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Exercise Snack Modality and Postprandial Glycaemic Control in Overweight and Obese Adults: A Systematic Review and Meta-Analysis

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ADMINISTRATIVE INFORMATION

Support - No financial support or external sponsorship has been secured at the time of this registration. Any funding obtained after registration will be declared by updating this record.

Review Stage at time of this submission - The review has not yet started.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 10 May 2026 and was last updated on 11 July 2026.

INTRODUCTION

Review question / Objective This review asks: do exercise snacks acutely reduce postprandial glucose incremental area under the curve compared with uninterrupted prolonged sitting in non-diabetic adults with overweight or obesity, and does the magnitude of this effect differ between aerobic walking and resistance exercise snack modalities?
The objective is to synthesise the available randomised controlled trial evidence through pairwise random-effects meta-analyses comparing each exercise snack modality against uninterrupted sitting on postprandial glucose incremental area under the curve as the primary outcome, and on postprandial insulin incremental area under the curve, glucose total area under the curve, and triglyceride total area under the curve as secondary outcomes, in a specifically defined population of adults with overweight or obesity without diabetes or prediabetes. The certainty of evidence for each outcome will be assessed using the GRADE framework and reported in Summary of Findings tables.

Rationale Postprandial hyperglycaemia is well established as an independent cardiovascular risk factor and an early physiological marker of insulin resistance, particularly in individuals with overweight or obesity. The interruption of prolonged sitting with brief, structured exercise bouts has attracted growing research interest as a low-cost, accessible strategy for attenuating postprandial glucose excursions. However, the published literature does not yet provide a clear answer to the comparative effectiveness question: whether aerobic, resistance, or combined snack modalities offer the greatest glycaemic benefit, and whether this benefit is preserved at shorter durations such as two or five minutes.
Existing systematic reviews and meta-analyses have pooled sedentary and diabetic populations in ways that obscure metabolic differences relevant

to the overweight but normoglycaemic population, and have reported outcomes on heterogeneous scales that are not directly commensurable without standardisation. The present review addresses these limitations by restricting inclusion to adults with overweight or obesity without diabetes or prediabetes, applying the standardised mean difference as a universal effect measure, and conducting separate modality-specific pairwise meta-analyses to preserve the scientific distinction between aerobic and resistance exercise mechanisms.

The original protocol pre-specified a Bayesian network meta-analysis as the primary analytical approach. Following completion of systematic searching, screening, data extraction, and formal network geometry assessment, it was determined that the available evidence base does not meet the minimum requirements for a valid network meta-analysis. The network formed by the included studies is star-shaped (all active arms are compared only against uninterrupted sitting, with no head-to-head comparisons between active modalities anywhere in the dataset) and only five studies with arm-level extractable data were identified across two modality types. The resistance modality node is supported by a single study, precluding stable indirect comparison estimates. The dose-response analysis was also not feasible as the minimum threshold of $k \geq 3$ studies at two or more duration nodes within any single modality was not met. Six of the eleven studies initially included following database and grey literature searching were subsequently excluded because arm-level outcome data were not available in the published reports, and authors did not respond to systematic contact requests. These methodological constraints are reported transparently as limitations of the current evidence base and strengthen the case for larger, standardised primary trials with head-to-head modality comparisons and open data policies. A pairwise random-effects meta-analysis represents the honest, appropriate, and methodologically defensible response to the evidence as found.

Condition being studied The review concerns postprandial glycaemic dysregulation in adults with overweight (BMI 25 to 29.9 kg per m squared) or obesity (BMI 30 kg per m squared or above) who have not been diagnosed with type 2 diabetes, prediabetes, or any other metabolic condition requiring pharmacological glycaemic management. Postprandial glucose excursions, measured as incremental area under the glucose curve following a standardised meal or oral glucose challenge, represent the primary physiological target. This population sits at the intersection of modifiable metabolic risk and documented sedentary behaviour, making it an appropriate and clinically important target for exercise snack research.

METHODS

Search strategy Searches will be run in PubMed/MEDLINE, SCOPUS, Web of Science Core Collection, SPORTDiscus via EBSCOhost, and CENTRAL. Search strings will be adapted for each database using controlled vocabulary (MeSH for PubMed; Emtree for SCOPUS) combined with free-text terms and Boolean operators. The example below is written for PubMed.

("exercise snack*" OR "activity break*" OR "exercise break*" OR "brief exercise bout*" OR "interrupted sitting" OR "movement break*") AND ("postprandial glucose" OR "glycaemic response" OR "blood glucose" OR "incremental area under the curve" OR "iAUC" OR "postprandial glycaemia") AND ("overweight" OR "obese" OR "obesity" OR "adipos*" OR "body mass index") AND ("randomized controlled trial" OR "crossover trial" OR "RCT" OR "randomised")

No date restrictions will be applied. The search will be limited to English language publications. Supplementary searching will include Google Scholar (first 200 results sorted by relevance, searched without publication type restriction; search terms and.

Participant or population Eligible participants are adults aged 18 years or older with a BMI of 25 kg per m squared or above, without a clinical diagnosis of type 2 diabetes, prediabetes, impaired fasting glucose, or any metabolic condition managed pharmacologically at baseline. Studies that enrol exclusively normal-weight participants will be excluded. Where a study includes a mixed population of overweight and normal-weight participants, it will be included only if outcomes for the overweight or obese subgroup are reported separately and can be extracted independently. No exclusions will be applied on the basis of sex, ethnicity, menopausal status, or self-reported physical activity level.

Intervention The intervention of interest is an exercise snack, defined as a discrete, structured bout of physical activity lasting 10 minutes or less, performed as an interruption to a period of prolonged sitting of at least 30 minutes within a postprandial measurement session. Three modalities will serve as nodes in the network.

Aerobic snacks: walking at a brisk pace; stepping in place; stationary cycling; or any equivalent activity of light to moderate aerobic intensity.

Resistance snacks: bodyweight squats; chair-based lower limb exercises; calf raises; or resistance band protocols targeting the lower body.
Combined snacks: protocols that incorporate both aerobic and resistance components within a single bout of 10 minutes or less.

Comparator The reference node for all network comparisons is uninterrupted sitting maintained for the full duration of the postprandial assessment period, typically two to three hours, with no prescribed movement. Studies that use a light walking comparator rather than passive sitting will be included only where a passive sitting arm is also present, or where the study can contribute indirect evidence to the network.

Study designs to be included Acute crossover randomised controlled trials in which each participant completes all experimental conditions across separate sessions are the primary design of interest. Parallel group randomised controlled trials that include both an exercise snack arm and an uninterrupted sitting control arm will also be eligible. Studies must include a standardised postprandial assessment protocol with glucose measured at multiple time points sufficient to calculate incremental area under the curve. Non-randomised designs, observational studies, and studies without a sitting control will be excluded.

Eligibility criteria Inclusion criteria are as follows.
Adults aged 18 years or older with BMI of 25 kg per m squared or above at enrolment.
No diagnosis of type 2 diabetes, prediabetes, or metabolic condition requiring glucose-lowering medication.
Exercise snack duration of 10 minutes or less per bout.
At least one eligible snack modality arm and one uninterrupted sitting control arm.
Glucose incremental area under the curve or convertible area under the curve reported following a standardised meal or oral glucose tolerance test.
Crossover or parallel group randomised controlled trial.
Full text available in English.
Exclusion criteria are as follows.
BMI below 25 kg per m squared throughout (normal weight only sample).
Participants with type 2 diabetes, prediabetes, or on glucose-lowering agents.
Exercise bouts exceeding 10 minutes per snack.
No passive sitting control condition present.
Outcome expressed only as fasting glucose, HbA1c, or a non-standardised composite index.
Conference abstracts, letters, editorials, and narrative reviews.

Information sources The five electronic databases to be searched are PubMed/MEDLINE, SCOPUS, Web of Science Core Collection, SPORTDiscus via EBSCOhost, and CENTRAL. These will be supplemented by Google Scholar (first 200 results by relevance) and ClinicalTrials.gov, and systematic hand-searching of reference lists. Embase is not searched directly; CENTRAL systematically indexes RCTs from Embase and Scopus provides substantial bibliographic overlap for clinical trial literature. This will be acknowledged as a residual limitation in the final manuscript.

Main outcome(s) The primary outcome is postprandial glucose incremental area under the curve, expressed in mmol per litre per minute, measured over a two-hour postprandial window following a standardised meal challenge or 75 g oral glucose tolerance test. The standardised mean difference will be used as the effect measure because glucose incremental area under the curve values differ across studies as a function of meal composition, glucose analyser calibration, and postprandial window duration; rescaling to within-study standard deviation units is necessary for valid cross-study synthesis.
Outcome directionality: postprandial glucose iAUC values will be coded so that a positive standardised mean difference consistently indicates a reduction in postprandial glucose (i.e., benefit). For all outcomes where lower values indicate better glycaemic control, values will be multiplied by –1 prior to pooling. This transformation will be documented in the methods section of the final manuscript.
Minimum clinically important difference.

Additional outcome(s) Postprandial insulin incremental area under the curve (pmol per litre per minute); standardised mean difference.
Peak postprandial glucose concentration (mmol per litre); standardised mean difference.
Glucose time in range (percent of assessment period) for studies using continuous glucose monitoring; standardised mean difference.

Data management All references retrieved from database searches were imported into EppiReviewer, where automated duplicate detection flagged probable duplicates based on title, author, and year similarity. All flagged probable duplicates were reviewed and confirmed by human review before any record was removed. Near-duplicate entries were documented with a

rationale for deduplication decisions. The total deduplicated record count served as the starting figure for the PRISMA 2020 flow diagram. Title and abstract screening was conducted independently by two reviewers within EppiReviewer. Records passing this stage proceeded to full-text assessment, also conducted independently by two reviewers. Disagreements at either stage were resolved by discussion; unresolved disagreements were referred to a third reviewer.

Data extraction was performed using a standardised form developed in Microsoft Excel, capturing study design, participant characteristics, intervention specifications (modality; duration; frequency; intensity), comparator description, meal challenge protocol, and all outcome data including measures of variability. Two reviewers extracted data independently and discrepancies were reconciled before analysis. Standard deviations not directly reported were derived using the formula SD = (upper CI – lower CI) × $\sqrt{n}$ ÷ (2 × 1.96) where 95% confidence intervals were available, or SD = SEM × $\sqrt{n}$ where standard error of the mean was reported. All derivation methods are documented in the extraction workbook.

Statistical analyses are conducted in RevMan Web (Cochrane Collaboration, Version 5). Pairwise random-effects meta-analyses are conducted for the primary outcome (postprandial glucose iAUC) and each pre-specified secondary outcome (insulin iAUC, glucose tAUC, triglycerides tAUC) using the inverse variance method. Heterogeneity is estimated using the restricted maximum likelihood (REML) estimator. The Hartung-Knapp-Sidik-Jonkman (HKSJ) correction is applied to all analyses to adjust standard errors for uncertainty in the heterogeneity estimate, providing more reliable inference particularly with small numbers of studies. The standardised mean difference (SMD) with 95% confidence intervals is the primary effect measure for all outcomes. Prediction intervals are calculated for the primary outcome. I^2 is reported as the primary heterogeneity statistic in the results text; τ^2 (REML, 95% CI) and the prediction interval are reported in the Summary of Findings table.

The Bayesian network meta-analysis originally planned using the gemtc package in R, and the dose-response meta-analysis planned using the dosresmeta package in R, are not conducted. The rationale is documented in this protocol amendment dated 26 June 2026 under INPLASY202650058. Network geometry assessment during data collection revealed the evidence base does not meet the minimum requirements for a valid network meta-analysis: the network is star-shaped with no head-to-head comparisons between active modalities, the resistance node is supported by a single study (k = 1), and the total network comprises five comparisons from four studies with confirmed arm-level data, falling below the minimum k ≥ 10 threshold for stable heterogeneity estimation and reliable treatment rankings. The dose-response analysis was not feasible as the minimum k ≥ 3 studies at two or more duration nodes within any single modality was not met.

Certainty of evidence is assessed using the standard GRADE framework (five domains: risk of bias, inconsistency, imprecision, indirectness, publication bias) implemented in GRADEpro GDT. Summary of Findings tables are prepared in GRADEpro GDT. The GRADE-NMA framework, including the intransitivity domain, is not applied as network meta-analysis is not conducted.

Quality assessment / Risk of bias analysis Each included study was assessed for risk of bias using the Cochrane Risk of Bias tool version 2 (RoB 2.0). For crossover trials, the crossover extension of RoB 2.0 was applied, with specific attention to carryover effects and adequacy of washout periods. Two reviewers conducted assessments independently, with disagreements resolved by consensus. Domain-level judgements are reported for all five domains (D1: randomisation process; D2: deviations from intended interventions including carryover; D3: missing outcome data; D4: measurement of the outcome; D5: selection of the reported result) using the three-level scale: Low risk, Some concerns, or High risk. An overall rating is assigned per study.

The overall certainty of evidence for each outcome is assessed using the standard GRADE framework with five domains: within-study risk of bias, inconsistency, imprecision, indirectness, and publication bias. GRADE is implemented in GRADEpro GDT. Summary of Findings tables are included in the main manuscript. Each downgrading decision is documented with a justification. Conclusions throughout the manuscript are calibrated to the GRADE certainty level: High certainty supports direct statements; Moderate certainty uses 'likely' or 'probably'; Low certainty uses 'may' or 'suggests'; Very low certainty uses highly qualified language and does not support clinical recommendations.

The transitivity assessment and GRADE intransitivity domain described in the original protocol are not applicable to the revised pairwise meta-analysis design and are removed from this amended version.

Strategy of data synthesis Primary analysis: a pairwise random-effects meta-analysis of all exercise snack modalities versus uninterrupted sitting is conducted for postprandial glucose iAUC

as the primary outcome. The standardised mean difference (SMD) with 95% confidence intervals is the effect measure. The REML estimator is used to estimate between-study heterogeneity (τ^2). The Hartung-Knapp-Sidik-Jonkman correction is applied. Prediction intervals are calculated and reported. I^2 is interpreted using the thresholds: below 25% low; 25 to 50% moderate; 50 to 75% substantial; above 75% considerable.

Multi-arm trial handling: Dunstan 2012 is a three-arm trial (uninterrupted sitting; light-intensity walking; moderate-intensity walking) contributing two active arms to the primary analysis. The shared control arm sample size is divided proportionally between the two active arm comparisons (n = 10 allocated to the light-intensity comparison; n = 9 to the moderate-intensity comparison) to avoid double-counting of control participants. Both active arms are entered as separate rows in RevMan Web and labelled Dunstan 2012a and Dunstan 2012b.

Subgroup analysis by modality: aerobic walking studies (Dunstan 2012a, Dunstan 2012b, Dey 2024, Chen 2018) and the resistance study (Climie 2018) are entered as separate subgroups within the primary meta-analysis in RevMan Web. A test for subgroup differences (Chi^2 test) is reported. The resistance subgroup constitutes a single-study comparison and is reported as an exploratory single-study signal rather than a pooled modality estimate.

Secondary outcomes: separate pairwise random-effects meta-analyses are conducted for postprandial insulin iAUC, glucose total area under the curve, and triglyceride total area under the curve using the same analytical specifications. Larsen 2015 contributes to secondary outcome analyses (glucose tAUC, insulin tAUC, triglyceride tAUC) using Day 1 data, as Day 1 represents the acute postprandial session directly commensurable with the single-session designs of all other included studies.

Publication bias: a funnel plot is generated for the primary outcome in RevMan Web and placed in supplementary material. Egger's regression test is not applied as $k < 10$ for all outcomes; this limitation is stated explicitly in the methods section of the manuscript.

Outcomes with $k < 3$ contributing studies are not pooled quantitatively and are reported narratively in the discussion with the available study count and reason for non-pooling stated explicitly.

The Bayesian network meta-analysis (gemtc, R), MCMC estimation procedures, prior distributions, convergence diagnostics, SUCRA rankings, league tables, network plots, node-splitting analyses, and dose-response meta-analysis (dosresmeta, R) described in the original Item 22 are not conducted. The rationale is documented in the amendment rationale above.

Subgroup analysis One pre-specified subgroup analysis is conducted as part of the primary RevMan Web analysis:

Modality subgroup (aerobic walking versus resistance): aerobic walking studies (Dunstan 2012a, Dunstan 2012b, Dey 2024, Chen 2018) and the resistance study (Climie 2018) are entered as separate subgroups. A Chi^2 test for subgroup differences is reported. This analysis is pre-specified and hypothesis-generating; the resistance subgroup is a single study and conclusions are explicitly labelled as exploratory.

The following pre-specified subgroup analyses from the original protocol cannot be conducted and are reported as not feasible in the limitations section of the manuscript:

Sex (male versus female): no included study reports outcomes stratified by sex in a form extractable for subgroup meta-analysis.

BMI category (overweight versus obese): no included study reports outcomes stratified by BMI category in a form extractable for subgroup meta-analysis.

Age (18 to 40 years versus above 40 years): insufficient studies per subgroup ($k < 3$) to meet the minimum pooling threshold.

Snack timing relative to meal (pre-meal versus post-meal commencement): all included studies initiate snacks in the postprandial period; no pre-meal snack studies meet all other eligibility criteria.

The original protocol text specifying stratified network thresholds for NMA ($k \geq 10$) is superseded. All subgroup analyses are pairwise, with $k \geq 3$ as the minimum pooling threshold. d will be noted in the PRISMA flow and limitations.

Sensitivity analysis The following sensitivity analyses are conducted for the primary outcome (postprandial glucose iAUC):

Leave-one-out analysis: each study is removed in turn and the pooled SMD and 95% CI is reported for each iteration. This is mandatory for all primary outcomes where $k \geq 3$, as specified in the Foundation Document methodology. Results are reported in a dedicated sensitivity analysis table.

High risk of bias exclusion: the primary analysis is re-run excluding studies rated High risk of bias in any domain under RoB 2.0, or with an overall rating of Some concerns where this is driven by a High rating in D2 (carryover/washout). Climie 2018, rated High in D2 due to a 24-hour washout interval, is the primary candidate for exclusion in this sensitivity analysis.

Aerobic-only sensitivity analysis: the primary analysis is re-run excluding Climie 2018 to

generate a pure aerobic walking pooled estimate. This analysis is labelled post-hoc and exploratory.
The following sensitivity analyses from the original protocol are removed as they were specific to the NMA analytical framework and are no longer applicable:
Re-running the NMA under at least two alternative prior distributions for the heterogeneity parameter τ.
Pairwise validation comparing conventional pairwise meta-analysis estimates to NMA direct estimates.
The sensitivity analysis restricting to studies using a standardised 75 g oral glucose tolerance test is retained as a post-hoc exploratory analysis. Given the final included dataset, this criterion is met only by Dunstan 2012; the analysis is therefore reported narratively rather than quantitatively.
The sensitivity analysis restricting to crossover designs only is retained but is effectively equivalent to the primary analysis as all included studies are crossover designs. This is noted in the methods.
Material changes in effect estimates or conclusions arising from any sensitivity analysis are reported prominently and discussed as robustness concerns in the discussion.

Language restriction The search will be restricted to studies published in English. Studies identified in other languages during the search will be noted in the PRISMA flow diagram and listed as excluded.

Other relevant information Protocol amendment: this protocol was amended on 26 June 2026 prior to commencement of any statistical analysis. The amendment revises the primary analytical method from Bayesian network meta-analysis (gemtc, R) to pairwise random-effects meta-analysis (RevMan Web), removes the dose-response meta-analysis, and updates Items 1, 8, 9, 20, 21, 22, 23, 24, 28, and 33 accordingly. The rationale is documented in the amendment notice at the beginning of this document and in the dedicated rationale section. The amendment was necessitated by network geometry assessment during data collection, which revealed insufficient studies per modality node, absence of head-to-head comparisons between active modalities, and failure to meet the minimum k threshold for valid NMA. All upstream methodological steps (search strategy, screening, data extraction, risk of bias assessment) are valid and unchanged. The amendment was filed before any pooled estimates were inspected.
Minimum k threshold for pooling: a minimum of k ≥ 3 studies is required for quantitative synthesis of any outcome. Outcomes with fewer than three contributing studies are reported narratively in the discussion, with the available study count and reason for non-pooling stated explicitly. This threshold applies to the revised pairwise meta-analysis framework.
Studies excluded following initial inclusion due to data unavailability: six of the eleven studies initially included following database and grey literature searching were subsequently excluded from quantitative synthesis because arm-level outcome data were not available in published reports and authors did not respond to systematic contact requests. These studies are: Larsen 2019, Thorsen 2019, Rafiei 2021 (overweight subgroup), Kowalsky 2017, Rodriguez-Hernandez 2017, and Duran 2023. Larsen 2015 contributes to secondary outcome analyses only; glucose iAUC for Larsen 2015 was reported only as a between-condition difference without arm-level means, precluding inclusion in the primary analysis. The exclusion reason for all six studies is documented as: data not available despite author contact. Author contact attempts, dates, and outcomes are documented in the supplementary author contact log.
Data transparency: the extracted dataset, RevMan Web analysis files, GRADE tables exported from GRADEpro GDT, and full Boolean search strings for all five databases will be deposited to Zenodo at the time of submission or acceptance. The resulting Zenodo DOI will be included in the Data Availability Statement of the final manuscript.

Country(ies) involved China.

Keywords Exercise snacks; postprandial glucose; systematic review; meta-analysis; pairwise meta-analysis; overweight; obesity; glycaemic control; aerobic exercise; resistance exercise; incremental area under the curve; sedentary behaviour; prolonged sitting.

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