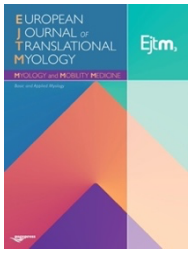
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Tongue ultrasonography for oropharyngeal dysphagia in neuromuscular disorders
Tongue ultrasonography as a quantitative biomarker for oropharyngeal dysphagia in neuromuscular disorders: a systematic review

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Abstract

Oropharyngeal Dysphagia (OD) is a prevalent and potentially life-threatening complication of Neuromuscular Disorders (NMDs). Tongue ultrasonography is an inexpensive, non-ionising, point-of-care technique that permits quantitative assessment of lingual muscle structure, but its value as a biomarker of OD across NMDs has not been systematically appraised. This systematic review aims to synthesize the available evidence on the diagnostic accuracy, reliability and clinical utility of quantitative tongue ultrasonography as a biomarker of OD in adults with NMDs. We systematically searched PubMed and Scopus for studies correlating quantitative tongue-ultrasound parameters, Tongue Thickness (TT) or Echo Intensity (EI), with instrumental swallowing assessment in adults with NMDs, following the PRISMA 2020 guideline. Study selection, data extraction and risk-of-bias appraisal were performed independently by two reviewers. Six studies (n = 10-38 per cohort) met the inclusion criteria. Reduced TT was a consistent marker of lingual atrophy in Amyotrophic Lateral Sclerosis (ALS) and correlated with oral-phase swallowing impairment, whereas functional measures of tongue strength were stronger predictors of aspiration risk. In Duchenne Muscular Dystrophy (DMD), increased TT reflected "pseudohypertrophy" from fatty and connective-tissue infiltration rather than preserved function and EI provided a complementary index of tissue quality in myopathic NMDs. Tongue ultrasonography is a promising, disease-sensitive biomarker for monitoring bulbar dysfunction in NMDs, but morphological indices should be integrated with functional swallowing data to predict aspiration risk. Standardized acquisition protocols and larger, longitudinal, multicentre studies are required before clinical implementation.

Key words: rehabilitation; oropharyngeal dysphagia; ultrasonography; neuromuscular disorders; swallowing dysfunction.

Tongue ultrasonography for oropharyngeal dysphagia in neuromuscular disorders

Oropharyngeal Dysphagia (OD) is a disorder of the oral and/or pharyngeal phases of swallowing, characterized by impaired bolus formation, control and transport from the mouth to the oesophagus.[1,2] Clinically, it may manifest as difficulty initiating swallowing, coughing, choking or the sensation of food sticking in the throat[3] and it is associated with serious complications including aspiration pneumonia, malnutrition, dehydration and reduced quality of life.[1,4]

Although OD arises from diverse aetiologies,[1,5] it is particularly significant in patients with Neuromuscular Disorders (NMDs).[4,6-8] Reported prevalence ranges from approximately 35% to more than 80%, depending on the specific condition and disease stage.[9] In Amyotrophic Lateral Sclerosis (ALS), OD appears earlier and more frequently in bulbar-onset disease but ultimately affects up to 80% of patients.[10] High prevalence is likewise reported in Duchenne Muscular Dystrophy (DMD), where dysphagia may affect up to 90% of patients in advanced stages,[11] in myotonic dystrophy type 1 (DM1), with estimates of 25-80%,[12] in Oculopharyngeal Muscular Dystrophy (OPMD), in which OD is a near-universal feature as the disease progresses,[13] and in Inclusion Body Myositis (IBM), with estimates of 40-86%.[14]

In NMDs, OD results from progressive impairment of the neuromuscular structures involved in swallowing, compromising both the efficiency and the safety of deglutition.[8,15,16] Pathophysiologically, these changes are driven mainly by progressive motor-unit loss, producing muscle atrophy, weakness and fatty infiltration of the swallowing musculature. The resulting incoordination and reduced strength of the oropharyngeal muscles impair bolus transport and increase the risk of airway invasion.[15,16]

The tongue is central to the oral phase of swallowing, contributing to bolus formation, control and propulsion. Consequently, tongue dysfunction is often among the earliest and most prominent manifestations of bulbar involvement in NMDs.[17] This anatomical and functional importance makes the tongue an attractive target for quantitative imaging biomarkers of early bulbar decline.[17]

Bedside clinical evaluation offers an initial appraisal of swallowing, but instrumental assessment is usually required for definitive diagnosis and characterization. The Videofluoroscopic Swallow Study (VFSS) is regarded as the reference standard for visualizing bolus-flow dynamics and detecting aspiration,[1] but it requires radiation exposure, specialized equipment and patient transport. Fibre-optic Endoscopic Evaluation of Swallowing (FEES) is a radiation-free alternative that directly visualizes pharyngeal and laryngeal structures[1] but also requires dedicated equipment and operator expertise. Against these constraints, Ultrasound (US) has emerged as a promising point-of-care tool

for assessing OD.[18,19] US allows direct, non-invasive visualization of the intrinsic and extrinsic tongue muscles and quantification of structural change such as atrophy (e.g., reduced thickness) and degeneration (e.g., increased echo intensity).[20] Being non-ionising and readily repeatable, it is well suited to bedside assessment, longitudinal monitoring and evaluation of rehabilitative interventions over time.[20]

Despite these advantages, the current evidence is heterogeneous, varying across NMD phenotypes and US acquisition protocols. Previous reviews have appraised US in neurogenic dysphagia, including heterogeneous neurological populations in which stroke predominates, and have considered multiple oropharyngeal structures rather than the tongue specifically.[18,20] To date, however, no systematic review has specifically assessed quantitative tongue US as a biomarker of OD across the NMDs. We therefore aimed to synthesize the available literature to evaluate the diagnostic accuracy, reliability and clinical utility of tongue US as a quantitative biomarker of OD in adults with NMDs.

Materials and Methods

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement.[21] Because clinical and methodological heterogeneity precluded meta-analysis, a narrative (qualitative) synthesis was pre-specified.

Search strategy

A systematic search of PubMed and Scopus was performed to identify studies applying tongue US to the assessment of OD in patients with NMDs. The search string was: (dysphagia OR "swallowing disorder*") AND (ultrasound OR ultrasonography OR "muscle ultrasound" OR "tongue ultrasound") AND ("tongue thickness" OR "tongue atrophy" OR "echo intensity" OR echogenicity) AND ("amyotrophic lateral sclerosis" OR ALS OR "muscular dystrophy" OR "neuromuscular disease*").

The search was restricted to English-language articles published up to May 2026 (last search conducted on 10 May 2026). Reference lists of included studies and relevant reviews were hand-searched for additional records.

Eligibility criteria

Eligibility was framed using the PICOS structure: i) Population: adults (≥18 years) with a diagnosed NMD; ii) Intervention: US measurement of quantitative tongue-morphology parameters, such as TT, EI or other echogenicity/structural indices; iii) Comparator: objective clinical or instrumental swallowing assessment (VFSS, FEES or pharyngeal manometry); iv) Outcome: correlation of US findings with the reference swallowing assessment; v) Study design: original observational or interventional studies reporting primary data

Studies were excluded if they enrolled only healthy participants, used US for non-swallowing lingual assessment (e.g., speech articulation only), lacked full-text availability or were animal studies, were not in English or reported no original data (e.g., opinion papers, reviews, editorials).

Study selection

Records were imported into reference-management software (Zotero) and de-duplicated. Two reviewers (M.C.M. and Y.D.) independently screened titles and abstracts against the eligibility criteria, resolving disagreements by discussion until consensus. Full texts of potentially eligible articles were then retrieved and independently assessed by the same reviewers for final inclusion.

Data extraction

Two reviewers (M.C.M. and Y.D.) independently extracted data using a standardized form, capturing study characteristics (authors, year, design, country), patient demographics (sample size, NMD diagnosis, disease duration), US methodology (device, probe, protocol, tongue parameters, measurement units), swallowing-assessment methods (instrumental modality, clinical scales) and key findings. Disagreements were resolved by consensus.

Quality and risk-of-bias assessment

Two reviewers (M.C.M. and Y.D.) independently assessed methodological quality and risk of bias using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Analytical Cross-Sectional Studies or the Newcastle-Ottawa Scale (NOS), according to study design. Discrepancies were resolved by discussion.

Tongue ultrasound technique

Tongue ultrasonography for oropharyngeal dysphagia in neuromuscular disorders

Tongue US is most commonly performed via a submental approach. As shown in Figure 1, measurements are typically acquired from the mylohyoid muscle to the tongue dorsum, enabling direct visualization and quantification of tongue-muscle thickness and structural integrity and providing objective evidence of atrophy or degeneration. Study-specific protocols and anatomical landmarks are detailed in the Results.

Results

Study selection

The search of PubMed and Scopus yielded 21 records. After removal of 8 duplicates, 13 records were screened by title and abstract, of which 6 were excluded (irrelevant population, intervention or outcome). Seven full-text articles were assessed for eligibility, of which one was excluded, leaving six studies for inclusion. The selection process is summarized in the PRISMA flow diagram (Figure 2).

Characteristics of included studies

The six included studies comprised one longitudinal case-control study, two cohort studies and three cross-sectional studies.[17,22-26] They originated from diverse settings: two from Japan,[17,22] one from Brazil,[23] one from Spain,[24] one from South Korea[26] and one European multicentre study involving Germany and the Netherlands.[25]

Populations comprised adults with ALS, DMD, DM1, IBM or OPMD. All studies used tongue US to quantify morphological parameters (TT and/or EI) and correlated these with objective swallowing assessment (VFSS, FEES or manometry). Study characteristics are summarized in Supplementary materials, Table 1.

Methodological quality and risk of bias

Overall, the studies were of moderate-to-high methodological quality, with considerable heterogeneity in design, sample size and outcome-assessment rigour. No study was at low risk of bias across all domains; only Nakamori et al. (2016) and Zeng et al. (2026) achieved high-quality appraisal scores, reflecting blinded assessment, standardized acquisition protocols and either multivariable confounding adjustment or z-score normalization.[22,25]

A consistent strength was the low-to-moderate information-bias profile: five of six studies used blinded or partially blinded assessors for at least one primary domain and all used instrumental swallowing outcomes (VFSS, FEES, Modified Barium Swallow Impairment Profile - MBSImP or RT-MRI) rather than clinical or self-reported scales alone.

Conversely, selection bias from small, single-centre samples was a global limitation, reducing representativeness and precision; sample sizes of 10-38 patients rendered all studies underpowered for subgroup analyses. Confounding control was often inadequate: only Kim et al. (2026) and Zeng et al. (2026) performed formal adjustment for demographic covariates and Umemoto et al. (2021) did not account for major demographic differences between disease groups.[17,25,26]

Spectrum bias was evident across ALS studies, whose populations largely comprised patients with established, often advanced, bulbar involvement, limiting inference about the diagnostic utility of tongue US in early or subclinical OD. Measurement heterogeneity (transducer frequency 1-5 MHz to 8-14 MHz, positioning 30° recline vs. 90° seated, differing landmarks and numbers of measurements averaged) further precluded quantitative pooling. Finally, four of six studies did not report inter- or intra-rater reliability for US acquisition, a notable gap given the operator dependence of tongue US. Study-level risk of bias is detailed in Table 1.

Main findings

In ALS, Nakamori *et al.* (2016) provided evidence that ultrasonographic TT is significantly reduced relative to healthy controls (41.9 ± 4.0 mm vs. 44.8 ± 3.0 mm; $p = 0.016$) and correlates with oral preparatory and transit time on VFSS ($p = 0.032$), but not with pharyngeal transit time. Longitudinal assessment of nine patients showed progressive TT reduction (0.315 mm/month*)*, underscoring the potential of serial measurement for monitoring progression.[22]

Recasens *et al.* (2023) extended this in a larger cross-sectional cohort of 38 ALS patients combining TT with tongue manometry and VFSS. TT was associated exclusively with impaired oral transit, whereas tongue strength, particularly anterior (≤34 kPa) and posterior (≤34.5 kPa) pressures, was a superior predictor of penetration/aspiration (PAS ≥3) and post-swallow residue (Bolus Residue Scale - BRS >1), with ROC-derived sensitivities ranging from 77% to 100% and specificities ranging from 62.5% to 86.7%. Thus, although TT reflects oral-phase morphology, functional measures of lingual strength carry greater diagnostic weight for swallowing safety and efficiency.[24]

Kim *et al.* (2026), in a feasibility study of ten ALS patients, corroborated these findings using the MBSImP as reference. After adjustment for age, sex and BMI, TT remained associated with

MBSImP oral (r = −0.816, p = 0.025), pharyngeal (r = −0.891, p = 0.007) and combined scores (r = −0.933, p = 0.002). Simple linear regression analysis demonstrated that reduced TT was significantly associated with greater oral-phase impairment (B = -0.119, 95% CI -0.216 to -0.022, *p* = 0.025) and with higher combined oral and pharyngeal MBSImP scores (B = -0.075, 95% CI -0.108 to -0.042, *p* = 0.002).[26]

Augusto *et al.* (2021) examined TT and FEES-assessed pharyngeal residue in 21 ALS patients. TT, posterior maximum tongue isometric pressure and posterior tongue isometric endurance were all reduced relative to normative values but did not differentiate patients with and without vallecular residue after 10 mL of moderately thickened liquid (p = 0.94 for TT). This null result suggests that the tongue's contribution to pharyngeal residue is multifactorial and that TT may lack discriminative power for efficiency-based outcomes in this scenario.[23]

Umemoto *et al.* (2021) contributed the only longitudinal multi-disease cohort, following 21 ALS, 30 DM1 and 14 DMD patients over means of 24.0, 47.2 and 61.1 months, respectively. TT was measured from the mylohyoid raphe to the tongue dorsum. ALS patients showed the most rapid, statistically significant decline in both TT ($p < 0.05$) and maximum tongue pressure ($p < 0.01$), whereas DM1 and DMD showed no significant longitudinal change. DMD patients exhibited a pseudohypertrophic pattern with the largest baseline TT (55.8 ± 6.8 mm; $p < 0.01$) despite lower tongue pressure, consistent with fatty infiltration and connective-tissue replacement rather than true muscular hypertrophy.[17]

Finally, Zeng *et al.* (2026) extended quantitative muscle ultrasound (QMUS) to IBM and OPMD. Abnormal tongue echogenicity was present in 38% of OPMD patients (severe z-scores >3 in 15%), while IBM patients showed predominantly extra-lingual orofacial involvement. Decreased MRI-T1 values of the tongue, indicating fatty infiltration, correlated with increased US echogenicity (Spearman ρ = -0.52, p = 0.005), providing cross-modal validation of QMUS as a biomarker of tissue degeneration. Combined with real-time MRI and T1 mapping, QMUS discriminated IBM from OPMD dysphagia phenotypes (AUC = 0.95; 95% CI 0.86-1.00), whereas FEES and clinical assessments did not.[25]

Discussion

This systematic review synthesizes evidence from six studies examining tongue US in the assessment of OD across a spectrum of NMDs. Collectively, ultrasonographic measurement of tongue morphology, particularly TT and EI, provides clinically relevant, quantifiable information on lingual structural integrity and its relationship to swallowing function, while also revealing limitations that preclude its stand-alone diagnostic use. The most consistent finding is the significant

reduction in TT in ALS relative to controls, with progressive atrophy correlating with oral-phase dysfunction on instrumental assessment. This is coherent with neurogenic denervation causing motor-unit loss and muscle atrophy, reflected morphologically as reduced tongue volume and functionally as impaired bolus formation and propulsion.[27,28] The association between TT and oral preparatory/transit times, reported by Nakamori *et al.* (2016), Recasens *et al.* (2023) and Kim *et al.* (2026), accords with early sonographic observations in ALS dysphagia.[22,24,26,28] Together these findings support tongue US as a screening tool for OD, especially where VFSS is unavailable or radiation exposure is a concern.[18,20]

The association Kim *et al.* (2026) reported between TT and pharyngeal-phase MBSImP scores after covariate adjustment, not replicated by Nakamori et al. (2016) using VFSS measures, may reflect the greater sensitivity of the MBSImP protocol to subtle pharyngeal involvement secondary to lingual weakness.[22,26,29,30]

Conversely, the inability of TT to predict post-swallow pharyngeal residue[23] can suggest the multifactorial nature of swallowing-efficiency impairment. Consistent with this, maximum tongue pressure, rather than morphology, has been reported as the principal correlate of swallowing safety and efficiency.[24] TT therefore can capture structural atrophy but not the full functional reserve of the lingual musculature, which can depend on surviving motor units, neuromuscular coordination and proprioceptive feedback.[15,27] Accordingly, combining TT with functional tongue-pressure measurement can determine superior prediction of aspiration risk, supporting a multiparametric approach to lingual assessment.[31]

Umemoto *et al.* (2021) added another important disease-specific perspective: TT trajectories may differ between neurogenic and myogenic NMDs. The pseudohypertrophic pattern in DMD, increased baseline TT despite reduced tongue pressure, can reflect fatty and connective-tissue infiltration rather than preserved function,[17] underscoring the risk of misinterpreting TT without knowledge of underlying tissue composition. This concern is directly addressed by the quantitative echogenicity approach of Zeng *et al.* (2026), which provides a surrogate of tissue quality complementing thickness.[25] The correlation between increased echogenicity and MRI markers of fatty infiltration in OPMD offers validation of QMUS as a biomarker of pathological remodeling, extending prior evidence that muscle US is sensitive in OPMD and that tongue fatty infiltration can be characterized against MRI.[32,33] EI may thus prove more informative than thickness alone in myopathic conditions, where tissue change can precede or dissociate from functional decline.

From a practical viewpoint, tongue US offers portability, absence of ionizing radiation, real-time bedside applicability and feasibility for longitudinal monitoring without the burden of repeated VFSS or FEES, advantages that are especially valuable in NMDs, where progression is rapid and frequent

reassessment is needed. Progressive TT reduction in ALS[17,22] suggests a potential role for serial US monitoring as a surrogate endpoint in trials targeting bulbar function.[18,19] Similarly, the quantitative approach of Zeng *et al.* (2026) positions echogenicity-based assessment as a candidate outcome in trials targeting muscle quality in myopathic NMDs such as IBM and OPMD, for which sensitive progression biomarkers remain an unmet need.[25]

Nevertheless, some limitations constrain firm clinical recommendations. All studies were small, limiting statistical power and generalizability. Methodological heterogeneity precluded direct inter-study comparison and derivation of universal normative values. The absence of standardized acquisition protocols is the most pressing barrier to implementation, a concern already presented in broader reviews of ultrasonography in neurogenic dysphagia[18] that call for consensus protocols. Finally, the predominant focus on static TT could overlook dynamic aspects of lingual function, fasciculation detection, real-time movement analysis and elastography, that may add diagnostic information.[34]

Conclusions

Tongue US is a promising, non-invasive tool for the quantitative assessment and monitoring of NMD-related dysphagia. The distinct patterns of tongue morphology and function across ALS and DMD underscore the importance of disease-specific interpretation. Although current evidence supports its utility for detecting muscle atrophy and tracking progression, further work is needed to standardize evaluation protocols, validate predictive biomarkers and integrate US into comprehensive dysphagia management. Therefore, future studies should prioritize larger, multicentre cohorts, standardized US techniques and correlation of findings with functional and nutritional outcomes.

List of Abbreviations

ALS, Amyotrophic Lateral Sclerosis

AUC, Area Under The Curve

BMI, Body Mass Index

BRS, Bolus Residue Scale

CI, Confidence Interval

DM1, Myotonic Dystrophy type 1

DMD, Duchenne Muscular Dystrophy

EI, Echo Intensity

FEES, Fibre-Optic Endoscopic Evaluation if Swallowing

IBM, Inclusion Body Myositis

JBI, Joanna Briggs Institute

MBSImP, Modified Barium Swallow Impairment Profile

MRI, Magnetic Resonance Imaging

NMDs, Neuromuscular Disorders

NOS, Newcastle-Ottawa Scale

OD, Oropharyngeal Dysphagia

OPMD, Oculopharyngeal Muscular Dystrophy

PAS, Penetration-Aspiration Scale

PICOS, Population, Intervention, Comparator, Outcome, Study design

PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses

QMUS, Quantitative Muscle Ultrasound

ROC, Receiver Operating Characteristic

RT-MRI, Real-Time Magnetic Resonance Imaging

TT, Tongue Thickness

US, Ultrasound

VFSS, Videofluoroscopic Swallow Study

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Maria Chiara Maccarone, Yannis Dionyssiotis: conceptualization, formal analysis, investigation, writing – original draft preparation. Maria Chiara Maccarone, Nicola Manocchio, Calogero Foti,

Yannis Dionyssiotis: methodology, writing – review and editing. All authors have read and approved the final version of the manuscript.

Conflicts of interest

The authors declare no conflicts of interest.

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Ethics approval

Not applicable.

Availability of data and materials

The data presented in this study are available on request from the corresponding author.

Use of Ai tools

During the preparation of this manuscript, the authors used AI for improvement of readability. The authors reviewed and edited the content modified by the AI tool.

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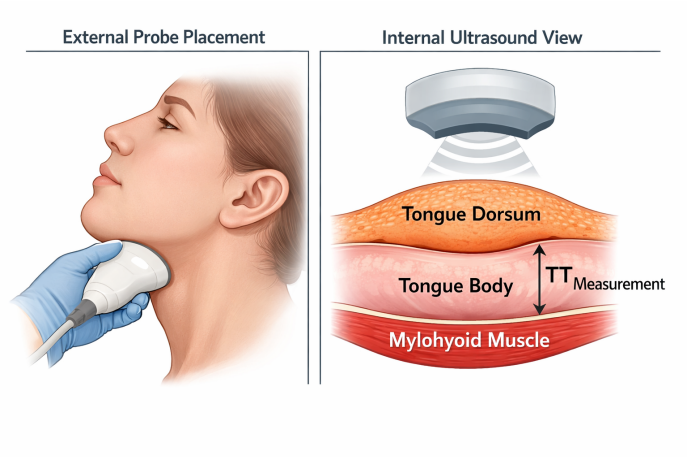


Figure 1. Submental tongue-ultrasound protocol. *Left panel:* external probe placement. *Right panel:* internal anatomical landmarks for tongue-thickness (TT) measurement.

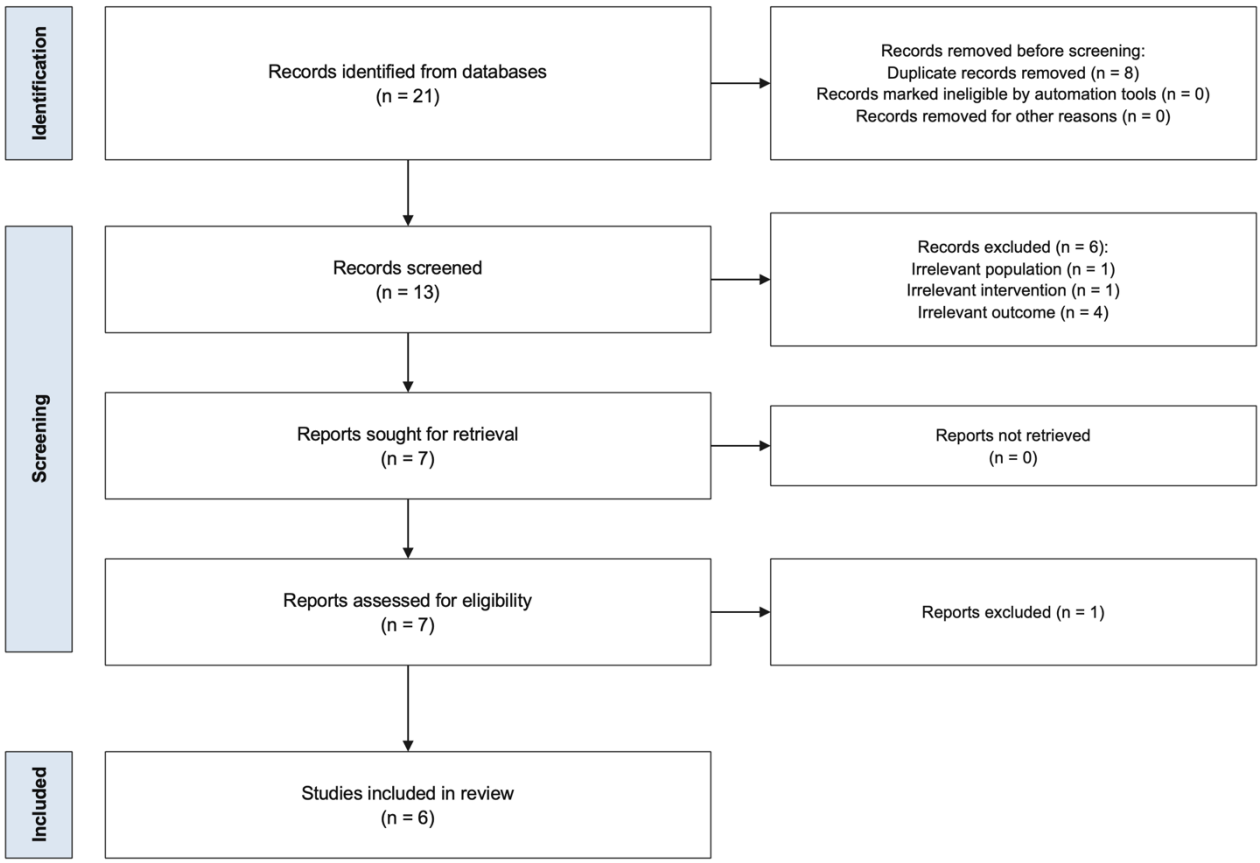


Figure 2. PRISMA 2020 flow diagram of study selection.

Table 1. Methodological quality and risk-of-bias assessment.

Study	Tool	Score	Selection bias	Information bias	Confounding control	Follow-up	Overall
Nakamori et al. (2016)	NOS (case-control)	8/9	Moderate	Low	Moderate-to-high	High	High
Umemoto et al. (2021)	NOS (cohort)	5/9	Moderate	Low	Low-to-moderate	High	Moderate
Augusto et al. (2021)	JBI (cross-sectional)	5/8	Moderate	Low	Moderate	N/A	Moderate
Recasens et al. (2023)	JBI (cross-sectional)	6/8	Moderate	Low-to-moderate	Moderate	N/A	Moderate-to-high
Kim et al. (2026)	JBI (cross-sectional)	5.5/8	High	Low	Moderate	N/A	Low-to-moderate
Zeng et al. (2026)	NOS (cohort)	7/9	Moderate	Low	Moderate-to-high	Moderate	High

NOS, Newcastle-Ottawa Scale; JBI, Joanna Briggs Institute Critical Appraisal Checklist; N/A, not applicable.

Online supplementary materials

Table 1. Characteristics of the included studies.