DOI: *10.4081/aiua.2025.14288*

REVIEW

The association between prediabetes and male sexual dysfunction: An updated meta-analysis

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Summary ***Background: Prediabetes, defined as impaired fasting glucose (IFG) or impaired glucose tolerance (IGT), is recognized as an increasing metabolic disorder globally. Although its vascular and metabolic implications are well established, the link between prediabetes and male sexual dysfunction is uncertain. This meta-analysis was performed to summarize available evidence on the relationship between prediabetes and sexual dysfunction in men.***

Methods: A systematic literature search of PubMed, Embase, and Scopus from inception to July 2025 was undertaken to retrieve observational studies reporting sexual dysfunction outcomes (erectile dysfunction or premature ejaculation) in prediabetic men. The eligibility criteria were adult men with prediabetes and comparative data with normoglycemic controls. Studies were screened by two independent reviewers who also extracted data and evaluated study quality using the Newcastle-Ottawa Scale (NOS). Meta-analysis with random effects model was employed to combine effect sizes and assess heterogeneity on the basis of I^2 statistic. Funnel plots and Egger's test were employed to investigate publication bias. GRADE approach was applied to grade the certainty of the evidence according to risk of bias, inconsistency, indirectness, imprecision, and publication bias.

Results: A total of ten studies with 11,000 participants were available for analysis. Combined odds ratio (OR) of sexual dysfunction in prediabetic men compared to normoglycemic men was 2.50 (95% CI: 1.35-4.64), indicating significant association with high heterogeneity ($I^2 = 87.9\%$, $p < 0.001$). Funnel plot asymmetry was checked by visual inspection and confirmed by Egger's regression test for publication bias, which was not significant ($p = 0.275$). According to GRADE, the quality of evidence was generally low, downgraded for high heterogeneity and imprecision but upgraded for large effect size.

Conclusions: We found that men with prediabetes have approximately 2.5-fold higher odds of sexual dysfunction than men with normoglycemia. Due to the high pooled effect size, although with low certainty of evidence, additional high-quality prospective studies are needed to replicate findings and explore the underlying mechanisms.

KEY WORDS: Prediabetes; Male sexual dysfunction; Erectile dysfunction; Premature ejaculation; Meta-analysis.

Submitted 28 August 2025; Accepted 14 September 2025

INTRODUCTION

Male sexual dysfunction, from a wide range of disorders such as *erectile dysfunction* (ED), *premature ejaculation* (PE), and decreased libido, is highly prevalent and has a severe impact on quality of life (1, 2). The dysfunctions are due to the multifactorial interaction of vascular, neurogenic, hormonal, and psychosocial factors (3). Diabetes mellitus is a recognized risk factor for male sexual dysfunction, particularly ED, due to its deleterious impact on endothelial function, neural integrity, and hormonal control (4, 5). The impact of pre-diabetes, a condition of *impaired fasting glucose* (IFG), *impaired glucose tolerance* (IGT), or HbA1c between 5.7-6.4% according to the *American Diabetes Association* (ADA) criteria (6), on men's sexual health is less clearly understood.

A growing body of literature indicates that even modest rises in blood glucose and concomitant insulin resistance may compromise endothelial function, reduce nitric oxide availability, and encourage neuropathic changes, all of which may contribute to sexual dysfunction prior to the development of overt diabetes (4, 7-10). For example, the evidence from observational research has characterized associations with pre-diabetes and all dimensions of male sexual dysfunction, including ED, as defined by the inability to attain or sustain an erection sufficient for satisfactory performance (11, 12) and PE, as defined by ejaculation that is premature in timing, and usually causing distress (13).

Despite increasing research on this subject, particularly epidemiological studies conducted over the last few years, no comprehensive synthesis has assembled all these findings to describe the overall relationship between pre-diabetes and male sexual dysfunction. Identifying this correlation is crucial for the detection of at-risk men in the early stages and the release of preventive and therapeutic interventions tailored for prediabetic men before they develop symptoms of sexual dysfunction. The systematic review and meta-analysis bridged the knowledge gap and tried to measure the overall correlation between pre-diabetes and male erectile dysfunction, ED, as well as premature ejaculation, PE, among adult men to provide insights into the current evidence to inform clinical practice and research.

Materials and methods

Literature search and study selection

A thorough and systematic literature search was carried out on the main electronic databases, i.e., PubMed, Embase, and Scopus, to identify all the studies relevant to the topic. The search strategy was broadened by using a large number of terms for both prediabetes and erectile dysfunction with the assistance of Boolean operators (\"OR\" and \"AND`). The search strategy combined both free-text keywords and *Medical Subject Headings* (MeSH) terms. Prediabetes was captured using terms such as "prediabetes," "*impaired fasting glucose* (IFG)," and "*impaired glucose tolerance* (IGT)." Sexual dysfunction was captured using terms including "*sexual dysfunction*," "*erectile dysfunction*," and other related concepts such as "*premature ejaculation*". This broadened strategy ensured the inclusion of relevant studies assessing various aspects of sexual dysfunction in individuals with prediabetes. The search was not restricted by language or publication date to include all pertinent articles published up to the date of the search. Search keywords and terms used in various databases are given in Table 1.

Eligibility criteria

Selection of studies for this meta-analysis was done on the basis of a pre-determined set of explicit a priori eligibility criteria in order to incorporate only the most relevant and methodologically sound research. We focused exclusively on observational studies, i.e., case-control, cross-sectional, and cohort designs, examining the association between prediabetes (American diabetes association or WHO criteria) and sexual dysfunction among male adult populations (≥ 18 years). To be considered, a study had to present sufficient data to allow for the calculation of *odds ratios* (ORs) and corresponding *confidence intervals* (CIs). Studies that did not meet these criteria, such as reviews, editorials, case reports, and conference abstracts with no complete data, were systematically excluded.

Additionally, we did not include animal studies or studies that lacked specific and clear-cut definitions for sexual dysfunction and prediabetes.

Screening and selection process

Following the comprehensive literature search, the studies retrieved were screened methodically against the pre-established eligibility criteria. All the records retrieved were first imported into reference management software to remove duplicates and commence the screening process. The titles and abstracts were screened by two independent reviewers to identify the potentially relevant articles. This was followed by a detailed review of the full texts of the articles to determine their ultimate eligibility. Any disagreement between the two reviewers was resolved through discussion and consensus, with the availability of a third reviewer for discussion where needed. This transparent process, which is fully documented in a PRISMA flow diagram, allowed for an open and unbiased determination of studies for meta-analysis.

Data extraction

A systematic and standard approach was used in the extraction of significant data from each qualifying study. Using a pre-designed data extraction form, two reviewers extracted significant study characteristics, including author, year of publication, country of origin, study design, and sample size. Comprehensive information on participant characteristics, including age and definitions of prediabetes and sexual dysfunction, was also recorded to enable detailed analysis. The primary interest of the data extraction was extracting the outcome measures as ORs and their 95% CIs. In cases where studies had not reported these measures, raw data from 2x2 contingency tables were extracted so that the ORs and CIs could be directly calculated, the same way for all the studies included.

Assessment of quality

The *Newcastle-Ottawa Scale* (NOS) was used to assess the methodological quality of included observational studies based on three broad domains: selection of study groups, comparability of groups, and ascertainment of exposure or outcome (14). The selection domain addresses the representativeness of the study sample, the adequacy of case definition (or exposure/outcome measure), and the selection of comparable controls/comparison groups. The com-

Table 1.
Search strategies and key terms used in various databases.

Database	Search strategy
PubMed (via MEDLINE)	(((“prediabetes”[Title/Abstract] OR “pre-diabetes”[Title/Abstract] OR “prediabetic state”[Title/Abstract] OR “borderline diabetes”[Title/Abstract] OR “impaired fasting glucose”[Title/Abstract] OR “impaired glucose tolerance”[Title/Abstract] OR “IFG”[Title/Abstract] OR “IGT”[Title/Abstract]) OR “Prediabetic State”[MeSH]) AND ((“erectile dysfunction”[Title/Abstract] OR “erectile function”[Title/Abstract] OR “sexual dysfunction”[Title/Abstract] OR “sexual function”[Title/Abstract] OR “ED”[Title/Abstract]) OR “Erectile Dysfunction”[MeSH]))
Embase (via Ovid)	(‘prediabetes’/exp OR ‘prediabetes’: ti,ab OR ‘pre-diabetes’: ti,ab OR ‘prediabetic state’: ti,ab OR ‘borderline diabetes’: ti,ab OR ‘impaired fasting glucose’: ti,ab OR ‘impaired glucose tolerance’: ti,ab OR IFG: ti,ab OR IGT: ti,ab) AND (‘erectile dysfunction’/exp OR ‘erectile dysfunction’: ti,ab OR ‘erectile function’: ti,ab OR ‘sexual dysfunction’: ti,ab OR ‘sexual function’: ti,ab OR ED: ti,ab)
Scopus	(TITLE-ABS-KEY(“prediabetes” OR “pre-diabetes” OR “prediabetic state” OR “borderline diabetes” OR “impaired fasting glucose” OR “impaired glucose tolerance” OR “IFG” OR “IGT”)) AND (TITLE-ABS-KEY(“erectile dysfunction” OR “erectile function” OR “sexual dysfunction” OR “sexual function” OR “ED”))

parability domain evaluates if the study controlled for the most important confounders, i.e., age, comorbidities, and other relevant risk factors. The exposure/outcome domain evaluates the ascertainment of exposure (in case-control studies) or outcome (in cohort/cross-sectional studies), the use of validated assessment tools, and whether the follow-up was long enough to determine outcomes. It is attributed a maximum of nine stars in these domains, with higher number of points reflecting greater methodological quality. Quality appraisal was performed independently by two reviewers, and disparities were settled through discussion and agreement. Scores ≥ 7 reflected high quality, 5-6 moderate quality, and < 5 low quality.

Certainty of evidence

The evidence quality in this meta-analysis was assessed strictly using the GRADE (*Grading of Recommendations, Assessment, Development and Evaluations*) method. The method systematically explored the body of evidence in five significant domains for determining confidence in the pooled effect estimate (15). The risk of bias was determined from the methodological quality of the studies included and any recognized design limitations, according to tools like the Newcastle-Ottawa Scale (14).
Inconsistency of results across studies was quantified by evaluating heterogeneity using the I^2 statistic (16).
Furthermore, indirectness of the evidence was ascertained by consideration of how well the populations, exposures, comparators, and outcomes of the studies correspond to the research question under investigation. Imprecision was taken into account by the total sample size and the width of the 95% confidence intervals around the pooled effect measure.
Finally, the potential for publication bias was explored visually through funnel plot symmetry and was confirmed statistically through a formal test, i.e., Egger's test (17, 18).

Statistical analysis

We performed statistical analysis to synthesize the results of the individual studies included in the meta-analysis and provide an overall conclusion regarding the association of prediabetes with sexual dysfunction. We used R statistical software, version 4.2 with appropriate packages such as 'meta' and 'metafor'. 19,20 We calculated pooled *odds ratios* (ORs) with 95% *confidence intervals* (CIs) to predict the overall effect size.

We ran both fixed-effects and random-effects models initially. But because of the huge degree of heterogeneity between the studies, as quantified by the I^2 statistic (greater than 75%), we ultimately reported the results from the more conservative random-effects model, which appropriately accounts for the variability between studies. Statistical heterogeneity, or the degree of inconsistency in the results, was a key consideration. It was formally measured using the I^2 statistic, with a value greater than 75% taken to indicate substantial heterogeneity (16). A Forest plot was constructed to show the individual study results and their contribution to the overall estimate. Furthermore, we searched for evidence of publication bias, the tendency to publish studies with significant or positive results. This was examined both visually, by observing the symmetry of a funnel plot, and statistically, by using Egger's linear regression test (17, 18).

Results

Screening and flow of studies

The PRISMA flow diagram in Figure 1 displays the systematic and rigorous process of study identification and selection for meta-analysis. The search process started with the identification phase, and 687 records were iden-

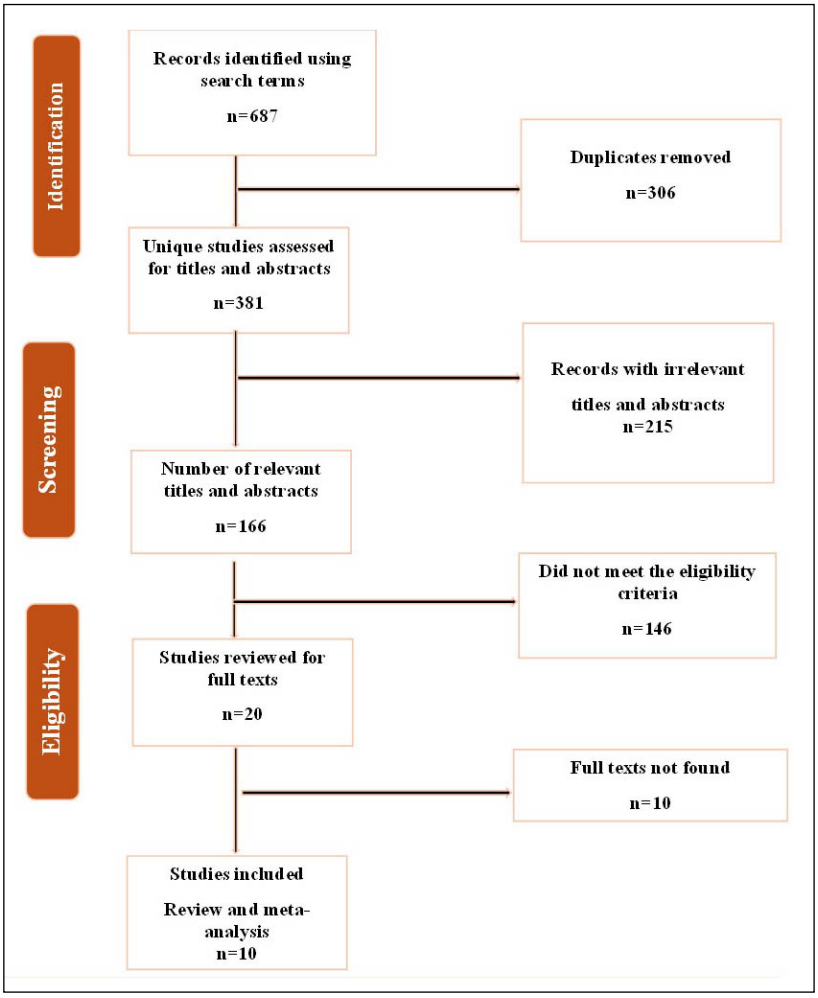


Figure 1.
PRISMA flow diagram exhibiting the flow of screening and identification of studies for the meta-analysis.

Table 2.
Characteristics of studies included in the meta-analysis (n = 10).

Study (year)	Study location	Study design	Sample size	Age (years)	Tools to diagnose pre-diabetes	Outcome measured	Tools to diagnose sexual dysfunction	Sexual dysfunction and Pre-DM	Sexual dysfunction without Pre-DM	Pre-DM without sexual dysfunction	No sexual dysfunction and no Pre-DM
Deutsch et al. 1980 (23)	USA	Case-Control study	183	41.1	Impaired Glucose Tolerance (IGT)	Premature ejaculation	Symptom-based questionnaire	5	64	2	61
Grover et al. 2006 (22)	Canada	Cross-Sectional study	3921	56.7 (40-88)	Impaired Fasting Glucose (IGF)	Erectile dysfunction	International Index of Erectile Function (IIEF) questionnaire	873	1064	681	1303
Corona et al. 2012 (24)	Italy	Cross-Sectional and longitudinal study	3451	57.3 ± 10.1	Impaired Fasting Glucose (IGF)	Erectile dysfunction	Structured Interview on Erectile Dysfunction (SIEDY)	536	1812	123	980
Rabijewski et al. 2015 (25)	Poland	Case-Control study	360	60	IGT or IFG or HbA1c (5.7%-)	Erectile dysfunction	IIEF questionnaire	53	44	123	140
Ettala et al. 2015 (22)	Finland	Cross-Sectional study	926	57	IGT or IFG	Erectile dysfunction	IIEF questionnaire	138	344	91	299
Chen et al. 2017 (26)	China	Case-Control study	1500	45.4	IGT or IFG	Erectile dysfunction	IIEF questionnaire	312	74	688	426
Rajput et al. 2018 (27)	India	Case-Control study	200	46.6	IGT and/or IFG	Erectile dysfunction	IIEF questionnaire	79	58	21	42
Krysiak et al. 2018 (21)	Poland	Case-Control study	67	41 (25-50)	IGT and/or IFG	Erectile dysfunction	IIEF questionnaire	25	2	24	16
Boeri et al. 2018 (28)	Italy	Cross-Sectional study	372	54.8	IGT or IFG or HbA1c (5.7%-)	Erectile dysfunction	IIEF questionnaire	78	225	8	61
Yildiz et al. 2025 (29)	Turkey	Retrospective study	57	18-65	IGT or IFG or HbA1c (5.7%-)	Premature ejaculation	Golombok Rust Scale of Sexual Satisfaction (GRISS)	26	25	4	2

tified. Upon the removal of 306 duplicates, 381 distinct studies were screened by title and abstract. The screening phase identified 166 relevant records, while 215 were irrelevant and therefore excluded. The final eligibility phase involved reading 20 full-text studies, of which 10 were excluded due to failure to meet the eligibility criteria or unavailability of a full-text document. This rigorous process concluded with the inclusion of 10 studies in systematic review and meta-analysis.

Characteristics of studies included in the meta-analysis

As shown in Table 2, ten studies carried out in a variety of countries, including the *USA, Canada, Italy, Poland, Finland, China, India,* and *Turkey,* with a mix of study designs that embraced case-control, cross-sectional, and a single retrospective study. The total number of subjects in all the studies was high, ranging from the lowest sample size of 67 men in *Krysiak et al.*'s study (21) to the highest sample of 3,921 men in *Grover et al.*'s study (22). The age of the subjects ranged from 18 to 65 years, and the mean age ranged from 41.1 to 60 years. Pre-diabetes diagnosis was always based on *impaired fasting glucose* (IFG), *impaired glucose tolerance* (IGT), or HbA1c levels, while sexual dysfunction was diagnosed with the assistance of a variety of tools, predominantly the *International Index of Erectile Function* (IIEF) questionnaire, but also symptom-based and other specialized questionnaires (Table 2).

For example, *Deutsch et al. 1980* used Symptom-based questionnaire to measure sexual dysfunction (premature ejaculation) (23), *Yildiz et al. 2025* used *Golombok Rust Scale of Sexual Satisfaction* (GRISS) scale to measure sexual dysfunction (premature ejaculation) (24). However, other eight studies used IIEF questionnaire to measure sexual dysfunction (erectile dysfunction) as shown in Table 2.

Association between pre-diabetes and male sexual dysfunction

As illustrated in Figure 2, we found a strong and statistically significant association between pre-diabetes and male sexual dysfunction (n = 10 studies). The estimated pooled odds ratio of 2.50, with a 95% CI of [1.35, 4.64], implies that pre-diabetic men are 2.5 times likely to experience sexual dysfunction compared to men without pre-diabetes. The finding on pooled estimate is proven by several individual studies, such as *Chen et al. 2017*, *Rajput et al. 2018*, and *Krysiak et al. 2018*, all of which demonstrate a significant positive association with statistically significant 95% CIs. However, substantial heterogeneity was observed between the studies with I^2 = 87.9%, p value < 0.0001, indicating that the findings vary significantly between individual studies.

Association between pre-diabetes and erectile dysfunction

As shown in Figure 3, The meta-analysis of eight studies concluded that prediabetes is highly correlated with increased erectile dysfunction risk, with prediabetic subjects having almost a threefold increased odds of erectile dysfunction risk over controls (random-effects OR = 2.75,

Figure 2.
Forest Plot depicting association between prediabetes and sexual dysfunction.

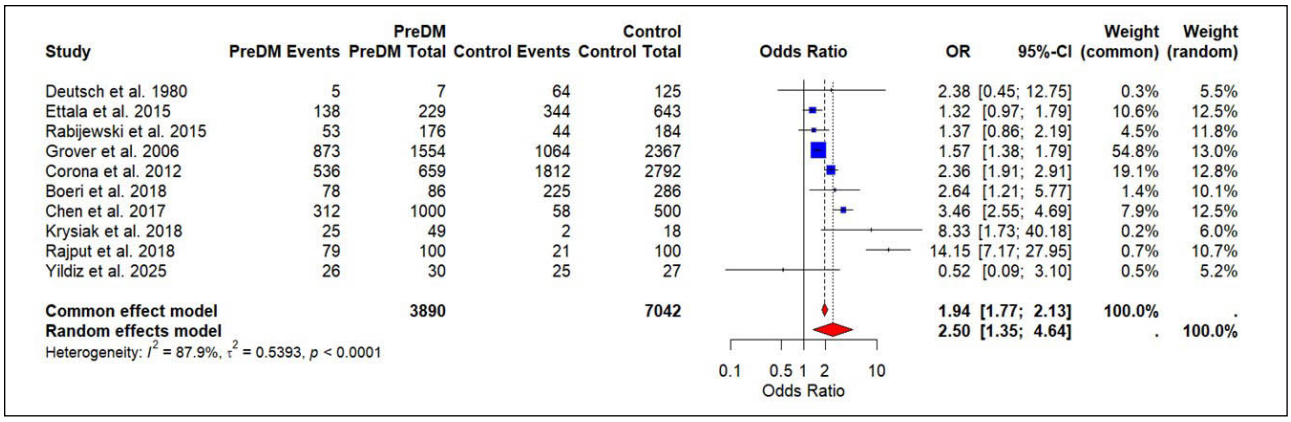
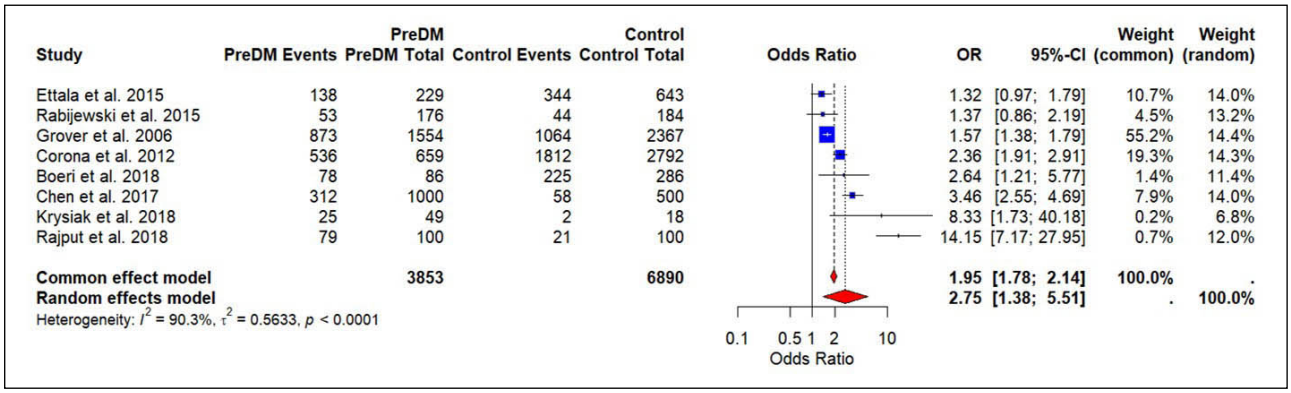


Figure 3.
Forest Plot depicting association between prediabetes and erectile dysfunction.



95% CI: 1.85-5.51). Odds ratios from individual studies varied considerably from 1.32 to 14.15, and while study weights differed, the pooled effect overall uniformly demonstrated increased risk. Substantial heterogeneity was observed (I^2 = 90.3%, p < 0.0001), reflecting differences in study populations and designs, but findings strongly support prediabetes as a distinct risk factor for erectile dysfunction.

Publication Bias

The funnel plot (Figure 4) is a scatter of individual studies, with their effect sizes (odds ratios) on the x-axis and their

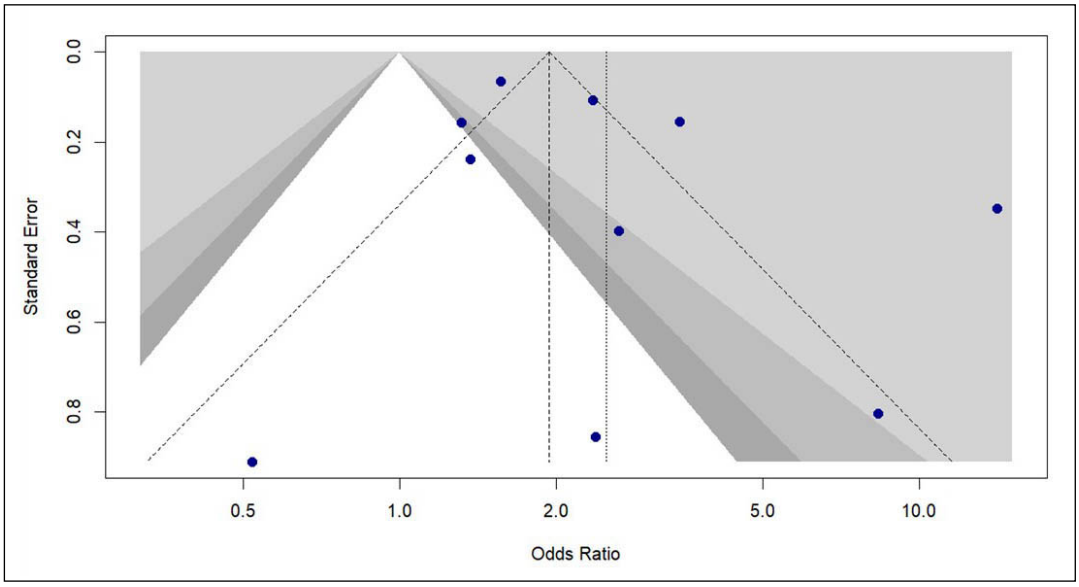


Figure 4.
Funnel Plot illustration for publication Bias.

Table 3.
Newcastle-Ottawa Scale (NOS) quality assessment: Quality assessment of included studies.

Study	Design	Selection	Comparability	Outcome/ Exposure	Final Score	Quality
Deutsch et al. 1980	Case-control	3/4	1/2	2/3	6/9	Moderate
Grover et al. 2006	Cross-sectional	5/5	2/2	3/3	10/10	High
Corona et al. 2012	Cross-sectional/cohort	4/4	2/2	3/3	9/9	High
Rabijewski et al. 2015	Case-control	4/4	2/2	2/3	8/9	High
Ettala et al. 2015	Cross-sectional	4/4	2/2	3/3	9/9	High
Chen et al. 2017	Cross-sectional	4/4	2/2	3/3	9/9	High
Rajput et al. 2018	Case-control	4/4	2/2	3/3	9/9	High
Krysiak et al. 2018	Cross-sectional	4/4	2/2	3/3	9/9	High
Boeri et al. 2018	Cross-sectional	4/4	2/2	3/3	9/9	High
Yildiz et al. 2025	Cross-sectional	3/4	1/2	2/3	6/9	Moderate

Table 4.
Summary of Findings (GRADE).

Exposure and outcome	Studies (participants)	Effect	Certainty of evidence	Meaningful interpretation
Prediabetes and sexual dysfunction (ED/PE) in men	10 studies (~11,000)	OR 2.50 (95% CI 1.35–4.64)	□●●○ Low	Prediabetic men are 2.5 times likely to develop sexual dysfunction than men without pre-diabetes; however, the magnitude of the effect size varies widely across individual studies and 95% CIs indicates imprecise effect size

a. High heterogeneity (I^2 = 87.9%) → downgrade for inconsistency.
b. CI reasonably wide → downgrade for imprecision.
c. Egger's test non-significant despite funnel asymmetry → no downgrade for publication bias.
d. Large effect size (OR > 2) with objective exposure + validated outcomes → upgrade by one level.

precision (standard error) on the y-axis. In the absence of publication bias or small-study effects, one would anticipate a perfectly symmetrical funnel plot, with studies scattering equally around the overall effect. However, the funnel plot in Figure 3 is asymmetric with an empty bottom-left quadrant and studies clustered on the right, suggesting that smaller studies with negative or non-significant results are absent. To formally test this visual impression, we applied a linear regression test for funnel plot asymmetry, also referred to as Egger's test. With a p-value of 0.2752, greater than the conventional significance level of 0.05, the result shows that there is no statistical evidence of asymmetry. While the funnel plot graphically suggests some asymmetry, with a cluster of studies on the right-hand side and a potential gap on the bottom left, the formal statistical test (Egger's test) gives evidence that there is no significant publication bias.

Quality assessment of studies

Based on the *Newcastle-Ottawa Scale* (NOS) quality assessment performed for the included studies, the majority of the studies included in the meta-analysis were high in methodological quality (Table 3). Eight of the ten studies were of high quality with scores between 8/9 and 10/10. All these studies had excellent selection processes, high group comparability, and good exposure and outcome variable ascertainment. The two exceptions to this trend were the *Deutsch et al. 1980* and *Yildiz et al. 2025* trials, which were both rated moderate quality with a score of 6/9 as shown in Table 3. The primary limitations in these two trials were in the selection and comparability domains, respectively. Overall, the summary evidence from the meta-analysis is based on a high-quality studies, strengthening the certainty of evidence.

Certainty of evidence: GRADE tool assessment findings

Final certainty of evidence

The certainty of the evidence for the association between prediabetes and male sexual dysfunction was graded as low using the GRADE approach (Table 4). Although the meta-analysis was statistically significant and the effect size was large (OR 2.50, 95% CI [1.35, 4.64]), confidence is tempered by significant limitations. A substantial heterogeneity (I^2 = 87.9%) implies a greater degree of variability in study settings, methods, and outcome measure evaluations tools or assessments, which decrease consistency of the evidence. Moreover, the less precise 95% CIs may also suggest imprecision, as the true effect size may vary markedly. While we included high-quality of studies, as evaluated by the NOS quality assessment and the magnitude of effect size was also high, the downgrades due to inconsistency and imprecision offset these strengths. Consequently, the pooled evidence can be interpreted as low certainty, representing that while a association between prediabetes and male sexual dysfunction is possible, future well-designed studies with larger sample size and standard outcome measurement tools could substantially change the estimated effect.

Table 5.
GRADE tool assessment findings (Prediabetes and Sexual Dysfunction).

Domain	Judgment	Decision	Rationale
Risk of bias	Not serious	No downgrade	Most studies were of high quality based on the NOS, with clear exposure/outcome definitions and appropriate analytic methods.
Inconsistency	Serious	-1	There was substantial heterogeneity (I^2 = 87.9%, p < 0.0001) in the magnitude of the effect across studies.
Indirectness	Not serious	No downgrade	The population, exposure (prediabetes by FPG/OGTT/HbA1c), and outcomes (validated ED/sexual function tools) align well with the review question.
Imprecision	Serious	-1	The confidence interval was fairly wide (OR 2.50; 95% CI 1.35-4.64), indicating some uncertainty in the exact magnitude of the effect.
Publication bias	Not suspected	No downgrade	The funnel plot was visually asymmetric, but Egger's test was non-significant, providing no statistical evidence of small-study effects.
Other considerations (upgrades)	Large effect	+1	The pooled odds ratio was greater than 2.0, with an objective exposure and validated outcomes, suggesting the large association is unlikely to be fully explained by unmeasured confounding.

Starting level (observational evidence): Low.
Net change: -1 (inconsistency) -1 (imprecision) +1 (large effect) → Overall certainty: Low.
Interpretation: We are confident there is an association, but the true magnitude may differ due to between-study variability and some imprecision.

Details of GRADE assessment: certainty of evidence

As shown in Table 5, based on the GRADE Evidence Profile (Table 5), the certainty of the evidence for the association of prediabetes with sexual dysfunction was downgraded primarily due to two reasons: serious inconsistency between studies, as indicated by a high heterogeneity (I^2 = 87.9%), and imprecision in the overall effect estimate, with the confidence interval being very wide. However, the review did not detect any serious concerns for risk of bias or indirectness because most included studies were of high quality and study populations, exposures, and outcomes all directly aligned with the review question. Additionally, a publication bias was not suspected due to a non-significant Egger's test. The overall evidence received an upgrade for the great pooled effect size (OR > 2.0), which indicates that the relationship between prediabetes and sexual dysfunction is unlikely to be fully explained by unmeasured confounding.

Discussion

This meta-analysis was performed to combine evidence that has been hitherto existing for the association between sexual dysfunction and prediabetes in men. Our systematic and rigorous approach yielded a group of ten observational studies, which collectively demonstrate a strong and positive association between the two conditions. The combined odds ratio of 2.50, with a 95% confidence interval of 1.35 to 4.64, shows that prediabetic men are 2.5 times more likely to have sexual dysfunction than their normoglycemic peers. This result gives strong evidence for the hypothesis that the metabolic and vascular alterations typical of prediabetes are early causes of microvascular complications, such as those involving male sexual health.

Our meta-analysis findings are in agreement with results from prior literature that have examined the relation between sexual health and metabolic disorders (25-27). Low prevalence of both sexual dysfunction and prediabetes in the general population makes clinical significance of such a relation plausible. This meta-analysis not only demonstrates the existence of such a relation but also its magnitude, providing a more robust evidence base for clinical recommendations. The supposed biological mechanisms behind this association are multifaceted and etiology of sexual dysfunction is defined as multifactorial involving a complex interplay of cardiometabolic risk factors rather than simple hyperglycemia, such as central adiposity, insulin resistance, and chronic inflammation (8, 28-31). All these are features of the prediabetic state and are supposed to result in vascular and neurological damage that causes sexual dysfunction. Prediabetes, which is defined as impaired glucose regulation, is a state of chronic low-grade inflammation, oxidative stress, and insulin resistance (32). These factors may lead to endothelial dysfunction (4, 7), with impaired nitric oxide production, an important molecule for smooth muscle relaxation and satisfactory penile blood flow, a important prerequisite for appropriate erectile function (8, 9). Additionally, peripheral neuropathy owing to prediabetes may lead to nerve damage that interrupts the signaling pathways essential for sexual arousal and response (33, 34). The interaction between vascular and neuropathic impairment offers an effective physiological mechanism for developing sexual dysfunction.

Strengths and limitations

Our meta-analysis has many strengths. We performed extensive searching in numerous main databases free from language constraints, minimizing the risk of omitting relevant studies. The use of random effects models adequately dealt with the extensive clinical and methodological heterogeneity among the included studies. Quality of the evidence was a key component of our analysis. Most of the observational studies, included in the meta-analysis, were of high methodological quality, although there were a few studies rated as moderate using

the Newcastle-Ottawa Scale. The strengths commonly observed were clear definition of sexual dysfunction and prediabetes, as well as the use of objective measures.
Despite these strengths, certain limitations must be acknowledged while interpreting the findings. First, we found a substantial heterogeneity between the observational studies, which may be attributed to a variety of factors. First, the studies differed by design (case-control *vs* cross-sectional), patient profile (comorbidities, age), and geographic location, which may result in population differences and lifestyle factors. Second, diagnostic tools for sexual dysfunction as well as prediabetes were not standardized. In spite of the use of validated tools like the IIEF questionnaire by the majority of the studies, heterogeneity may have been caused by differences in small details in diagnostic thresholds and measurement tools. This further highlights the need for standardized diagnostic criteria in future studies to reduce methodological heterogeneity. The high heterogeneity also led to downgrading of the evidence quality by the GRADE approach, which also indicates the significant limitation of the literature currently. In addition, several of the studies were limited by sample representativeness and were more prone to recruiting participants from specialist clinics rather than the general population. While this did not lead to a technical downgrading of the evidence certainty for risk of bias, it is a concern of note when making inferences to the wider population. Second, due to the fact that there were not many included studies, we were not able to perform subgroup analysis because at least ten studies within each subgroup are normally required to give valid results. This was a drawback as it prevented us from investigating whether the association can differ by factors like age, ethnicity, or type of diagnostic tool. Also, despite Egger's regression test for publication bias not being significant, its results must be interpreted with some caution since the test lacks high statistical power if applied to a small number of studies. That is, we cannot reliably conclude that publication bias does not exist.

Clinical implications of findings

The clinical implications of our results are enormous. In light of the commonality of prediabetes, health care professionals ought to appreciate the greater risk of sexual dysfunction among patients who have it. Screening for and controlling prediabetes with lifestyle modifications could be a preventive measure not only against type 2 diabetes but also against sexual dysfunction. The findings provide good reasons for integrating the topic of sexual health into routine clinical practice for prediabetic patients. By early detection of sexual dysfunction, medical practitioners can intervene appropriately, which may improve quality of life and ensure healthier compliance with metabolic control guidelines.

Conclusions

In summary, our meta-analysis provides compelling evidence that prediabetes is strongly linked with heightened risk for male sexual dysfunction. While the overall summary is strong and supported by probable biological mechanisms, the striking amount of heterogeneity across studies implies that there is a need for more uniform research in this area. Future studies must be more uniform in their design, with more attention to prospective designs, in order to acquire more precise knowledge regarding the temporal interaction between sexual dysfunction and prediabetes as well as regarding the effectiveness of early interventions. The findings of this review attest to the merit of a wide-ranging strategy for the management of prediabetes that includes both metabolic control and comorbidities such as sexual health.

Declarations

Ethical approval and consent for participate: *Not applicable.*

Availability of data and material: *All data generated or analyzed during this study are included in the published article.*

Competing interests: *The authors declare that they have no competing interests.*

Funding: *None.*

Authors' contributions: *AEM, and SA, conceptualization; MA methodology; SA, and MA, participated in data collection and investigation. SA, and MA undertook statistical analysis and reporting of results. SA, AEM, and MA wrote the manuscript. All authors have participated in the final revision. AEM review and do the final editing. All authors read and approved the final manuscript.*

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