Review Article

Bioelectrical Impedance Analysis Versus Dual-Energy X-Ray Absorptiometry for Sarcopenia Assessment in Type 2 Diabetes Mellitus: Protocol for a Systematic Review and Meta-Analysis

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Background: Sarcopenia affects approximately 10-27% of adults with type 2 diabetes mellitus (T2DM), roughly double the prevalence in age-matched non-diabetic populations. Dual-energy X-ray absorptiometry (DXA) is the consensus reference method for quantifying muscle mass, but its cost, radiation exposure, and infrastructure requirements limit its routine clinical use. Bioelectrical impedance analysis (BIA) is portable, inexpensive, and radiation-free. However, T2DM-associated alterations in tissue hydration, extracellular water distribution, and electrical conductivity may compromise BIA accuracy. No disease-specific systematic review has evaluated whether BIA constitutes a viable alternative to DXA for sarcopenia assessment in T2DM.

Objectives: To evaluate whether BIA is a viable alternative to DXA for (1) muscle mass and body composition estimation, (2) sarcopenia classification and prevalence estimation, and (3) sarcopenia screening in adults with T2DM, using a three-tier synthesis framework.

Methods: Five electronic databases (PubMed, Embase, Scopus, Web of Science, CINAHL) will be searched from inception without language restrictions, supplemented by citation searching. Studies comparing BIA with DXA in adults with confirmed T2DM reporting any agreement statistic or sarcopenia prevalence are eligible. Two reviewers will independently screen records, extract data, and assess risk of bias using QUADAS-C. Tier 1 analyses will pool ICC and Bland-Altman bias using random-effects models and Fisher z-transformation. Tier 2 will pool DXA-based sarcopenia

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prevalence (logit scale) and BIA-DXA risk difference. Tier 3 will narratively synthesise sensitivity, specificity, and AUC. GRADE will be applied to assess the certainty of evidence.
Dissemination: Findings will be published in a Scopus-indexed journal and presented at a reputable conference.

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1. Background and Rationale

1.1. Sarcopenia in type 2 diabetes mellitus

Sarcopenia — the progressive generalised loss of skeletal muscle mass, strength, and function — is a prevalent and clinically consequential complication of type 2 diabetes mellitus (T2DM). Meta-analytic estimates suggest that approximately 10-27% of adults with T2DM meet diagnostic criteria for sarcopenia, roughly double the prevalence observed in age-matched non-diabetic populations [1][2]. The co-occurrence of sarcopenia and T2DM is mechanistically important: skeletal muscle is the primary site of insulin-mediated glucose disposal, and its loss compounds insulin resistance, worsens glycaemic control, increases fall risk, and accelerates functional decline [3][4]. This bidirectional relationship has motivated international consensus groups — the European Working Group on Sarcopenia in Older People (EWGSOP2) and the Asian Working Group for Sarcopenia (AWGS 2019) — to recommend routine sarcopenia screening in T2DM populations [5][6].

1.2. Current diagnostic methods and their limitations

Both EWGSOP2 and AWGS 2019 endorse dual-energy X-ray absorptiometry (DXA) as the reference method for quantifying appendicular lean mass and sarcopenia [5][6]. DXA provides precise, reproducible measurements of regional and whole-body composition. However, DXA is costly, requires dedicated facilities and trained operators, involves low-level ionising radiation, and imposes weight limits that may exclude obese patients with T2DM. These constraints limit its widespread adoption in community and outpatient settings, where the majority of T2DM patients receive care.

Bioelectrical impedance analysis (BIA) measures the opposition to alternating electrical current to estimate body composition. BIA is inexpensive, portable, radiation-free, and operable by non-specialist staff, making it attractive for high-volume diabetes clinics. Both EWGSOP2 and AWGS 2019 endorse BIA

as an alternative to DXA for sarcopenia assessment, provided that population-specific validation has been established [5][6].

1.3. Validity of BIA in T2DM — the evidence gap

The validity of BIA in T2DM is uncertain due to disease-specific physiological factors. T2DM is associated with expanded extracellular water, altered intracellular-to-extracellular fluid ratios, peripheral oedema related to autonomic neuropathy, increased visceral and ectopic fat deposition, and metabolic consequences of chronic hyperglycaemia on tissue conductivity [7][8]. BIA-derived estimates rely on empirical hydration assumptions (typically a fat-free mass hydration fraction of approximately 0.73) that were established in healthy populations and may not hold in T2DM. Whether these disease-specific alterations introduce clinically meaningful systematic bias relative to DXA — and whether that bias is sufficient to affect sarcopenia classification decisions — has not been evaluated in a disease-specific systematic review.

1.4. Existing reviews and the unaddressed gap

Existing systematic reviews comparing BIA and DXA have been conducted in general or healthy adult populations [9][10], elderly individuals without disease-specific stratification [11], or paediatric populations [12]. Reviews addressing sarcopenia diagnosis have examined BIA across mixed populations or focused on diagnostic accuracy alone without addressing measurement agreement or prevalence concordance [13][14]. No systematic review has evaluated BIA as a viable alternative to DXA specifically in adults with T2DM, accounting for the disease-specific alterations that are most likely to affect BIA validity.

1.5. Rationale for the three-tier framework

The clinical question: Is BIA a viable alternative to DXA for sarcopenia assessment in T2DM? — cannot be adequately answered from agreement data alone. Excellent agreement metrics are necessary but not sufficient: a method may show high correlation while exhibiting systematic bias that shifts individuals across sarcopenia diagnostic thresholds. Conversely, a near-zero pooled bias may coexist with wide individual-level limits of agreement, precluding interchangeability for clinical decisions. This review therefore employs a three-tier synthesis framework: Tier 1 addresses measurement agreement, Tier 2

addresses classification concordance and prevalence, and Tier 3 addresses diagnostic performance — together providing the multi-level evidence base needed to evaluate clinical viability.

2. Objectives

The primary objective of this systematic review and meta-analysis is to determine whether BIA is a viable alternative to DXA for sarcopenia assessment in adults with type 2 diabetes mellitus, addressed across three pre-specified analytical tiers:

1. To evaluate the measurement agreement between BIA and DXA for muscle mass and body composition outcomes in adults with T2DM, including pooled intraclass correlation coefficient (ICC), Bland-Altman mean bias and 95% limits of agreement, and Pearson/Spearman correlation coefficients.
2. To estimate DXA-based sarcopenia prevalence in adults with T2DM and to quantify the difference in sarcopenia prevalence between BIA and DXA through bilateral prevalence comparison and pooled risk difference meta-analysis.
3. To evaluate the diagnostic performance of BIA for sarcopenia screening using DXA as the reference standard, including sensitivity, specificity, positive and negative predictive values, and area under the receiver-operating characteristic curve.

Secondary objectives include examining the influence of BIA modality (single-frequency versus multi-frequency or direct segmental), risk-of-bias level, and outcome type (lean/muscle mass versus fat mass) on agreement estimates, and assessing the certainty of the evidence using the GRADE framework adapted for agreement outcomes.

3. Methods

3.1. Protocol and reporting standards

This protocol is reported in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols 2015 (PRISMA-P 2015) [15]. The completed PRISMA-P checklist is provided in Appendix A. The full systematic review will be reported in accordance with PRISMA 2020 [16] and PRISMA-S [17]. Risk of bias will be assessed using QUADAS-C [18]. This protocol has been registered on

PROSPERO (registration pending at time of submission; CRD number to be inserted on assignment). The search strategy and analysis code will be deposited on the Open Science Framework before publication.

3.2. Eligibility criteria

3.2.1. Population

Adults aged 18 years or older with a confirmed diagnosis of type 2 diabetes mellitus, defined using any validated diagnostic criteria (e.g. WHO 1999, American Diabetes Association 2003 onwards, or equivalent national criteria). No restriction on age, sex, ethnicity, disease duration, treatment modality, glycaemic control status, BMI, or comorbidities. Studies enrolling mixed populations are eligible if data for the T2DM subgroup can be extracted separately.

3.2.2. Index test

Bioelectrical impedance analysis in any modality, including single-frequency BIA, multi-frequency BIA, direct segmental multi-frequency BIA, and bioimpedance spectroscopy. Any commercially available BIA device is eligible—no restriction on measurement protocol, electrode configuration, or prediction equation.

3.2.3. Reference standard

Dual-energy X-ray absorptiometry, any manufacturer (Hologic, GE Lunar/Prodigy, or equivalent). No restriction on DXA scan protocol, software version, or body region assessed.

3.2.4. Outcomes

At least one of: (a) a quantitative agreement statistic between BIA and DXA (ICC, correlation coefficient, Bland-Altman analysis, concordance correlation coefficient, Cohen's kappa); (b) sarcopenia prevalence by DXA or BIA; or (c) diagnostic performance statistics (sensitivity, specificity, AUC) of BIA for sarcopenia detection.

3.2.5. Study design

Cross-sectional body composition validation or agreement studies; prospective and retrospective cohort studies providing baseline BIA-DXA comparison data; randomised controlled trial baseline assessments where both BIA and DXA were performed before intervention. Any study design is eligible provided it

performed both BIA and DXA in the same participants at the same or closely adjacent time point (within 48 hours, with no intervening intervention).

3.2.6. Exclusion criteria

Studies enrolling exclusively non-T2DM populations (type 1 diabetes, gestational diabetes, prediabetes, or healthy controls only); studies in participants under 18 years; studies reporting fat mass outcomes only with no muscle mass, lean mass, appendicular skeletal muscle mass, or sarcopenia data; narrative reviews, systematic reviews, editorials, letters, and conference abstracts without extractable primary data; case reports and case series ($n < 10$); animal studies.

3.3. Information sources and search strategy

Five electronic databases will be searched from inception to 24 March 2026 without date or language restrictions: PubMed/MEDLINE, Embase (via Elsevier), Scopus, Web of Science Core Collection, and CINAHL Ultimate (via EBSCOhost). The search strategy combines four concept blocks with Boolean AND: (A) sarcopenia or muscle mass terms; (B) type 2 diabetes mellitus terms; (C) bioelectrical impedance analysis terms; (D) dual-energy X-ray absorptiometry terms. MeSH terms, Emtree terms, and free-text equivalents are used in combination. The full PubMed strategy is provided in Appendix B. Supplementary searching will include backward and forward citation searching of all included studies. Cochrane CENTRAL will not be searched as measurement agreement studies are not indexed as trials.

3.4. Study selection

Following two-stage deduplication (DOI matching followed by title fuzzy matching at >90% similarity threshold), records will be screened independently by two reviewers (SR and RS) using Rayyan or equivalent software. Stage 1 involves title and abstract screening against the eligibility criteria; Stage 2 involves full-text assessment of all potentially eligible records. Disagreements at each stage will be resolved by consensus discussion; GT will arbitrate unresolved disagreements. Reasons for exclusion at the full-text stage will be recorded. A PRISMA 2020 flow diagram will document the selection process.

3.5. Data extraction

Data will be extracted independently by SR and RS using a pre-specified, standardised seven-domain extraction form. Domains: (1) study characteristics (design, country, year, sample size); (2) participant clinical characteristics (age, sex, BMI, HbA1c, diabetes duration, treatment); (3) methodological details

(BIA device, protocol, DXA device, body composition outcome, sarcopenia criterion and cut-off); (4) agreement statistics (ICC with 95% CI, Bland-Altman bias and limits of agreement, Pearson/Spearman correlation coefficient); (5) sarcopenia prevalence data (numerators, denominators, criteria used) by each method; (6) diagnostic performance statistics (sensitivity, specificity, PPV, NPV, AUC, optimal cut-off); (7) QUADAS-C domain ratings with justifications. Where Bland-Altman statistics are presented only in figures, values will be digitised to ±1.0 units of precision. Discrepancies between reviewers will be resolved by discussion; GT will arbitrate unresolved disagreements.

3.6. Risk of bias assessment

Risk of bias will be assessed using QUADAS-C (Vali et al., BMJ Evidence-Based Medicine 2024;29:43-50), which is specifically designed for comparative accuracy studies that compare two index tests against a common reference standard. QUADAS-C evaluates five domains: (1) patient selection; (2) index test (BIA) standardisation; (3) reference standard (DXA); (4) flow and timing; (5) comparative analysis. Each domain will be rated Low risk, Unclear risk, or High risk, with an Overall rating. Assessment will be conducted independently by SR and RS; GT will arbitrate unresolved disagreements.

3.7. Statistical analysis and data synthesis

3.7.1. Tier 1 — Measurement agreement

ICC and Pearson/Spearman correlation coefficients will be Fisher z-transformed before meta-analysis. A correlation meta-analysis will use a multilevel random-effects model (rma.mv in metafor; random = ~1|study/observation) as the primary analysis to account for multiple correlated outcomes per study, with a naive univariate random-effects REML model as a sensitivity analysis. Spearman correlations will receive a 1.06/(n-3) variance correction. Bland-Altman mean bias will be expressed in the DXA minus BIA convention throughout (positive values indicate DXA reads higher than BIA) and pooled within the same-unit subgroups (kg; kg/m^2; %) using REML. The SD of differences will be pooled using log-scale variance pooling (Tipton-Shuster method). Pooled limits of agreement will be reconstructed as: pooled bias ± 1.96 × pooled SD. Prediction intervals will be reported for all pooled estimates.

3.7.2. Tier 2 — Sarcopenia prevalence

DXA-based sarcopenia prevalence will be pooled on the logit scale (PLO) using random-effects REML, with Freeman-Tukey double arcsine transformation (PFT) as sensitivity analysis. Bilateral BIA-minus-

DXA sarcopenia prevalence risk difference will be pooled using random-effects meta-analysis. Directional consistency of the bilateral comparison will be reported as a proportion.

3.7.3. Tier 3 — Diagnostic performance

Sensitivity, specificity, PPV, NPV, and AUC will be synthesised narratively. Bivariate or HSROC modelling will not be performed unless five or more studies contribute diagnostic performance data, as recommended by the Cochrane Diagnostic Test Accuracy Group [19].

3.7.4. Heterogeneity and subgroup analyses

Between-study heterogeneity will be assessed using I^2, τ^2, and Cochran's Q for all pooled analyses. Pre-specified subgroup analyses: (a) BIA modality (single-frequency versus multi-frequency/direct segmental); (b) risk of bias level (low/unclear versus high overall QUADAS-C rating); (c) outcome group (lean/muscle mass versus fat mass). Pre-specified sensitivity analyses: (a) leave-one-out; (b) exclusion of studies with digitised Bland-Altman data; (c) exclusion of high-ROB studies; (d) Pearson-only correlation; (e) Freeman-Tukey versus logit prevalence. Publication bias will be assessed visually using study-level funnel plots; formal Egger's test will not be performed if $k < 10$ for any analysis.

3.8. Certainty of evidence

GRADE will be applied to assess the certainty of evidence for each pooled outcome, adapted for agreement and diagnostic accuracy outcomes. Ratings will be downgraded for risk of bias, inconsistency, indirectness, imprecision, and publication bias. Certainty ratings will be presented in a GRADE Summary of Findings table.

3.9. Amendments

Any amendments to this protocol after registration will be documented with date and rationale in the PROSPERO record and disclosed in the final manuscript per PRISMA 2020 Item 24c.

4. Ethics and Dissemination

Ethical approval is not required for this systematic review, as it uses only published, aggregate data and does not involve individual participant data. Findings will be submitted for peer-reviewed publication in the Journal of Cachexia, Sarcopenia and Muscle and presented at ESICON 2026 (Endocrine Society of

India Annual Meeting, Chennai, October 2026). All analysis code, the data extraction workbook, and full search strategies will be deposited on the Open Science Framework with a CC-BY 4.0 licence before publication.

Appendix A. PRISMA-P 2015 Checklist

Item	Section	Checklist item	Location
1a	Title	Identify the report as a protocol of a systematic review.	Title page — "protocol for a systematic review and meta-analysis"
1b	Registration	If registered, provide the registry name and registration number.	PROSPERO — registration pending; CRD to be inserted on assignment
2a	Authors — Contact	Provide name, institutional affiliation, e-mail address of all protocol authors; provide physical mailing address of the corresponding author.	Title page — all five authors with affiliations and corresponding author contact
2b	Authors — Contribution	Describe the contributions of each protocol author and identify the guarantor of the review.	Methods §3.4 and §3.5; SR is review guarantor
3	Amendments	If the protocol represents an amendment to a previously completed or published protocol, identify it as such and list the changes.	Not applicable — first version
4a	Support — Sources	Indicate sources of financial or other support for the review.	Title page — no external funding; MAHE institutional support
4b	Support — Sponsor	Provide the name for the review funder and/or sponsor.	Title page — MAHE
4c	Support — Role	Describe roles of funder(s), sponsor(s), and/or institution(s), if any, in developing the protocol.	No role — independent academic initiative
5	Rationale	Describe the rationale for the review in the context of what is already known.	Introduction §1.1–1.5
6	Objectives	Provide an explicit statement of the question(s) the review will address with reference to PICO.	Objectives §2
7a	Eligibility — Characteristics	Specify the study characteristics (PICOS) and report characteristics.	Methods §3.2.1–3.2.6

Item	Section	Checklist item	Location
7b	Eligibility — Information sources	Describe the information sources planned to inform the search strategy.	Methods §3.3
8	Information sources	Describe all intended information sources (databases, registers, grey literature).	Methods §3.3
9	Search strategy	Present a draft of at least one electronic database search strategy.	Appendix B — full PubMed strategy
10a	Study records — Management	Describe the mechanism(s) planned to manage records and data.	Methods §3.4 (Rayyan)
10b	Study records — Selection process	State the process for selecting studies.	Methods §3.4
10c	Study records — Data collection	Describe the planned method of extracting data.	Methods §3.5
11	Data items	List and define all variables for which data will be sought.	Methods §3.5
12	Outcomes and prioritisation	List and define all outcomes for which data will be sought; prioritise.	Methods §3.7
13	Risk of bias	Describe anticipated methods for assessing risk of bias.	Methods §3.6
14	Data synthesis	Describe the criteria under which study data will be quantitatively synthesised.	Methods §3.7
15a	Meta-bias(es)	Specify any planned assessment of meta-bias(es).	Methods §3.7.4 (funnel plot, Egger)
15b	Meta-bias(es)	Describe any planned adjustment for meta-bias(es).	Methods §3.7.4
16	Confidence in evidence	Describe how the strength of the body of evidence will be assessed.	Methods §3.8 (GRADE)

Appendix B. Full PubMed Search Strategy

Searched: PubMed/MEDLINE | Date: 24 March 2026 | Results: 59 records

The strategy combines four concept blocks with Boolean AND:

Concept A — Sarcopenia and muscle mass

"Sarcopenia"[MeSH] OR "Muscle, Skeletal"[MeSH] OR "Body Composition"[MeSH] OR "Muscular Atrophy"[MeSH] OR sarcopenia[tiab] OR sarcopenic[tiab] OR "muscle mass"[tiab] OR "muscle wasting"[tiab] OR "skeletal muscle"[tiab] OR "lean mass"[tiab] OR "lean body mass"[tiab] OR "appendicular lean mass"[tiab] OR "appendicular skeletal muscle mass"[tiab] OR "skeletal muscle index"[tiab] OR "fat-free mass"[tiab]

AND Concept B — Type 2 diabetes

"Diabetes Mellitus, Type 2"[MeSH] OR "type 2 diabetes"[tiab] OR T2DM[tiab] OR T2D[tiab] OR NIDDM[tiab] OR "non-insulin-dependent diabetes"[tiab] OR diabetic[tiab]

AND Concept C — Bioelectrical impedance

"Electric Impedance"[MeSH] OR "bioelectrical impedance"[tiab] OR bioimpedance[tiab] OR "bioelectrical impedance analysis"[tiab] OR BIA[tiab] OR InBody[tiab] OR Tanita[tiab] OR "multi-frequency"[tiab] OR "multifrequency"[tiab] OR "single-frequency"[tiab]

AND Concept D — DXA

"Absorptiometry, Photon"[MeSH] OR "dual energy x-ray absorptiometry"[tiab] OR "dual-energy x-ray absorptiometry"[tiab] OR DXA[tiab] OR DEXA[tiab]

Note: Equivalent strategies using database-specific controlled vocabulary (Emtree for Embase; CINAHL Subject Headings) and free-text equivalents were used for all other databases. Full strategies for all five databases are available from the corresponding author on request and will be deposited on OSF before publication.

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Declarations

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