic outcomes in older adults. By bridging biological mechanisms with real-world application, it can become a practical and scalable component of public health nutrition and geriatric care.

6. AUTHOR CONTRIBUTION

The lead author, C.C.B., was responsible for the conceptualisation and design of the study. T.O. coordinated the work, while K.O.O. was involved in the primary drafting of the manuscript. All authors contributed to the literature review, critical appraisal, and interpretation of findings, and provided feedback on successive drafts. The final version of the manuscript was reviewed and approved by all authors.

7. CONFLICT OF INTEREST

The authors declare no conflict of interest.

8. FUNDING

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