Research Article

Efficacy Of High Tone Power Therapy Combined With A Targeted Physical Therapy Program For Overactive Bladder In People With Multiple Sclerosis: A Randomized Controlled Trial

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Abstract:

Objective: Overactive bladder (OAB) is a predominant urinary tract disorder in people with multiple sclerosis (PwMS). We sought to assess the therapeutic effects for high tone therapy (HTT) in treatment of OAB symptoms and quality of life (QOL) in PwMS.
Methods: A prospective, randomized controlled study included forty remitting relapsing MS patients of both sexes (RRMS) with moderate OAB symptoms were randomly allocated into 2 equal groups: The treatment group (GA) received HTT + targeted physical therapy program.; and the control group (GB) received targeted physical therapy program only. The intervention session in each group was conducted for 60 minutes, 3 times per week for 3 months. Pre and post treatment evaluation was done for all patients including Urodynamic study (bladder capacity, maximum urine flow rate (Qmax), bladder compliance and detrusor activity) for bladder function, Overactive bladder symptom (OABS) score for severity of the bladder symptoms and International Consultation on Incontinence-Overactive Bladder Module (ICIQ-OAB) for QOL.
Results: Post intervention, there were statistically significant differences between both groups in OABS score, ICIQ-OAB, bladder capacity, detrusor activity, and bladder compliance with more favor to GA ($P < 0.01$); while there was no significant difference in voiding function between both groups ($p > 0.05$)**.**
Conclusions: Adding application of HTT to rehabilitation can improve bladder symptoms and QOL in PwMS

Key words: Bladder Function, Quality of Life, Urgency, Urodynamic Studies.

INTRODUCTION:

Multiple sclerosis (MS) is a persistent immune-related neuro-inflammatory, demyelinating disease of the CNS associated with persistent axonal injury [1]**.** It is among the leading causes of non-traumatic impairments among youths, predominately aged 20 to 40 [2]. The epidemiology of MS exhibits considerable geographic, demographic, and ethnic heterogeneity. Globally, around 2.8 million people are living with MS. The largest burden rates have been reported in temperature regions, particularly in Northern Europe, North America, and Australia, where the prevalence ranges from approximately 100 to 200 cases per 100.000 population [3]**.** In Egypt, a nationwide study approved that prevalence of MS to be around 25 cases per 100.000 population, highlighting the growing burden of the disease within the Egyptian community [4]**.**
In addition to the neurological manifestations of MS, it is frequently associated with bladder dysfunctions, which are among the most prevalent and distressing non-motor complications of the disease. Approximately 75 – 90 % of people with MS experience bladder dysfunction during the course of the disease. These symptoms substantially impair quality of live (QOL) and negatively affect overall life satisfaction [5.]
Overactive bladder (OAB) is a predominant urinary tract dysfunction in PwMS. It is characterized by compelling need to void, typically associated with frequent diurnal voiding and nocturia with or without urgency and is associated with diverse urodynamic abnormalities. Furthermore, many patients experience voiding symptoms, including hesitancy, urinary retention, and sensation of incomplete bladder emptying [6]**.**
It was adopted that obesity has been reported to (OAB) symptoms. As well as the neurogenic mechanisms responsible for bladder dysfunction in MS, excess body weight may aggravate lower urinary tract symptoms by

increasing intra-abdominal pressure, comprising pelvic floor function, and promoting systemic inflammatory processes. These factors can exacerbate urinary urgency, frequency, nocturia and urinary incontinence. Moreover, obesity has been linked to reduced mobility and increased disability in individuals with MS, which may further impair bladder control and adversely affect the physical and psychological well-being [7].

Electrical stimulation (ES) has emerged as an effective non-pharmacological intervention for management of OAB. Current evidence demonstrates that ES can significantly reduce urinary urgency, frequency and urge incontinence, thereby improving bladder control and enhance QOL. It is also regarded as a safe, less-invasive therapeutic option, particularly for patients who are refractory to or intolerant of pharmacological management [8].

High tone power therapy (HTT) is an electrotherapeutic modality that utilize medium-frequency electrical stimulation which aims to enhance cellular metabolism and improve tissue circulation by replicating the physiological responses associated with vigorous physical activity [9]. The technique employs alternating currents with frequency ranges from four to 33 KHz and adjustable intensities. These frequency-specific currents are thought to generate cellular oscillations and tissue vibrations, thereby promoting neuromuscular stimulation, and potentially facilitating nerve regeneration [10]. Nevertheless, despite its therapeutic rationale, high-quality evidence supporting the routine clinical implementation of HTT remains scarce [11].

Bladder dysfunction is highly prevalent in (PwMS); however, effective rehabilitation strategies remain insufficiently explored. Although increasing attention has been directed toward non-pharmacological intervention, a substantial gap persists in the literature regarding the most effective physiotherapeutic approaches for managing OAB in MS population [12]. Therefore, given the paucity of available evidence this study explores the clinical effectiveness of HTT and determining whether its combination with selected physical therapy program produces superior outcomes compared with physical therapy alone. The outcome of the current research may contribute to optimizing evidence-based rehabilitation strategies for managing OAB in (PwMS).

MATERIALS AND METHODS

Study design.

This study is a single blind randomized controlled trail (RCT). It received ethical approval from research ethics committee of Faculty of Physical Therapy, Cairo University, Egypt, and was conducted in strict accordance with ethical principles of Declaration of Helsinki governing research involving human participants (NO: P.T.REC /012/005399). This study was registered in the Clinical Trials.gov (Registry ID: NCT06837675). After receiving information about the study's purpose and procedures, all participants signed a written consent form. The study was undertaken between February 2025 to March 2026 at the outpatient rehabilitation facility of faculty of physical therapy, Cairo University, and outpatient MS Unit of El-Mounira general hospital.

Participants

Forty RRMS patients of both sexes participated in this study. They were included if they have the following criteria; their age ranged from 20 to 50 years, BMI was (18.5- 24.9 $Kg/m^{2)}$, Expanded Disability Status Scale (EDSS) ranged from 2 to 6 [13] ,bladder symptoms more than 3 months with moderate OABSS score (6-11) [14], medically stable and receiving same medical treatment regimen. Medications known to affect bladder function were discontinued 3 weeks before participation.

The exclusion criteria were: Unstable cardiac condition (myocardial infarction, severe cardiac failure), Systemic diseases (Diabetes Mellitus, Rheumatoid arthritis, Acute kidney injury), Any tumor affects lumbosacral spine, Any cognitive problems, Open wound, burn and loss of sensation, Patients with metal implants, Any other diseases that may cause OABS as inflammatory or urinary tract infections, Prostatitis in male or Female genital disorders, Any history of abdominal or bladder surgeries or diseases, Stress related urinary incontinence ; positive cough stress test, Patients in acute relapse stage and Patients with diabetic poly neuropathy.

Randomization and allocation

Sample size was estimated using G*power software (version 3.1.9.2) based on the pilot data for maximum flow rate obtained from five participants per group. A minimum 18 participant per group required (a-0.05, power 80% and effect size = 0.9" and allocation ratio+ 1:1). To account for potential dropouts, 20 participants were recruited for each group.

One hundred and twenty-five PwMS of both sexes conformed to the Revised McDonald's criteria for diagnosis of MS 2017 [15] were screened and assessed for eligibility. Sixty-five patients diagnosed as overactive bladder. Twenty-five patients were excluded from this study (21 patients were ineligible for study participation and 4 subjects refused to participate) resulting in forty RRMS patients of both sexes**.** Using a computer-based random generator with permuted blocks, all the patients were randomly allocated to two equal groups (20 patients in each group). The study group (A) received HTT in addition to selected physical therapy program and the control group (B) received selected physical therapy only (Figure: 1).

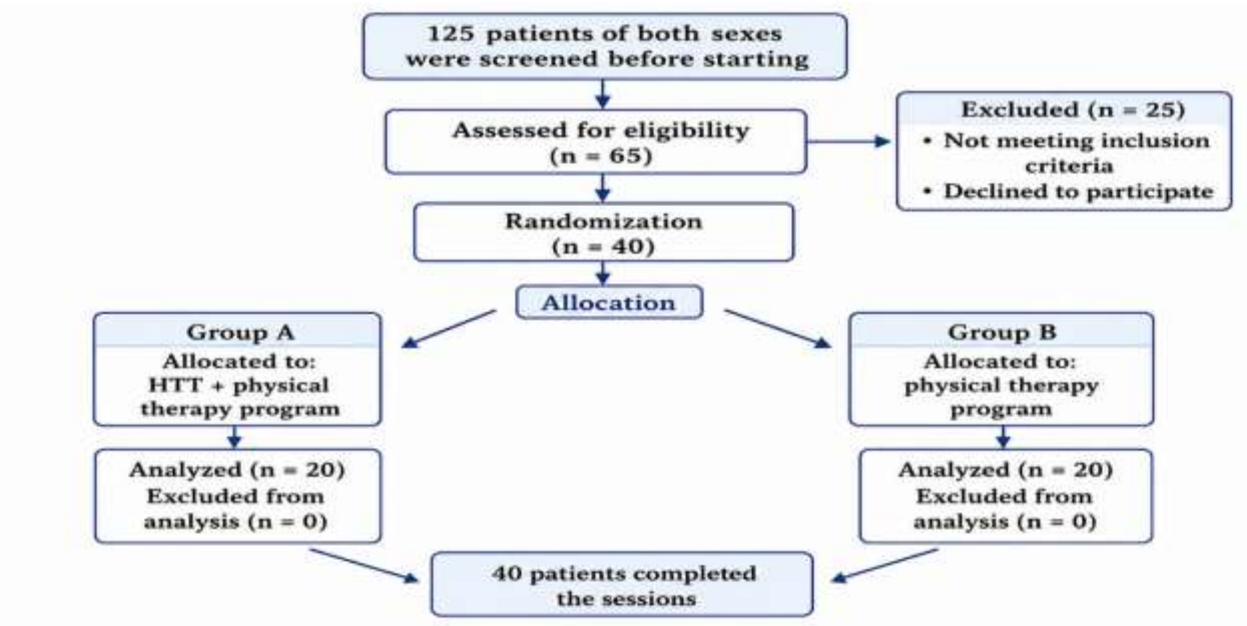

Fig (1): Allocation diagram

Intervention:

Participants in GA underwent 30 minutes of HTT then 30 minutes of targeted physical therapy program. Participants in GB underwent 60 minutes of targeted physical therapy program. Every patient had three sessions a week for three months with total 36 sessions.

HTT is a device powered by a stationary 230 V mains electricity supply (Hi-Top 191H: gbo Medizintechnik Rimbach, Germany). It is a medium-frequency sinusoidal alternating current with maximum output 70 v and maximum output current 250mA [8]**.** The amplitude and frequency of carrier sinusoidal waveform are simultaneously modulated, allowing the stimulation to follow electro sensitive threshold. At modulation of frequency, 20 Hz within wave this pattern produces tetanic muscle contraction results in activation of target muscles. Typical stimulation cycle 3 seconds ramp up phase, 3 seconds stimulation and 3 seconds' rest. Stimulation commenced at 4096 Hz and was ramped up 32,768 Hz within 3 seconds after 3- second plateau at the maximum frequency a downward from 32.768 to 4096 Hz was applied with adjustment of on patient sensitivity [8, 9.]

For ensuring stimulation of pudendal nerve, all procedures were carried out with the patient in supine lying position. Electrodes were applied two on back on lumbosacral spine [16], and two electrodes were placed on both suprapubic area [17]**.** The stimulation intensity was adjusted until the maximum comfortable level that elicited a mild motor response, when present [18]. the treatment was immediately stopped if participants felt any unfavorable reactions including painful sensation, paresthesia, or autonomic symptoms.

Both groups underwent selected physical therapy regimen in form of strengthening pelvic floor muscles (PFM) and improving core stability. The program comprised the following components: posterior pelvic tilt exercise, bridging exercises, bilateral pelvic rocking exercise, single and bilateral knee to chest exercise, Kegels exercises, and diaphragmatic breathing exercises. Participants completed 3 sets of 10 repetitions separated by rest intervals to minimize excessive fatigue.

Outcome measures

Pre and post treatment evaluations were done for all patients. The bladder function was measured by Urodynamic study including bladder capacity, Detrusor muscle activity; voiding function (maximum urine flow rate (Qmax,) and bladder compliance. The assessment begun with Uroflowmetry, subsequently measure of post-voided residual urine volume using either transabdominal ultrasound or urinary catheter [19]. Cystometry was conducted to assess intravesical pressure during bladder filling and to evaluate bladder storage function, including bladder capacity, sensation, stability, and compliance prior to filling the vesical pressure was verified to be zero or near zero [20].

Arabic version of the Overactive bladder symptom score (OABSS) used to measure severity of OAB symptoms. This assessment tool had a validated and approved Arabic version addressed to patients in Arabic model. It compromises from four items that assess frequency, nocturia, urgency and urge incontinence. Total score from zero to 15, higher score indicates higher severity[14]. The QOL was tested using Arabic version of the international consultation on incontinence questionnaire of overactive bladder module (ICIQ-OAB) [21].

Statistical analysis

Statistical analyses were done using SPSS windows version 23.0 (IBM SPSS, Inc., Chicago, IL, USA) with a significant level set $\alpha = 0.05$. Data were assessed for normal distribution, equality of variances and potential outliers. The Shapiro-Wilks test indicated that all variables were normally distributed ($p > 0.5$). Data are expressed as mean ± standard deviation for all outcomes except for gender reported as (counts). Two-way mixed design (MANOVA) was conducted for evaluation of the effects of treatment and time on overall set of outcome measures. When multivariate effects reached statistical significance follow-up univariate ANOVAs with Bonferroni adjustment to reduce risk of type I error.

Prior to analysis, assumptions of MANOVA were assessed and confirmed. Homogeneity of covariance matrices were evaluated using Box's M test where used multicollinearity among the dependent variables were evaluated through Pearson's correlation coefficients. Residual analysis demonstrated approximately normal distribution, homogenous variances, and no influential outliers, indicating assumptions for multivariate analysis were adequately satisfied.

RESULTS:

Twenty MS patients with neurogenic overactive bladder symptoms (NOABs) were recruited in each group. There was no significant difference between groups in age, gender, BMI and EDSS ($p > 0.05$) (Table 1).

Two-way Mixed design multivariate analysis was performed to evaluate the difference between participants in both groups in the magnitude of change across their outcome measure scores. Significant multivariate effects were observed for the main effects of groups, as indicated by Wilk's A = 0.32, $F_{(6, 33)} = 11.72$, P-value = (0.001**), Partial Eta Squared ($\eta^{2)}$ = (0.68). Also, there were significant effect on time (pre-post treatment) as Wilk's A = 0.01, $F_{(6, 33)} = 738.49$, p-value < 0.001*, $\eta^2 = 0.99$, also for the interaction between groups and time as Wilk's A= 0.05, $F_{(6, 33)} = 110.74$, p-value < 0.001*, $\eta^2 = 0.95$.

Between-groups comparison:

After three months of interventions: There were statistically significant differences among both groups ($P<0.05$) in OABSS, ICIQ-OAB, urodynamic bladder capacity; MCC, urodynamic detrusor activity; DO amplitude, urodynamic voiding function; Q_{max}, and bladder compliance with more favor to study group as in Table 2.

Within-group comparison: At study group, there were statistically significant differences between pre and post interventions in OABSS, ICIQ-OAB, urodynamic bladder capacity; MCC, urodynamic detrusor activity; DO amplitude, urodynamic voiding function; Q_{max}, and bladder compliance as in Table 3.

For control group, there were statistically significant differences between pre-post interventions in OABSS, ICIQ-OAB, urodynamic bladder capacity; MCC, urodynamic detrusor activity; DO amplitude, and bladder compliance while there was no statistical significant difference in urodynamic voiding function; Q_{max} as in Table 3.

Table 1: Baseline Demographic Characteristics of participants

Characteristics	GA	GB	t- value	P Value
Age (years)	**33±7.89**	**33.6±7.82**	**-0.24**	**0.81**
Weight (kg)	**69.45±5.92**	**71±5.48**	**-0.86**	**0.4**
Height (cm)	**170.35±8.39**	**171.7±8**	**-0.52**	**0.61**
BMI (kg/m²)	**23.92±0.9**	**24.08±0.88**	**-0.56**	**0.58**
EDSS (score)	**3.55±1.15**	**3.2±1.11**	**0.98**	**0.33**
Gender, n (%)				
Female	**11(55%)**	**8 (40%)**	**χ2=0.9**	**0.34**
Male	**9 (45%)**	**12 (60%)**		

BMI, body mass index; X2, Chi Square; Data are mean± SD for all demographics except gender (%), P-Value < 0.05 indicate statistical significance, cm: centimeter, kg/cm^2: kilogram per centimeter square, EDSS: Expanded Disability Status Scale.

Table 2. Comparison between both groups at start of treatment and at end of 3 months of treatment

Outcomes	Time	GA	GB	MD (95% CI)	P Value
OABSS (score)	Baseline	9.45±1.43	9.5±1.4	-0.05(-0.96,0.86)	0.91
	After 3 months	6±0.97	7.3±1.34	-1.3(-2.05, -0.55)	0.001**
ICIQ-OAB (score)	Baseline	9±1.59	9.65±1.39	-0.65(-1.61,0.31)	0.18
	After 3 months	5.6±1.43	8.3±1.08	-2.7(-3.51, -1.89)	0.001**
Urodynamic bladder capacity					
MCC (ml)	Baseline	227.7±22.67	226.95±19.57	0.75(-12.81,14.31)	0.91
	After 3 months	282.05±20.16	252.4±19.12	29.65(17.07,42.23)	0.001**
Urodynamic detrusor activity					
DO amplitude (cmH2O)	Baseline	30.05±3.73	29.9±2.36	0.15(-1.85,2.15)	0.88
	After 3 months	21.85±3.12	25.7±3.34	-3.85(-5.92, -1.78)	0.001**
Urodynamic voiding function					
Q_{max} (ml)	Baseline	7.3±1.78	7.45±1.67	-0.15(-1.26,0.96)	0.79
	After 3 months	12.15±1.81	7.9±1.59	4.25(3.16,5.34)	0.001**
Bladder compliance (cmH2O)	Baseline	10.2±2.07	10.75±2.17	-0.55(-1.91,0.81)	0.42
	After 3 months	15.7±2.25	13.25±1.94	2.45(1.1,3.8)	0.001**

* Data are mean± SD, MD; mean difference, CI; confidence interval, P-Value < 0.05 indicates statistical significance, OABSS: overactive bladder symptoms score, ICIQ-OAB: International Consultation on Incontinence Questionnaire Overactive Bladder Module, ml: milliliter, MCC: maximum cytomitric capacity, DO: detrusor over activity, cmH2O: centimeters of water, Qmax: maximum urine flow rate.

Table 3. Within-groups Comparisons for all outcome measures.

Outcomes	GA (n=20)	GB (n=20)

	Change from baseline to 3 months		Change from baseline to 3 months	
	MD (95% CI)	**P Value**	**MD (95% CI)**	**P Value**
OABSS (score)	**3.45(2.94,3.96)**	0.001*	**2.2(1.69,2.71)**	0.001*
ICIQ-OAB	**3.4(2.79,4.01)**	0.001*	**1.35(0.74,1.96)**	0.001*
Urodynamic bladder capacity				
MCC (ml)	**-54.35(-58.66, -50.04)**	0.001*	**-25.45(-29.76, -21.14)**	0.001*
Urodynamic detrusor activity				
DO amplitude (cmH2O)	**8.2(7.57,8.83)**	0.001*	**4.2(3.57,4.83)**	0.001*
Urodynamic voiding function				
Q_{max} (ml)	**-4.85(-5.36, -4.34)**	0.001*	**-0.45(-0.96,0.06)**	0.08
Bladder compliance (cmH2O)	**-5.5(-5.87, -5.13)**	0.001*	**-2.5(-2.87, -2.13)**	0.001*

MD; mean difference, CI; confidence interval, P-Value < 0.05 indicates statistical significance, OABSS: overactive bladder symptoms score, ICIQ-OAB: International Consultation on Incontinence Questionnaire Overactive Bladder Module, ml: milliliter, MCC: maximum cytomitric capacity, DO: detrusor over activity, cmH2O: centimeters of water, Qmax: maximum urine flow rate.

DISCUSSION

This study evaluated the combined effects of HTT with targeted exercise therapy on bladder function and QOL in with MS associated with OAB patients. As far as we are aware, no pervious RCTs have evaluated the efficacy of HTT in this specific evaluation. Moreover, strong evidence based regarding the therapeutic effects of HTT in individuals with UMNLs remain limited. Nevertheless, previous research had examined the impact of HTT in patients with MS, although neither specifically addressed OAB-related outcomes.

In 2014 a randomized controlled trail conducted by Kusbsik et al. assessed the impact of HTT in twenty MS patients. The authors found markedly improvement within group in (balance, muscle tone, gait, functional capacity, and QOL) [22]. More recently, Yassin et al., (2025) conducted an RCT involving 40 patients with MS who received either HTT or selected physical therapy regimen indicated that HTT provides additional benefits in reducing fatigue and enhancing functional outcome in this population [23].

These results may serve as indirect evidence supporting the promising therapeutic role of HTT in neurorehabilitation and underscore the necessity for further high-quality studies to establish its efficacy in individuals with UMNLs. In this context, the current RCT focuses on the gap of literature by evaluating the efficacy of HTT on OAB symptoms in PwMS. The results of the current study are anticipated to offer preliminary yet clinically meaningful evidence that may influence future large-scale investigations and contribute to the advancement of evidence based clinical protocols for the implementation of HTT. In the current RCT, HTT group exhibited greater improvement in OABSSICIQ-OAB scores, and all evaluated urodynamic parameters following the intervention compared with those in the group B.

HTT represents a form of neuromuscular electrical stimulation (NMES) that delivers current of medium frequency with frequency and amplitude modulated simultaneously [24]. Previous evidence has demonstrated that external NMES is an effective adjunctive therapy for minimizing bladder-related manifestations and optimizing PFMS, sexual health and patient satisfaction among females with urge incontinence [25]. Furthermore, a systematic review of Ali et al., (2022) concluded that NMES yields greater improvement in PFMS than exercise therapy alone [26]. These finding supports the potential role of electrical stimulation-based intervention in managing of lower urinary tract disorders. High tone external muscle stimulation is regarded as high-frequency electrotherapeutic modality, delivers frequencies that exceed those used in conventional transcutaneous electrical nerve stimulation (TENS) and NMES [9]. Previous studies have also demonstrated that HFES is effective in reducing symptoms severity as assessed by OABSS rather than conventional TENS or exercise therapy alone in patients with overactive bladder. Furthermore, studies have shown that Khz range carrier frequency reduce skin resistance and enable deeper tissue penetration [27]. These results suggests that HFES may be more effective than low frequency stimulation represents safe and effective therapeutic option, particularly for individuals seeking nonpharmacological and non-surgical treatment alternatives by inducing rapid, repetitive, and forceful contractions, HFES offers several physiological benefits, including improving muscular endurance and functional performance within a short time in rehabilitation [28]. Through the generation of near maximal or maximal tetanic contractions, HFES enhance recruitment of motor units rapidly, promoting neuromuscular plasticity, accelerating power, and improving overall functional capacity [29].

The observed improvements in this study may attributed to the electrode placements used that are consistent with previous evidence suggesting that stimulation of the lumbosacral and suprapubic regions may activate pelvic neural pathways and pelvic floor musculature, thereby enhancing bladder storage capacity and suppressing involuntary bladder contractions through spinal reflex mechanisms. These effects are likely mediated through pelvic-to-spinal somatic reflex pathways involved in lower urinary tract function regulation [15]. Peripheral electrical nerve stimulation. Including HTT, may non-invasively modulate CNS activity through activation of peripheral afferent pathways. By stimulating pudendal afferent and motor fibers, HTT may activate the inhibitory micturition reflexes and reduce urinary urgency through enhanced PFM contractions [30]. Given that normal micturition depends on coordinated interactions among afferent signalling, central integration, and efferent control, HTT may help restore the balance between the excitatory and inhibitory neural mechanisms governing lower urinary tract function [31].

Furthermore, PFM stimulation may improve bladder control through both mechanical and neurophysiological mechanisms. Enhanced activation of PFM provides greater support to bladder and urethral outlet, while simultaneous stimulation of pudendal afferent fibers could modulate spinal and supraspinal micturition circuits, resulting in inhibition of detrusor over activity and reduction of urgency symptoms [32]. In addition, pudendal afferent stimulation may improve bladder storage capacity by modulating of the lower urinary tract function autonomic control and supressing involuntary detrusor contractions through reflex neural pathways [33].

Previous studies have demonstrated that high tone power therapy (HiTop) had beneficial long-term effects on muscle power and promotes increase in muscle mass [34]. These effects may attribute to stimulatory properties of HTT, which induce action potential in receptors, peripheral nerves and muscle Fibers with discharge patterns that closely resemble physiological tissue activity. Such stimulation provides sufficient intensity to activate neural structures without exceeding the threshold that could lead to conduction block, thereby eliciting physiological muscle contraction through activation of CNS pathways which may further contribute to its physiological effects [35].

Compared with conventional low frequency electrical stimulation, the modulation of medium frequency currents delivered by HTT offers also several non-stimulatory advantages, including enhancing ionic diffusion and influence the distribution of biochemical substances including pain mediators by products thereby contributing to pain reduction enhancing the ionic migration and influence the dissipation of biochemical products including pain mediators or metabolic substances contributing pain reduction. Beyond its analgesic effect, reduced tissue impedance, enhanced penetration into deeper tissues and improved patient satisfaction owing to diminished cutaneous discomfort. These characteristics may facilitate more effective stimulation while increasing treatment tolerability [31].

According to the finding of this study HTT was well tolerated by patients with MS despite the relatively prolonged duration of each treatment session. The bioelectrical energy delivered through HTT may contribute to neurophysiological recovery and facilitate the rehabilitation process in individuals with OAB. The combined therapeutic strategy of pudendal afferent neuromodulation and PFM strengthening provides a non-invasive and effective management neurogenic bladder over activity in patients with MS associated OAB. Through the synergic effects of bladder inhibition and improve PFM function, intervention may enhance urinary control and reduce symptom burden.

Strengths and Limitations:

The present investigations are strengthened by various features. First, based on available evidence, it is the first RCT to focus on the efficacy of HTT combined with a targeted physical therapy program for OAB in PwMS. Second, the randomized controlled design with standardized treatment protocols enhanced the internal validity of the study. Third, treatment efficacy was evaluated using both patient-reported outcome measures (OABSS and ICIQ-OAB) and objective urodynamic parameters, providing a comprehensive assessment of clinical outcomes. Finally, the use of

validated assessment tools and standardized intervention protocol improves the reducibility and clinical applicability of the findings.
Despite the promising findings, this study has limitations; first, the neurophysiological mechanisms underlying the therapeutic effects of HTT remain largely speculative, owing to the limited body of evidence investigating its application in patients with UMNLs specially MS. Second, the lack of sham stimulation control group prevents the complete exclusion of placebo-related effects. Third, although treatment duration was standardized across groups, difference in intervention content may have introduced performance and attention-related biases.

Conclusions and practical implementations
The results of this study demonstrated that Adding HTT into rehabilitation can improve bladder symptoms and QOL in PwMS. HTT can be incorporated as a safe and effective adjunctive intervention within rehabilitation programs for OAB in PwMS. By improving urinary signs and symptoms and strengthening of pelvic floor muscles, HTT may provide a non-invasive option, particularly for patients who achieve insufficient symptom control with conservative or pharmacological treatment.

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- **conflicts of interest**
  - no potential conflicts of interest with respect to the research , authorship , and /or publication of this article.
- **Financial support and sponsorship**
  - NIL

- **Ethical approval and consent form**
  - The patients signed a written consent form. The ethical committee of faculty of physical therapy, cairo university , approved the study procedure
    NO: P.T.REC/012/00539
- **Clinical trial registry**
  - This study was a registered in the clincaltrials.gov **(NCT06837675).**
- **Data availability statement**
  - The data that support the finding of this study are available on request from the corresponding author.

References:

1. Boutitah-Benyaich, I., Eixarch, H., Villacieros-Álvarez, J. et al. . (2025). MS: molecular pathogenesis and therapeutic intervention. Sig Transduct Target Ther. ;10, 324 https://doi.org/10.1038/s41392-025-02415-4
2. Hardy, T. A. (2026). Diagnostic Approach to Presumptive Demyelinating Solitary CNS Lesions. CONTINUUM: Lifelong Learning in Neurology; 32(2), 424–455. https://doi.org/10.1212/cont.0000000000001690
3. Khan, G. & Hashim, M.J. (2025). Epidemiology of MS: Global, Regional, National and Sub-National-Level Estimates and Future Projections. J Epidemiol Glob Health; 15, 21. https://doi.org/10.1007/s44197-025-00353-6
4. Ghonimi, N.A.M., Elbaz, R.H., Mahdy, M.E. et al., (2025). Suicide ideation in MS Egyptian patients: neurologic and psychiatric correlates. Middle East Curr Psychiatry; 32, 45https://doi.org/10.1186/s43045-025-00536-8
5. Islamoska, S., Forman, C. R., Panicker, J. N., Flachenecker, P., Phé, V., Brichetto, G., Blok, B., & Barken, K. B. (2024). The impact of bladder problems on well-being in MS - A cross-sectional study. MS and related disorders; 87, 105661. https://doi.org/10.1016/j.msard.2024.105661
6. Hentzen, C., Chesnel, C., Lagnau, P., Blouet, E., Teng, M., & Amarenco, G. (2024). Transcutaneous tibial nerve stimulation in patients with MS and overactive bladder: a real-life clinical and urodynamic assessment. World journal of urology; 42(1), 136. https://doi.org/10.1007/s00345-024-04836-2
7. Panicker, J. N., Fowler, C. J., & Kessler, T. M. (2015). Lower urinary tract dysfunction in the neurological patient: clinical assessment and management. The Lancet. Neurology; 14(7), 720–732. https://doi.org/10.1016/S1474-4422(15)00070-8
8. Hentzen, C., Chesnel, C., Lagnau, P., Blouet, E., Teng, M., & Amarenco, G. (2025). Role of detrusor overactivity and interval between bladder sensations on the severity of overactive bladder symptoms in patients with MS. The French journal of urology; 35(4), 102847. https://doi.org/10.1016/j.fjurol.2024.102847

9. Abo El-Regal, W. K., Obaya, H. E., Taha, E. M. & Hawaas, K. L. (2021). "Effect of High-tone power therapy on Neurophysiological Measures and Function Outcome in Patients with Diabetic Neuropathy". Egypt. J. of Appl. Sci; 36 (1): 10 –21. DOI: 10.21608/ejas.2021.152343
10. Namvar, H., Olyaie, Gh., Bagheri, H., Naiemi, E., Hoseinifar, M., & Sargolzehi, M. (2022). Effect of High-Tone External Muscle Stimulation (High-Tone Therapy) in Neuro-Musculoskeletal Disorders: A Narrative Review. Journal of Modern Rehabilitation; 16(3):208-213. https://doi.org/10.18502/jmr.v16i3.10143
11. Nair, K. P., & Marsden, J. (2014). The management of spasticity in adults. BMJ (Clinical research ed.); 349, g4737. https://doi.org/10.1136/bmj.g4737
12. Sapouna, V., Thanopoulou, S., Papriakas, D., Papakosta, S., Sakopoulou, M., Zachariou, D., Zikopoulos, A., Kaltsas, A., Vrachnis, N., Vrachnis, D., Sofikitis, N., & Zachariou, A. (2023). Pelvic Floor Muscle Training and Its Benefits for MS Patients Suffering from Urinary Incontinence and Sexual Dysfunction.; 15(10), e47086. https://doi.org/10.7759/cureus.47086
13. Cheng, E. M., Hays, R. D., Myers, L. W., Ellison, G. W., Beckstrand, M., & Vickrey, B. G. (2001). Factors related to agreement between self-reported and conventional Expanded Disability Status Scale (EDSS) scores. MS (Houndmills, Basingstoke, England); 7(6), 405–410. https://doi.org/10.1177/135245850100700610
14. Elbaset, M. A., Hashem, A., Taha, D. E., Zahran, M. H., & El-Hefnawy, A. S. (2019). Validation of the Arabic linguistic version of the Overactive Bladder Symptoms Score questionnaire. Arab Journal of Urology; 17(4), 265–269. https://doi.org/10.1080/2090598X.2019.1627061
15. Montalban, X., Lebrun-Frénay, C., Oh, J., Arrambide, G., Moccia, M., Pia Amato, M., Amezcua, L., Banwell, B., Bar-Or, A., Barkhof, F., Butzkueven, H., Ciccarelli, O., Chataway, J., Cohen, J. A., Comi, G., Correale, J., Deisenhammer, F., Filippi, M., Fiol, J., Freedman, M. S., … Thompson, A. J.. (2025). Diagnosis of multiple sclerosis: 2024 revisions of the McDonald criteria. Lancet Neurol. Oct; 24 (10):850-865. https://doi.org/10.1016/S1474-4422(25)00270-4
16. Stewart F, Gameiro LF, El Dib R, Gameiro MO, Kapoor A, Amaro JL. (2016). Electrical stimulation with non-implanted electrodes for overactive bladder in adults. Cochrane Database of Systematic Reviews; Issue 12. Art. No.: CD010098. CD010098.pub4. Accessed 24 June 2026. https://doi.org/10.1002/14651858.CD010098.pub4
17. Kosilov, K. V., Loparev, S. A., Ivanovskaya, M. A., & Kosilova, L. V. (2014). Randomized controlled trial of cyclic and continuous therapy with trospium and solifenacin combination for severe overactive bladder in elderly patients with regard to patient compliance. Therapeutic advances in urology; 6 (6), 215–223. https://doi.org/10.1177/1756287214544896
18. Vaganée, D., Van de Borne, S., Voorham-van der Zalm, P., Voorham, J., Fransen, E. and De Wachter, S. (2020), Pelvic Floor Muscle Electromyography as a Guiding Tool During Lead Placement and (Re)Programming in Sacral Neuromodulation Patients: Validity, Reliability, and Feasibility of the Technique. Neuromodulation: Technology at the Neural Interface, 23: 1172-1179. https://doi.org/10.1111/ner.13177
19. Abdel-Fattah, M., Chapple, C., Breeman, S., Cooper, D., Bell-Gorrod, H., Kuppanda, P., Guerrero, K., Dixon, S., Cotterill, N., Ward, K., Hashim, H., Monga, A., Brown, K.
Drake, M., Gammie, A., Mostafa, A., Bruce, R., Bell, V., Kennedy, C., Evans, S. … Norrie, J. (2025). Invasive urodynamic investigations in the management of women with refractory overactive bladder symptoms: FUTURE, a superiority RCT and economic evaluation. Health technology assessment (Winchester, England), 29(27), 1–139. https://doi.org/10.3310/UKYW4923
20. Sinha, S., Tarcan, T., Speich, J.E., Plata, M., Finazzi-Agró, E., & Drake, M.J. (2025). ICS teaching module on urodynamics for lower urinary tract symptoms in men. Continence. https://doi.org/10.1016/j.cont.2025.101758
21. Taha, DE. , Elbaset, M.A., Hashem, A. et al. (2021). Validation of the Arabic linguistic version of the International Consultation on Incontinence Questionnaire-overactive bladder (ICIQ-OAB). Afr J Urol; 27, 51. https://doi.org/10.1186/s12301-021-00153-x
22. Kubsik, A., Klimkiewicz, P., Klimkiewicz, R., Jankowska, K., Jankowska, A., & Woldańska-Okońska, M. (2014). The influence of high-tone power therapy on the functional status of patients with MS; 37(217), 24–29. PMID: 25154195.

23. Yassin Turky, K. T., Shalaby, N. M., Abdelmonem, A. F. et al. (2025). Effect of high-tone external muscle stimulation on fatigue and functional outcomes in MS: A randomized controlled trial. SPORT TK-EuroAmerican Journal of Sport Sciences; 14, 54. https://doi.org/10.6018/sportk.665861
24. Mahmoud, J. M., Fayez, E. S., Ahmed, S., Gelany, F. M., Hassan, I. M., & El-Zanaty, M. Y. (2026). Impact of High Tone Power Therapy on Lower Limb Spasticity and Gait Speed in Patients at Least Six Months Post-Stroke: A Randomized Controlled Trial. Physiotherapy research international: the journal for researchers and clinicians in physical therapy; 31(2), e70175. https://doi.org/10.1002/pri.70175
25. Kurt, T. B., Yilmaz, B., & Celenay, S. T. (2024). Effects of external neuromuscular electrical stimulation in women with urgency urinary incontinence: a randomized sham-controlled study. World journal of urology; 42(1), 423. https://doi.org/10.1177/20406223211063059
26. Ali, M. U., Fong, K. N., Kannan, P., Bello, U. M., & Kranz, G. (2022). Effects of nonsurgical, minimally or noninvasive therapies for urinary incontinence due to neurogenic bladder: a systematic review and meta-analysis. Therapeutic advances in chronic disease; 13, 20406223211063059. https://doi.org/10.1177/20406223211063059
27. Medina, L. E., & Grill, W. M. (2016). Nerve excitation using an amplitude-modulated signal with kilohertz-frequency carrier and non-zero offset. Journal of neuroengineering and rehabilitation; 13(1), 63. https://doi.org/10.1186/s12984-016-0171-4
28. Rashid, S., & Sajid, O. (2025). Effectiveness of Electric Muscle Stimulation (EMS) and Transcutaneous Electric Nerve Stimulation (TENS) in patients with overactive bladder: A randomized controlled trial. Pakistan journal of medical sciences; 41(11), 3259–3264. https://doi.org/10.12669/pjms.41.11.12777
29. Gueugneau, N., Grosprêtre, S., Stapley, P., & Lepers, R. (2017). High-frequency neuromuscular electrical stimulation modulates interhemispheric inhibition in healthy humans. Journal of neurophysiology; 117(1), 467–475. https://doi.org/10.1152/jn.00355.2016
30. Ge, Q., Xu, H., Fan, Z., Li, W., Chen, Z., Yue, D., Xu, J., Zhang, S., Xue, J., Shen, B., & Wei, Z. (2023). Efficacy of peripheral electrical nerve stimulation on improvements of urodynamics and voiding diary in patients with neurogenic lower urinary tract dysfunction: a systematic review and meta-analysis. International journal of surgery (London, England); 109(5), 1342–1349. https://doi.org/10.1097/JS9.0000000000000168
31. Babazadeh-Zavieh, S. S., Karshenas, F., Tayebi, S., Rabiei, N., & Haeri, S. M. J. (2025). Effects of interferential stimulation on clinical symptom and urodynamic findings in women with voiding dysfunction: A protocol of randomized clinical trial. PloS one; 20(10), e0330610. https://doi.org/10.1371/journal.pone.0330610
32. Quaghebeur, J., Petros, P., Wyndaele, J. J., & De Wachter, S. (2021).The innervation of the bladder, the pelvic floor, and emotion: A review. Autonomic neuroscience: basic & clinical; 235, 102868. https://doi.org/10.1016/j.autneu.2021.102868
33. Ladi-Seyedian, S. S., Sharifi-Rad, L., & Kajbafzadeh, A. M. (2020). Management of Bladder Bowel Dysfunction in Children by Pelvic Floor Interferential Electrical Stimulation and Muscle Exercises: A Randomized Clinical Trial. Urology; 144, 182–187. https://doi.org/10.1016/j.urology.2020.07.015
34. Ogrodzka-Ciechanowicz, K., Głąb, G., Ślusarski, J., & Gądek, A. (2021). Quadriceps muscle strength recovery with the use of high-tone power therapy after anterior cruciate ligament reconstruction: a randomized controlled trial. BMC musculoskeletal disorders; 22(1), 975. https://doi.org/10.1186/s12891-021-04862-w
35. Dawah, R. M., Seddik, F. Grase M. O. (2024). The effect of high tone external muscle stimulation on polyneuropathy: a systematic review and meta-analysis. Health, sport, rehabilitation; 10 (2), 83-94. https://doi.org/10.58962/HSR.2024.10.2.83-94