Efficacy of Electromyographic Biofeedback for Dysfunctional Voiding in Children and Adolescents: A Systematic Review and Meta-analysis of Randomized Trials

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OBJECTIVE To assess the efficacy of electromyographic biofeedback (EMGBF) in the treatment of dysfunctional voiding (DV) in children and adolescents by synthesizing evidence from randomized controlled trials.

METHODS We conducted a systematic review and meta-analysis of randomized and controlled trials evaluating EMGBF therapy in pediatric patients diagnosed with DV. Searches were performed across seven databases (Cochrane Central Register of Controlled Trials, PubMed/MEDLINE, EMBASE, Scopus, Web of Science, Livivo, and LILACS) up to January 2025. Gray literature was also searched using Google Scholar, ProQuest, and medRxiv.

RESULTS Four randomized controlled trials were included, totaling 244 patients. The meta-analysis showed that EMGBF therapy significantly increased maximum urinary flow rate (MD: 4.69; 95% CI: 1.06-8.31), normalized voiding flow patterns (RR: 2.70; 95% CI: 1.43-5.10), reduced postvoid residual urine (MD: 11.11; 95% CI: 2.38-19.84), and improved enuresis (RR: 2.34; 95% CI: 1.05-5.20). Additionally, a subset of 17 patients with vesicoureteral reflux (VUR) was evaluated. Among those who underwent EMGBF, VUR resolution was observed in all but one patient with grade IV reflux. Reported resolution rates were 88.8% at 6 months and 77.7% at 1 year in the intervention group, compared with 37.5% and 12.5%, respectively, in the control group. However, these findings should be interpreted with caution given the limited number of patients and lack of randomization for VUR-specific outcomes.

CONCLUSION EMGBF is an effective and well-tolerated intervention for treating dysfunctional voiding in children and adolescents. Benefits include improvements in urinary symptoms, urodynamic parameters, and infection rates. Although preliminary findings suggest a possible positive effect on VUR, further high-quality trials are warranted to confirm these observations and to optimize therapeutic protocols. UROLOGY 206: 114–120, 2025.

Dysfunctional voiding (DV) is a common cause of lower urinary tract dysfunction (LUTD) in children and adolescents. The International Children's Continence Society (ICCS) terminology document defines a child with dysfunctional voiding as one who "habitually contracts the urethral sphincter during voiding" and goes on to state that the term should be used only if repeated uroflow measurements show a staccato pattern or unless verified by urodynamics.[1] It often presents with symptoms such as urinary urgency, urinary incontinence, recurrent urinary tract infections (UTIs), and constipation, with potential long-term consequences including upper urinary tract damage and vesicoureteral reflux (VUR).[2-5]

There is possible evidence that DV can cause secondary VUR. Studies have shown that failure to address underlying voiding dysfunction can lead to unsuccessful or recurrent reflux after surgical reimplantation.[6-8]

Conservative management for DV typically begins with standard urotherapy, including education,

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behavioral modification, and regular voiding schedules. Electromyographic biofeedback (EMG BF) has emerged as a noninvasive, adjunctive therapy aiming to re-establish coordinated voiding through visual or auditory feedback. BF systems mostly involve training through computer animation games. Children move objects on the screen (such as dolphins, birds, and monkeys) by relaxing and contracting their pelvic floor muscles. The actions in the game represent an appropriate muscle response. To complete the game, children must tighten and relax their pelvic floor muscles when urinating in a controlled manner according to the instructions of the animated game.[9-11] Despite its growing use, evidence for its efficacy remains inconclusive due to methodological heterogeneity across studies.

This systematic review and meta-analysis aimed to access the efficacy of EMG BF in children and adolescents with DV, focusing on both clinical and urodynamic outcomes using only randomized controlled trials (RCTs) that adhere to International Children's Continence Society (ICCS) diagnostic criteria.[1]

METHODS

This systematic review and meta-analysis were conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 guidelines and was registered on the PROSPERO database (International Systematic Review Registry): CRD42020212463.[12] The review protocol was developed a priori to evaluate the efficacy of electromyographic biofeedback (EMG BF) therapy in pediatric patients with dysfunctional voiding (DV).

Eligibility Criteria

We included randomized controlled trials (RCTs) involving children and adolescents (< 18 years) with DV who received EMG BF therapy. Eligible studies were required to use uroflowmetry for the diagnosis of DV, in accordance with the International Children's Continence Society (ICCS) criteria.[1] Studies were excluded if they: (1) were nonrandomized or observational; (2) did not evaluate EMG BF as an intervention; or (3) included mixed populations without isolated DV analysis.

Information Sources and Search Strategy

A comprehensive literature search was conducted across seven electronic databases - PubMed, Embase, Scopus, Cochrane Library, Web of Science, Lilacs, and Livivo - from inception to January 2025. Additional sources included gray literature databases (Google Scholar, ProQuest, and medRxiv) and reference lists of relevant studies. Search terms included combinations of "biofeedback," "electromyography," "dysfunctional voiding," and "children." Details of the search and selection process are presented in the PRISMA 2020 flow diagram (Fig. 1).

Study Selection and Data Extraction

After duplicate removal, two independent reviewers screened titles and abstracts for eligibility. Full texts of potentially eligible articles were then reviewed. Discrepancies were resolved through discussion or by consulting a third reviewer. Extracted data included study design, sample size, participant characteristics, intervention protocols, outcome measures, and main results. A summary of the included studies is presented in Table 1 (Fig. 2).

Outcomes Assessed

Primary outcomes included improvement in uroflowmetry parameters such as increase maximum urinary flow rate, normalization of voiding pattern, and reduction in postvoid residual (PVR) volume. Secondary outcomes included reduction in the incidence of urinary tract infection (UTI) episodes and resolution or improvement of clinical symptoms such as daytime urinary incontinence and enuresis.

Risk of Bias Assessment

Risk of bias was assessed using the Cochrane Risk of Bias Tool, evaluating seven domains: sequence generation, allocation concealment, blinding, incomplete outcome data, selective reporting, and other biases. All four included RCTs were judged to have an overall low risk of bias. However, all exhibited high performance bias due to the lack of participant and personnel blinding. Allocation concealment and detection bias were judged as unclear in some studies (Fig. 3).

Statistical Analysis

Where data were suitable, meta-analysis were performed using a random-effects model. Mean differences (MDs) were calculated for continuous outcome and risk ratios (RRs) for dichotomous outcomes, with 95% confidence intervals (CIs). Statistical heterogeneity was assessed using the I^2 statistic, with $I^2 > 50\%$ considered substantial.

RESULTS

Study Selection

A total of 4.982 records were retrieved through database searches with 3.042 remaining after duplicate removal. After screening titles and abstracts, 27 articles were selected for full-text review, of which 23 were excluded for not meeting the inclusion criteria. An additional 355 records were identified through gray literature, from which 11 full-text articles were assessed but none were eligible. Four randomized controlled trials met all eligibility criteria and were included in the qualitative and quantitative synthesis (Fig. 1).

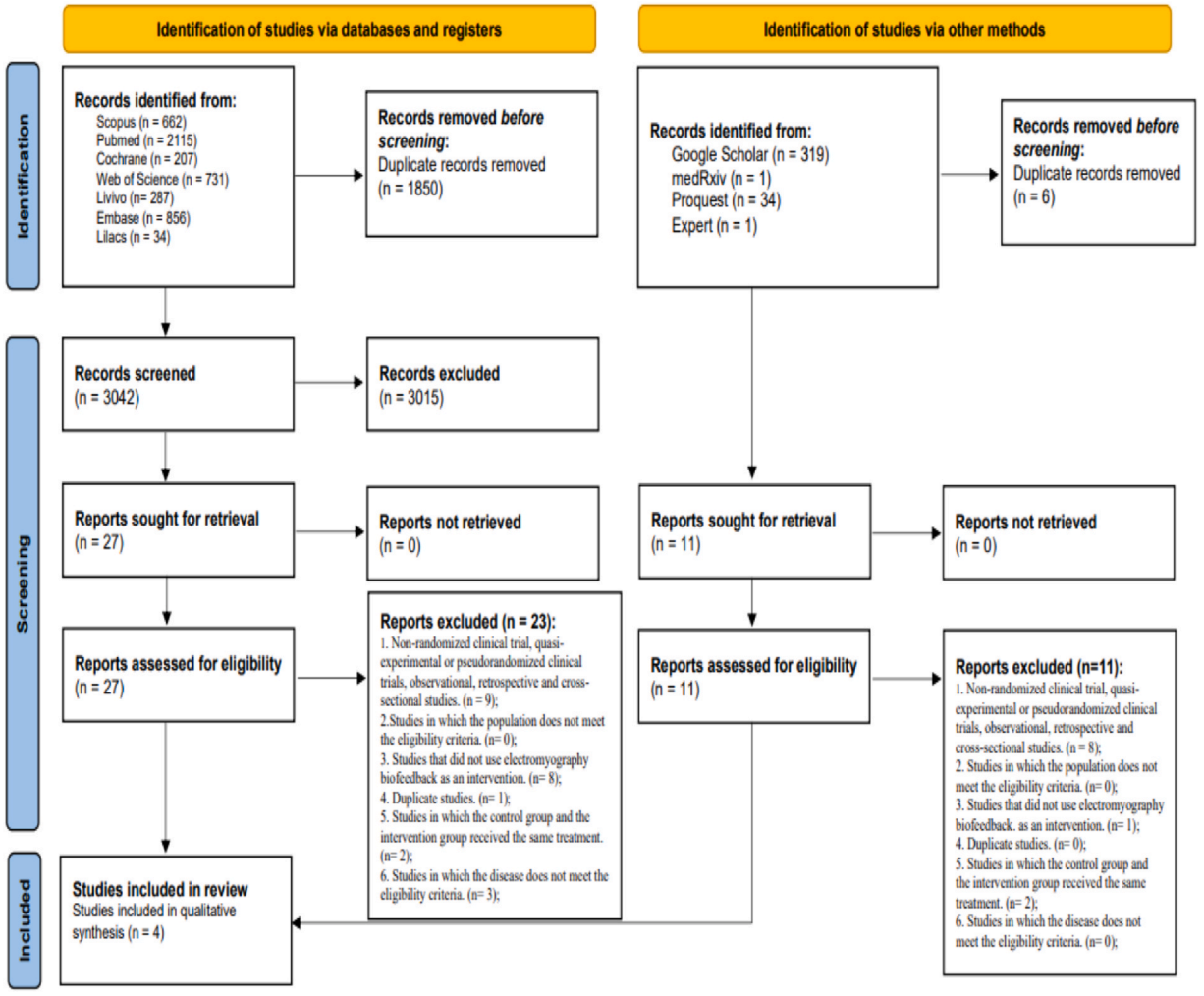

Figure 1. Flow diagram of literature search and selection criteria.

Studies	Designs	Diagnosis	Diagnostic tool	Total (M/F)	EG (M/F)	CG (M/F)	Age range
Kajbafzadeh et al. 2011	RCT	DV VUR	Uroflowmetry EMG	80 (18/62)	40 (8/32)	40 (10/30)	5-16
Kibar et al. 2010	RCT	DV	Uroflowmetry EMG	94 (28/66)	62 (21/41)	32 (7/25)	5-15
Ladi-Seyedian et al. 2020	RCT	DV Hydronephrosis	Uroflowmetry EMG	57 (21/36)	29 (10/19)	28 (11/17)	5-13
Reis et al. 2019	RCT	DV	Uroflowmetry	14 (7/7)	10 (4/6)	4 (3/1)	5-16

Notes: RCT: randomized controlled trial, DV: dysfunctional voiding, VUR: vesicoureteral reflux, EMG: electromyography.

Figure 2. Table 1. Characteristic of included studies.

Study Characteristics

The included RCTs were conducted in Turkey, Brazil, and Iran, published between 2010 and 2020, and involved a total of 244 patients (171 girls and 73 boys), with a mean age of 8 years (range: 5-16 years). All studies employed uroflowmetry-based diagnostic criteria for DV, in accordance with ICCS guidelines (Table 1 – Fig. 2). Control groups received standard urotherapy, while intervention groups received EMG BF, often combined with pelvic floor muscle training (PFMT). The frequency of EMG BF sessions varied from 6 to 20, administered once or twice per week, with total treatment durations ranging from 3 weeks to 6 months (Table 2 – Fig. 4).

Postvoid Residual Volume (PVR)

PVR was assessed in three RCTs, including a total of 230 children. At 6 months, a significant reduction in mean residual volume was observed in the EMG BF

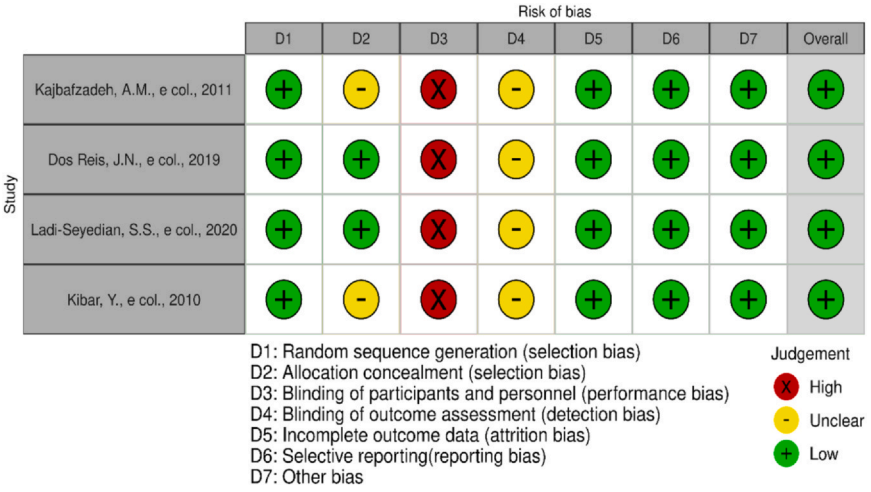

Figure 3. Risk of bias assessment of the included randomized controlled trials using the Cochrane Risk Tool.

Studies	Type of BF	Intervention		Frequency	Course of Treatment	Follow up
		EG	CG			
Kajbafzadeh et al. 2011	ABF EMG	BF + PFMT + SUT	SUT	Twice a week PFMT: 30 min a day	3 weeks - 6 weeks	1 year
Kibar et al. 2010	BF EMG	BF + SUT	SUT	N	N	6 months
Ladi-Seyedian et al. 2020	ABF EMG	BF + PFMT + SUT	SUT	Once a week PFMT: 15 min a day	10 weeks - 15 weeks	1 year
Reis et al. 2019	ABF EMG	BF + SUT	SUT + ES	Twice a week	5 weeks - 10 weeks	6 months

Notes: ABF: animated biofeedback, BF: biofeedback, EMG: electromyography, SUT: standard urotherapy, PFMT: pelvic floor muscle training, ES: electrical stimulation, N: not informed

Figure 4. Table 2. Intervention methods and evaluation time of the included studies.

group compared to controls (MD: 11.11 mL; 95% CI: 2.38-19.94; I^2 = 73%). However, no statistically significant difference was found at 12 months (MD: 9.91 mL; 95% CI: –1.09 to 20.91; I^2 = 82%). Overall, EMG BF appears to reduce PVR in children with DV[13-15] (Supplementary Fig. 1).

Abnormal Voiding Pattern

All four RCTs assessed abnormal voiding pattern, including 244 patients in the meta-analysis. After 6 months, EMG BF significantly increased the likelihood of normalization (RR: 1.60; 95% CI: 1.02-2.50; I^2 = 81%). At 12 months, this benefit was more pronounced (RR: 2.70; 95% CI: 1.43-5.10; I^2 = 63%) despite moderate heterogeneity[13-16] (Supplementary Fig. 2).

Enuresis

Enuresis was evaluated in three RCTs, involving 43 patients in the meta-analysis. At 6 months, no significant difference was observed between groups (RR: 1.31; 95% CI: 0.73-2.35; I^2 = 36%). At 12 months, however, EMG BF demonstrated a significant benefit (RR: 2.34; 95% CI: 1.05-5.20; I^2 = 0%)[13,14,16] (Supplementary Fig. 3).

Maximum Urinary Flow Rate

All Three RCTs assessed maximum urinary flow rate in a total of 230 children. At 6 months, no significant difference was detected (MD: 2.24 mL/s; 95% CI: –1.44 to 5.93; I^2 = 80%). However, at 12 months, EMG BF significantly increased maximum flow rate compared to controls (MD: 4.69 mL/s; 95% CI: 1.06-8.31; I^2 = 58%)[13-15] (Supplementary Fig. 4).

Urinary Tract Infections (UTIs)

UTI incidence was assessed in four RCTs, including 86 patients in meta-analysis. No significant difference was found between groups at either 6 months (RR: 1.22; 95% CI: 0.94-1.59; I^2 = 0%) or 12 months (RR: 1.68; 95% CI: 0.81-3.45; I^2 = 45%).[13-16] These findings suggest that EMG BF may have limited effect on reducing UTI incidence (Supplementary Fig. 5).

Daytime Urinary Incontinence (DUI)

Daytime urinary incontinence was assessed in three RCTs including 55 patients. At 6 months, no significant difference was observed between groups (RR: 1.17; 95% CI: 0.83-1.66; I^2 = 38%), (RR: 1.48; 95% CI: 0.51-4.30; I^2 = 72%). Heterogeneity was moderate to substantial.

Overall, EMG BF did not appear to have a significant impact on DUI outcomes[13,14,16] (Supplementary Fig. 6).

Certainty of the Evidence

The certainty of the evidence was rated as high for normalization of voiding pattern and maximum urinary flow rate, moderate for enuresis resolution, PVR reduction, and UTI incidence, and low for daytime urinary incontinence. Downgrades were mainly due to clinical heterogeneity and wide confidence intervals across studies.

DISCUSSION

This systematic review and meta-analysis included four randomized controlled trials involving 244 patients diagnosed with dysfunctional voiding (DV) who were treated with electromyographic biofeedback (EMG BF). The primary objective was to assess the efficacy of EMG BF therapy in improving clinical and functional outcomes compared to standard urotherapy or other conservative treatments.

Postvoid residual (PVR) volume showed a trend toward reduction in the short term and became statistically significant at 12 months (MD = 11.11 mL), although moderate heterogeneity remained (Supplementary Fig. 1). These findings suggests that the therapeutic effects of EMG BF may consolidate over time, supporting its use in the long-term management of DV.

A consistent finding across studies was the improvement in voiding function, evidenced by a significant increase in normalization of voiding pattern in the EMG BF group compared to control at both 6 months (RR = 1.60) and 12 months (RR = 2.70), with a high certainty of evidence (Supplementary Fig. 2).

Enuresis resolution did not significantly differ between groups at 6 months, but a significant benefit was observed at 12 months (RR = 2.34), indicating that extended therapy duration may be necessary (Supplementary Fig. 3). Similarly, maximum urinary flow rate improved significantly at 12 months (MD = 4.69 mL/s), reinforcing the physiological benefit of EMG BF through improved pelvic floor coordination (Supplementary Fig. 4).

In contrast, urinary tract infection (UTI) and daytime urinary incontinence rates showed no significant differences between groups. The certainty of evidence for these outcomes was rated as moderate and low, respectively, due to clinical heterogeneity and wide confidence intervals (Supplementary Figs. 5 and 6). These symptoms are likely influenced by multifactorial etiologies beyond the scope of EMG BF alone.

One of the most striking findings was the impact of EMG BF on VUR resolution. In the study by Kajbafzadeh et al, 88.8% of children with VUR in the intervention group achieved resolution at 6 months, vs only 37.5% in the control group.[13] This supports the hypothesis that correcting dysfunction voiding may improve or eliminate secondary VUR in select populations.

Hydronephrosis was assessed in one RCT, with resolution observed in 71.4% of patients in the EMG BF group vs 42.8% in controls group, at 6 months, and sustained in 61% vs 28.5% at 12 months.[14]

Bladder capacity, assessed in two RCTs, reported a significant short-term improvement in the EMG BF group, which was not sustained at 12 months.[13] Kajbafzadeh et al also reported a significant reduction in voiding time in the EMG BF group, with persistent improvement over time. Short-term increases in voided volume were observed in three RCTs.[13–15]

Urgency was included as an outcome in two studies, with resolution in 88% of patients in one EMG BF group.[13,16] DVSS scores showed more substantial reductions in the EMG BF group, although not always statistically significant across trials.[13,16] EMG activity during voiding was assessed in three RCTs, with greater resolution in the intervention group over time.[13,14]

The intervention protocols differed in frequency, duration, and inclusion of pelvic floor muscle training (PFMT). This training incorporated Kegel exercises, postural awareness, abdominal pattern recognition, and breath–pelvic floor coordination. Despite this variability, EMG BF consistently demonstrated clinical and functional benefits in DV management.

However, the independent effect of EMG BF remains unclear due to the frequent combination with PFMT and urotherapy. For example, Fazeli et al found no significant differences in key outcomes, suggesting limited benefit of BF as an isolated adjunct.[17] In contrast, a previous meta-analysis by Qi et al reported favorable outcomes for BF in improving multiple DV-related parameters,[18] though methodological limitations such as inclusion of retrospective studies and mixed intervention groups weaken its conclusions.

Compared to previous reviews, our study is distinguished by strict eligibility criteria, including only RCTs that used uroflowmetry-based DV diagnosis in accordance with ICCS guidelines.[1] This methodological rigor enhances internal validity and clinical applicability.

Nonetheless, the limited number of eligible trials, small sample sizes, and intervention heterogeneity remain important challenges. The GRADE summary reflects this, with high certainty for objective outcomes like uroflowmetry normalization, but lower certainty for subjective outcomes such as daytime incontinence and UTIs. These findings reinforce the need for standardized protocols and better-designed studies in future research.

LIMITATIONS

This review has several limitations. First, only four randomized controlled trials met the strict inclusion criteria, limiting the sample size and statistical power. Second, there was considerable heterogeneity in patient

demographics, intervention protocols (eg, session frequency, duration), and outcome definitions, reflected in moderate to high I^2 values in several analyses. A third limitation is the lack of standardized EMG BF protocols across studies. Despite these issues, all included studies met rigorous diagnostic criteria for DV, increasing the reliability and relevance of the findings.

CONCLUSION

Electromyographic biofeedback (EMG BF) therapy appears to be a promising noninvasive intervention for children and adolescents with dysfunctional voiding, with demonstrated benefits in objective urodynamic outcomes (eg, flow patterns, maximum urinary flow rate, and postvoid residual volume) and some subjective symptoms (eg, urgency, enuresis). However, current evidence does not support significant benefits in treating daytime urinary incontinence or reducing UTIs. Preliminary evidence suggests that correcting DV may contribute to VUR resolution in selected cases, but this requires cautious interpretation and further investigation. Larger, multicenter randomized controlled trials with standardized EMG BF protocols are needed to confirm these findings and define the role of biofeedback in pediatric lower urinary tract dysfunction.

Disclosures

This research received no external funding.

Ethical Declaration

This study is a systematic review and meta-analysis of previously published data. Ethical approval and informed consent were not required.

CRediT Authorship Contribution Statement

Carla Labonia Passos: Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Maria Beatriz Mendes Souza**: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Mila Torii Corrêa Leite**: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Bruna Cecilia Nunes Carvalho**: Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Humberto Saconato**: Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Luiz G. Freitas Filho**: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Data Availability

All data supporting the findings of this study are included in the manuscript and supplementary materials. Additional details are available from the corresponding author upon reasonable request.

Declaration of Competing Interest

The authors have no conflict of interest to declare.

Appendix A. Supporting Information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.urology.2025.08.046.

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