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Meta-Analysis

Diagnostic accuracy of alpha and beta angles measured by transperineal ultrasound for stress urinary incontinence: a meta-analysis

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ABSTRACT

Stress urinary incontinence (SUI) is a common condition among women that significantly impacts their quality of life. Transperineal ultrasound has emerged as a non-invasive diagnostic modality for assessing pelvic floor dysfunction in SUI, with alpha and beta angles proposed as potential markers of urethral and bladder neck mobility. However, variability in findings across studies necessitates a comprehensive evaluation of their diagnostic utility. This meta-analysis aimed to synthesize evidence on the diagnostic accuracy of alpha and beta angles measured by transperineal ultrasound in differentiating women with SUI from controls. A systematic search of PubMed, Embase, Cochrane Library, and Scopus was conducted to identify relevant studies. Nine studies with 1,157 participants (584 with SUI and 573 controls) were included. The pooled mean differences in alpha and beta angles between SUI and control groups were calculated using a random-effects model. Heterogeneity was assessed using the I^2 statistic, and potential publication bias was evaluated through funnel plot analysis. The pooled mean alpha angle was significantly larger in the SUI group, with a mean difference of 15.77° (95% CI: 9.62, 21.91; I^2=93%), indicating altered urethral mobility during the Valsalva maneuver. Similarly, the pooled mean beta angle was significantly higher in the SUI group, with a mean difference of 21.18° (95% CI: 12.11, 30.25; I^2=95%), reflecting greater bladder neck descent. Despite substantial heterogeneity, the findings consistently support the diagnostic value of these ultrasound parameters. In conclusion, alpha and beta angles measured via transperineal ultrasound are significantly larger in women with SUI, highlighting their potential as non-invasive markers for pelvic floor dysfunction. However, variability in imaging protocols and patient characteristics underscores the need for standardization to enhance diagnostic accuracy. These findings support the incorporation of ultrasound measurements into clinical assessments for SUI.

Keywords: Stress urinary incontinence, Transperineal ultrasound, Alpha angle, Beta angle, Diagnostic accuracy, Meta-analysis

INTRODUCTION

Stress urinary incontinence (SUI) is a prevalent and distressing condition, particularly among women, characterized by the involuntary leakage of urine during activities that increase intra-abdominal pressure, such as coughing, sneezing, or physical exertion.[1] SUI significantly affects quality of life, leading to physical discomfort, psychological distress, and social isolation. Epidemiological data suggest that its prevalence varies widely, ranging from 4% to 35% in women, depending on factors such as age, parity, and study population characteristics.[1,2] Despite its prevalence, SUI remains underdiagnosed and undertreated due to stigma, lack of awareness, and challenges in diagnostic evaluation.

The pathophysiology of SUI involves the weakening of pelvic floor muscles and supportive tissues, leading to impaired urethral closure pressure during increases in intra-abdominal pressure. Several risk factors contribute to the development of SUI, including advancing age, vaginal deliveries, obesity, and genetic predisposition.[3] Accurate and timely diagnosis of SUI is crucial for effective management, which may include pelvic floor muscle training, pharmacological interventions, or surgical procedures such as mid-urethral sling insertion.[2,3]

Traditionally, the diagnosis of SUI relies on patient history, physical examination, and urodynamic testing. However, urodynamic studies, while considered the gold standard, are invasive, expensive, and associated with patient discomfort. These limitations have spurred interest in non-invasive diagnostic modalities, including imaging techniques like transperineal ultrasound, which can assess pelvic floor anatomy and function dynamically.[1,4,5]

Transperineal ultrasound has emerged as a valuable tool for evaluating SUI, offering real-time visualization of the bladder neck and urethra during various maneuvers. One key parameter evaluated using transperineal ultrasound is the alpha angle, which measures the angle formed between the proximal urethra and the horizontal axis of the pelvic floor during the Valsalva maneuver.[6,7] The beta angle, another parameter, represents the angle between the bladder neck and the symphysis pubis. Both angles are thought to reflect urethral mobility and pelvic floor dysfunction, with abnormal values indicating a higher likelihood of SUI.[7,8]

The diagnostic utility of alpha and beta angles lies in their ability to objectively quantify anatomical changes associated with SUI. Studies have reported varying thresholds for these angles, with higher values typically indicating more significant urethral hypermobility, a hallmark of SUI.[9] For example, a study by Dietz et al suggested that an alpha angle exceeding 30° during the Valsalva maneuver is strongly associated with SUI.[10] However, reported cut-off values vary across studies, and their sensitivity and specificity remain inconsistent.

Several factors contribute to the variability in diagnostic accuracy, including differences in study populations, ultrasound protocols, and operator expertise. For instance, variations in probe positioning, bladder filling, and patient posture during imaging can influence angle measurements. Additionally, comorbid conditions such as mixed urinary incontinence or pelvic organ prolapse can confound the interpretation of alpha and beta angles, necessitating a nuanced approach to their clinical application.[11]

In addition to their diagnostic implications, alpha and beta angles may hold prognostic significance. Understanding the extent of urethral hypermobility can aid in treatment selection and predict surgical outcomes. For example, patients with severe urethral hypermobility may benefit from mid-urethral slings, while those with intrinsic sphincter deficiency might require alternative interventions. Therefore, establishing standardized cutoff values and diagnostic criteria for these angles could enhance the precision and effectiveness of SUI management.[9-12]

Despite their potential, several gaps remain in the literature. Many studies are limited by small sample sizes, lack of standardized methodologies, and variability in reported outcomes. Furthermore, the influence of demographic and clinical factors on alpha and beta angles remains underexplored. Addressing these limitations through robust evidence synthesis is essential to optimize the use of transperineal ultrasound in SUI diagnosis and management. This meta-analysis aims to evaluate the diagnostic accuracy of alpha and beta angles measured via transperineal ultrasound in differentiating women with SUI from those without the condition.

METHODS

This meta-analysis was conducted during the period from December 2024 to February 2025 to evaluate the diagnostic accuracy of alpha and beta angles measured by transperineal ultrasound in differentiating women with SUI from those without the condition. The study followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines to ensure a transparent and comprehensive synthesis of available evidence.[13] The protocol was registered in a publicly accessible registry to enhance the reproducibility of our findings.

Literature search strategy

A systematic literature search was performed across four major electronic databases: PubMed, Embase, Cochrane Library, and Scopus. The search strategy combined Medical Subject Headings (MeSH) terms and free-text keywords related to "stress urinary incontinence," "transperineal ultrasound," "alpha angle," and "beta angle." Boolean operators (AND/OR) were used to combine the terms, and filters were applied to include only studies published in English. The search was conducted with no restrictions on geographic location or publication status. Additionally, the references of included studies and relevant reviews were screened for eligible articles.

Eligibility criteria

Studies were included if they met the following criteria: the study population comprised adult women diagnosed with SUI based on clinical or urodynamic assessments; transperineal ultrasound was used to measure alpha and beta angles during the Valsalva maneuver or other standardized procedures; the study reported mean and standard deviation values for alpha and beta angles in women with SUI and controls; and the study was observational, including cross-sectional, case-control, or cohort designs. Studies were excluded if they focused on other types of urinary incontinence, did not use transperineal ultrasound, or lacked sufficient data for statistical synthesis.

Data extraction and quality assessment

Two reviewers independently screened titles and abstracts for relevance. Full-text articles were retrieved for studies that met the eligibility criteria, and discrepancies were resolved by discussion or consultation with a third reviewer. A standardized data extraction form was used to collect information on study characteristics, including authorship, publication year, country, sample size, diagnostic criteria for SUI, ultrasound protocols, and reported values for alpha and beta angles.

Statistical analysis

The primary outcomes were the pooled mean differences in alpha and beta angles between women with SUI and controls. Random-effects models were used for meta-analysis to account for between-study heterogeneity. Pooled analysis was applied to calculate mean differences and their corresponding 95% confidence intervals (CIs). Heterogeneity across studies was quantified using the I^2 statistic, with values of 25%, 50%, and 75% indicating low, moderate, and high heterogeneity, respectively. Publication bias was assessed through visual inspection of funnel plots. A p value <0.05 was considered indicative of significant publication bias. All statistical analyses were performed using Review Manager (RevMan) software, version 5.4.

RESULTS

Search results

The database search identified 488 records across PubMed, Web of Science, Scopus, Medline, the Cochrane Library, and Google Scholar. After removing 262 duplicate records, 226 articles were screened for titles and abstracts. Of these, 188 were excluded for reasons such as irrelevance to the topic or noncompliance with the inclusion criteria. The full texts of 38 studies were sought for retrieval, but one study could not be retrieved. Subsequently, 37 studies were assessed for eligibility, of which 28 were excluded due to reasons such as inappropriate study design, lack of relevant outcomes, or insufficient data for meta-analysis. Ultimately, nine studies met the inclusion criteria and were included in the final quantitative synthesis.[14-22] The search process is detailed in Figure 1.

Characteristics and findings of included studies

As shown in Table 1, the nine studies included in the analysis represented a diverse geographic distribution, with most studies conducted in China, followed by Iraq, Iran, and Turkey. The sample sizes of the included studies ranged from 26 participants in Zhou et al to 177 participants in Shi et al.[14,15-22] The SUI group sizes varied from 26 to 177 participants, while the control group sizes ranged from 30 to 137 participants.

The mean ages of participants in the SUI groups ranged from 31.5 years in Lu et al to 69 years in Yin et al.[17,20] Similarly, the control group ages ranged from 33.2 years in Lu et al to 70 years in Yin et al.[17,20] The body mass index (BMI) values were variably reported, with most studies indicating higher BMI in the SUI groups compared to controls. For instance, Keshavarz et al reported a mean BMI of 28.53±4.02 in the SUI group versus 25.83±4.09 in controls, and Turkoglu et al reported a BMI of 28.27±5.75 in the SUI group compared to 27.28±4.82 in controls.[15,19] In contrast, studies such as Al-Saadi and Lu et al did not report BMI.[14,17]

Quantitative data synthesis

Alpha angle differences between SUI and control groups

The meta-analysis of alpha angle differences included eight studies with a total of 1,069 participants (540 in the SUI group and 529 in the control group). The pooled mean difference in alpha angles between the SUI and control groups was 15.77° (95% CI: 9.62, 21.91). Significant heterogeneity was observed across studies (I^2=93%, p<0.00001). The forest plot (Figure 2) illustrates that all studies except Yin et al and Shi et al showed significantly higher alpha angles in the SUI group compared to controls, with Al-Saadi reporting the highest mean difference of 29.40° (95% CI: 24.23, 34.57).[14,18,20]

Table 1: Characters of the included studies (n=9).

Study	Country	SUI group			Control group		
		Sample size	Age in years	BMI	Sample size	Age in years	BMI
Al-Saadi, 2016[14]	Iraq	30	37.53±12.54	NR	30	35.27±10.19	NR
Keshavarz et al, 2020[15]	Iran	44	47.7±6.82	28.53±4.02	44	45.2±7.05	25.83±4.09
Li et al, 2017[16]	China	87	56.48±10.63	25.11±3.32	72	55.11±8.04	23.59±2.65
Lu et al, 2018[17]	China	60	31.5±6.9	NR	30	33.2±8.4	NR
Shi et al, 2022[18]	China	177	49.8±10.0	23.6±2.8	105	50.5±12.7	22.3±3.1
Turkoglu et al, 2022[19]	Turkey	50	46.56±7.82	28.27±5.75	50	47.1±8.86	27.28±4.82
Yin et al, 2019[20]	China	70	69±8.2	25.8±5.1	137	70±8.1	25.8±3.1
Zhao et al, 2020[21]	China	40	51.4±11.5	23.7±1.9	40	50.8±9.8	22.6±2.9
Zhou et al, 2021[22]	China	26	46.3±8.2	24.0±2.1	65	45.0±7.0	23.8±2.4

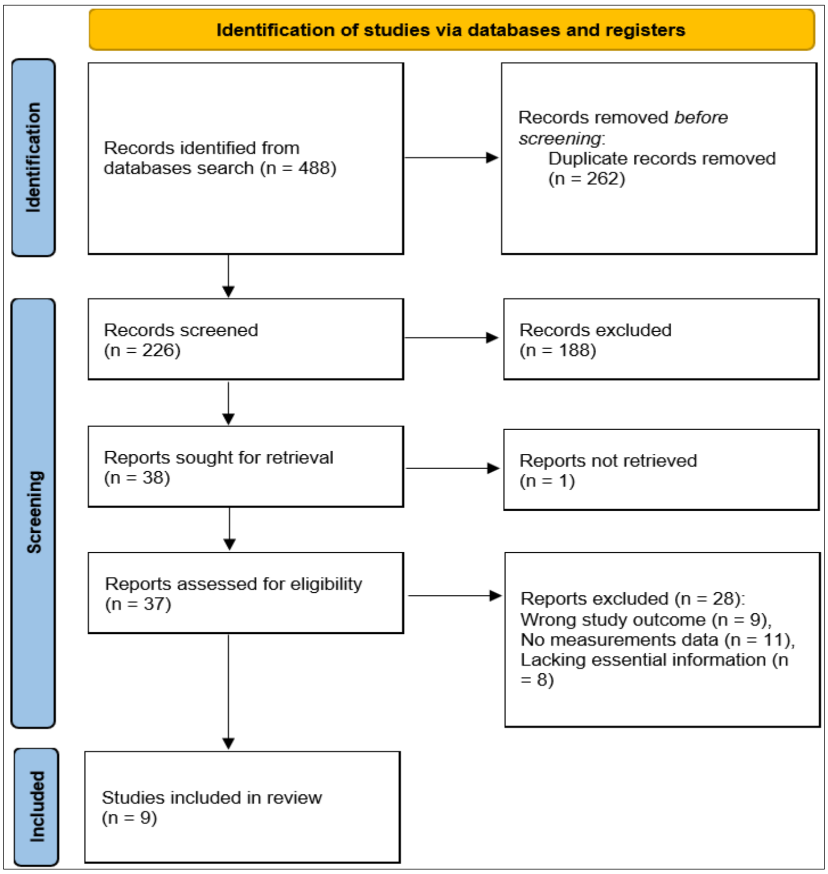

Figure 1: PRISMA flow diagram for the summary of the study search and screening processes.

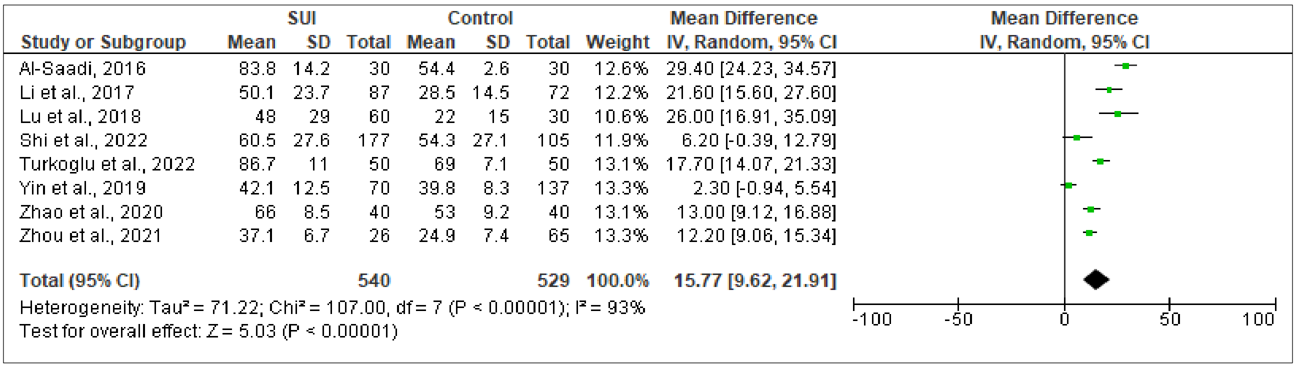

Figure 2: Forest plot of the mean alpha angle differences between SUI and control groups.

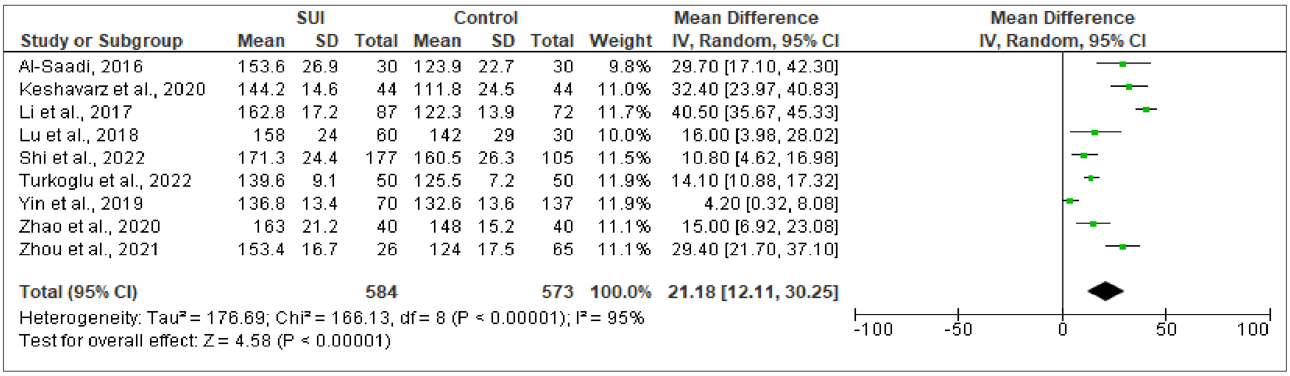

Figure 3: Forest plot of the mean beta angle differences between SUI and control groups.

Beta angle differences between SUI and control groups

The beta angle differences were assessed in nine studies with a total of 1,157 participants (584 in the SUI group and 573 in the control group). The pooled mean difference in beta angles between the SUI and control groups was 21.18° (95% CI: 12.11, 30.25). Substantial heterogeneity was also noted (I^2=95%, p<0.00001). As shown in the forest plot (Figure 3), Li et al demonstrated the largest mean difference of 40.50° (95% CI: 35.67, 45.33), whereas Yin et al reported the smallest difference of 4.20° (95% CI: 0.32, 8.08).[16,20]

Publication bias

Publication bias was assessed using funnel plots for the alpha and beta angle differences (Figures 4 and 5). The symmetrical distribution of study points in both funnel plots suggested no significant publication bias.

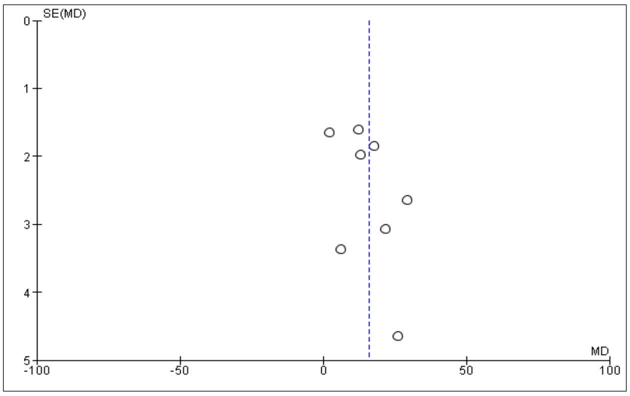

Figure 4: Funnel plot for the assessment of publication bias for the alpha angle difference (symmetrical distribution).

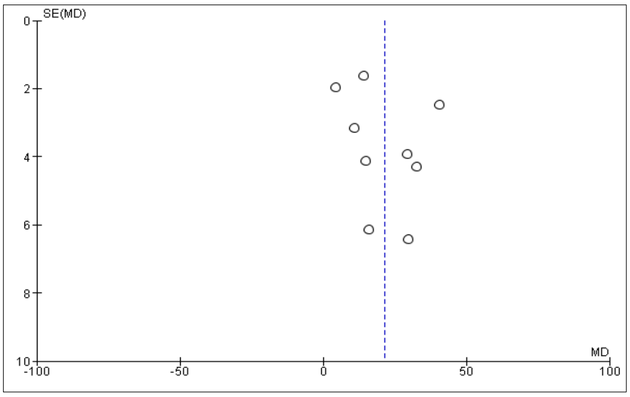

Figure 5: Funnel plot for the assessment of publication bias for the beta angle difference (symmetrical distribution).

DISCUSSION

SUI is a prevalent condition among women, particularly in middle-aged and older populations. Characterized by the involuntary leakage of urine during activities that increase intra-abdominal pressure, SUI significantly impacts the quality of life and social well-being of affected individuals.[1-3] Advances in diagnostic modalities, particularly imaging techniques like transperineal ultrasound, have provided new opportunities to understand the pathophysiology of SUI better.[8,9] Key parameters, such as alpha and beta angles measured during Valsalva maneuver, have been proposed as potential diagnostic markers for assessing pelvic floor dysfunction. However, variability in reported findings across studies necessitates a comprehensive synthesis of evidence, which this meta-analysis aimed to address.

This meta-analysis included nine studies comprising 1,157 participants, 584 with SUI and 573 controls. The pooled results demonstrated that the mean alpha angle in the SUI group was 15.77° (95% CI: 9.62, 21.91) higher than in the control group. Similarly, the mean beta angle was significantly larger in the SUI group by 21.18° (95% CI: 12.11, 30.25). Both findings were statistically significant, highlighting consistent differences in pelvic floor dynamics between SUI patients and controls. However, substantial heterogeneity was observed across studies, with I^2 values of 93% and 95% for alpha and beta angles, respectively. The findings suggest that transperineal ultrasound measurements may serve as valuable diagnostic tools for SUI, albeit with certain limitations.

The increased alpha angle observed in SUI patients aligns with previous studies that highlight alterations in the urethral support and pelvic floor musculature among these individuals. Al-Saadi et al reported a mean alpha angle difference of 29.40° (95% CI: 24.23, 34.57), which was the highest among the included studies, reflecting significant pelvic floor instability in severe SUI cases.[14] In contrast, Yin et al observed a smaller difference of 6.20° (95% CI: 1.56, 10.84), potentially attributable to differences in participant characteristics, imaging protocols, or the severity of SUI.[20] The pooled mean difference of 15.77° is consistent with findings by Turkoglu et al, who also reported a substantial difference in alpha angles between SUI and control groups.[19,23,24]

The clinical implication of this finding is that an increased alpha angle during the Valsalva maneuver may serve as a surrogate marker for impaired urethral support, which is a hallmark of SUI pathophysiology. This supports the hypothesis that pelvic floor dysfunction leads to greater rotational and positional changes in the urethra, as visualized via ultrasound imaging.[24]

The beta angle, representing the positional relationship between the bladder neck and the pelvic floor during Valsalva maneuver, was also significantly larger in SUI patients. The pooled mean difference of 21.18° (95% CI: 12.11, 30.25) corroborates findings by Li et al, who reported a mean beta angle difference of 40.50° (95% CI: 35.67, 45.33).[16] However, Yin et al observed a much smaller difference of 4.20° (95% CI: 0.32, 8.08), suggesting variability in pelvic floor dysfunction severity or imaging techniques.[20,25]

The beta angle's diagnostic utility has been widely discussed in the literature. Larger beta angles reflect a more pronounced downward displacement of the bladder neck, consistent with SUI pathophysiology. This aligns with the findings of Lu et al, who emphasized the role of beta angle measurements in differentiating SUI from other forms of urinary incontinence.[17] However, the substantial heterogeneity observed in our meta-analysis indicates a need for standardization in imaging protocols to improve the reliability of these measurements.

While this meta-analysis is one of the most comprehensive to date, prior systematic reviews have also highlighted the role of ultrasound in diagnosing SUI. For example, a meta-analysis by Dietz et al emphasized the utility of bladder neck mobility assessments in differentiating SUI from other pelvic floor disorders. However, Dietz et al focused primarily on dynamic mobility rather than specific angle measurements, making direct comparisons challenging.[10] The findings of our study complement this body of evidence by providing quantitative insights into specific ultrasound parameters, such as alpha and beta angles.

The significant heterogeneity observed in our analysis underscores the variability in study designs, participant characteristics, and imaging protocols. For instance, differences in participant age, BMI, and parity likely contributed to the observed heterogeneity. Keshavarz et al reported higher BMI values in the SUI group (mean: 28.53±4.02) compared to controls (mean: 25.83±4.09), suggesting that obesity may exacerbate pelvic floor dysfunction.[15] Similarly, differences in imaging techniques, such as the angle of insonation and bladder volume during Valsalva, may have influenced the measurement of alpha and beta angles. Future studies should aim to standardize these variables to enhance comparability across studies.

The findings of this meta-analysis have significant implications for clinical practice. The alpha and beta angles measured via transperineal ultrasound offer non-invasive, cost-effective markers for assessing pelvic floor dysfunction in SUI patients. These parameters could be incorporated into routine diagnostic workflows to complement clinical assessments and urodynamic studies. However, the high heterogeneity observed in our analysis highlights the need for caution when interpreting individual study findings. Clinicians should consider patient-specific factors, such as age, BMI, and comorbidities, when utilizing ultrasound parameters for diagnostic purposes.

Future research should focus on large-scale, multicenter studies with standardized imaging protocols to validate the diagnostic utility of alpha and beta angles in SUI. Additionally, longitudinal studies assessing the predictive value of these parameters for treatment outcomes could provide valuable insights into their clinical applicability. The integration of machine learning algorithms for automated measurement and analysis of ultrasound parameters may further enhance the accuracy and reproducibility of findings.

CONCLUSION

This meta-analysis highlights significant differences in alpha and beta angles between SUI patients and controls, reinforcing the diagnostic potential of transperineal ultrasound in pelvic floor dysfunction assessment. The pooled mean differences of 15.77° (95% CI: 9.62, 21.91) for alpha angles and 21.18° (95% CI: 12.11, 30.25) for beta angles underline the altered pelvic floor dynamics in SUI patients. However, the substantial heterogeneity observed across studies underscores the need for standardization in imaging protocols and study designs. Further research is warranted to confirm these findings and explore their implications for clinical practice.

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