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Original Article

Urodynamic Impact of Pulsed Electromagnetic Field Therapy in The Neurogenic Overactive Bladder after Partial Spinal Cord Injury: A Randomized Controlled Study

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Abstract:

Purpose: This study was performed to assess the urodynamic effect of pulsed electromagnetic field therapy (PEMFT) in the neurogenic overactive bladder following partial spinal cord injury.

Methods: forty patients have overactive bladder post partial spinal cord injury above T12 were evaluated using a urodynamic test and revised urinary incontinence scale (RUIS) patients were divided into 2 groups: - Group (A): twenty patients treated by low-frequency pulsed electromagnetic field therapy (PEMFT) and pelvic floor muscle exercises. Group (B): twenty patients were treated with pelvic floor muscle exercises and placebo PEMFT.

Results: group (A) revealed an increase in urodynamic parameters and a decrease in RUIS score more than group (B).

Conclusion: In individuals with a partial spinal cord injury, pulsed electromagnetic field treatment (PEMFT) has a positive urodynamic impact on an overactive bladder.

Keywords: urodynamics, neurogenic overactive bladder, partial spinal cord injury and pulsed electromagnetic field therapy (PEMFT).

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1. Introduction:

The term "neurogenic bladder" refers to bladder dysfunction caused by injury or illness to the central nervous system (CNS) **[1],** As a result, it is a broad diagnosis that includes any damage to the CNS that causes bladder dysfunction **[2].**

Neurogenic bladder affection is common in all persons who have had a spinal cord injury (SCI), who have chronic neurological impairments, as well as in 70% of ambulatory SCI patients **[3].** Bladder affection is widespread in spina bifida, which affects around one from every 1000 live babies **[4].**

Individuals with Overactive Bladder Syndrome (OAB) have symptoms such as urine urgency, excessive urinary frequency, or urge incontinence. These symptoms are not dangerous, but they might cause mortification. The most troublesome symptom is incontinence **[5].**

In cases of spinal cord injury, such as in individuals with paraplegia, the early period referred to as spinal shock is often marked by excessive urine retention with occasional leakage, a pattern described as overflow incontinence. As recovery from spinal shock begins, the urination reflex returns, but voluntary control over bladder contraction is still absent. Over time, the bladder may lose part of its storage capacity, and increase reflex activity can develop, producing a spastic neurogenic bladder**.** This dysfunction prevents full evacuation of urine, leading to a persistent residual volume **[6].**

Magnetic field stimulation (MFS) is a revolutionary non-invasive approach for stimulating the nervous system that may stimulate deep brain regions via generated electric currents without causing pain or discomfort. Furthermore, MFS of the pelvic floor and sacral roots has been demonstrated in numerous clinical trials, including placebo-controlled ones, to be helpful for overactive bladder (OAB). MFS similarly suppresses detrusor overactivity as electrical stimulation but with far greater therapeutic effects. the sacral nerve roots magnetic field stimulation has the potential to be a successful OAB alternative treatment **[7].**

Urodynamic studies (UDS) encompass a set of specialized tests such as urinary flowmetry, bladder cystometry combined with electromyography, Valsalva leak-point pressure assessment, and urethral pressure profiling designed to evaluate the functional status of the urinary tract. In cases of neurogenic bladder dysfunction, performing UDS during both the storage and voiding phases represents the most accurate and objective approach for identifying abnormalities in bladder and urethral activity. This comprehensive evaluation is often essential to determine the extent to which neurological impairment has altered the performance and coordination of various components of the lower urinary tract, enabling a precise and complete diagnosis **[8].**

2. Materials and Methods:

This active-controlled randomized clinical trial enrolled forty patients aged 30–40 years who had been diagnosed with neurogenic overactive bladder resulting from a partial spinal cord lesion located above the T12 level, with symptom duration exceeding four months. Diagnosis was established through comprehensive clinical assessment supported by spinal imaging, including Computed Tomography (CT) and/or Magnetic Resonance Imaging (MRI). All participants were recruited from the outpatient clinics of the Faculty of Physical Therapy, South Valley University.

All participants signed informed consent of the study. Patients were divided randomly using a simple randomization table created by a computer software program. Participants were allocated into 2 equal intervention groups by masked caregiver-provider according to participants' phone numbers. Group (A) 20 patients received low-frequency PEMFT (15 Hz, 50% intensity output for 5 s/min for 20 minutes) and pelvic floor muscle training 3 times/ week for 6 weeks, and group (B) 20 patients received placebo low frequency PEMFT and pelvic floor muscle training 3 times/ week for 6 weeks. The study was conducted from July, 2024 to February, 2025.

Exclusion Criteria:

Participants were excluded if they had:

1. Overactive bladder resulting from other neurological conditions, including sensory bladder symptoms in cases of polyneuropathy or diabetes mellitus.
2. Previous pelvic trauma or surgical intervention involving the bladder, such as pelvic fractures, or musculoskeletal disorders of the pelvis including chronic pelvic pain syndrome.

3. Spinal cord injuries located below the T12 segment, or presentation of overactive bladder combined with stress urinary incontinence (mixed type).
4. Partial spinal cord injury above T12 in individuals who were receiving pharmacological treatment to manage bladder function.

II- Procedures:

A. Evaluation procedures:

Assessment:

Both groups underwent pre- and post-treatment evaluation by
urodynamic testing and urinary flowmetry.

Urodynamic testing was conducted with the Dantic 5000/5500 system, which integrates voiding cystometry capabilities. The device is a trolley-mounted unit equipped with a built-in display and printer, and features a portable patient module containing H_2O and CO_2 pumps, a standard-mounted uroflow transducer, and a standard puller mechanism.

Revised Urinary Incontinence Scale (RUIS): This scale incorporates questions from the incontinence severity index and has been validated as a reliable measure for determining the degree of urinary incontinence **[9].**

B. Treatment: -

- Low-frequency pulsed electromagnetic field therapy (PEMFT) was delivered using the ASTAR Magnetotherapy Premium device (**Figure 1**), set to 16 Hz with an output intensity of 1.5 mT, applied for 6 seconds each minute during a 20-minute session **(Figure 2**). The treatment was administered three times per week for a total of 18 sessions. Patients were positioned in the prone posture to facilitate repeated stimulation of the sacral nerve roots **(Figure 3).** In addition to PEMFT, participants in this group performed pelvic floor muscle exercises for 15 minutes per session, three times weekly, over the same 18-session period.

Figure 1: ASTAR magneto-therapy (Adopted from the list of ASTAR products, ASTAR website).

Figure 2: parameters used in treatment application (taken by authors).

Figure 3: patient position during PEMFT application (taken by authors).

- **Pelvic floor muscle training** Patients in both groups performed pelvic floor muscle exercises 3 times/week for 6 weeks under physiotherapist supervision. Each session included 10 sets of 10-second contractions with rest intervals. Quality control was maintained using standardized logs and weekly reassessments, and the activity of the muscle was recorded by surface EMG biofeedback as follows: **[10]**

1- Long squeezes: -

- Contract your pelvic floor muscles, hold the contraction briefly, then release completely and allow full relaxation.
- Record the time patient can hold the contraction.
- Repeat the squeeze and hold until the pelvic floor muscle tire and record the times of repetition.

2- Short squeeze:

- Quickly tighten your pelvic floor muscles, then immediately let them go again.
- Record times of repetitions.
- Always let the muscles fully relax after each squeeze.

Pelvic floor muscle contraction monitored by EMG biofeedback

EMG biofeedback application: **(Figure 4)**

- Prior to electrode placement, hair in the perineal region was carefully removed, and the underlying skin was cleansed with an antiseptic solution and allowed to dry completely.
- Single-use, self-wired electrodes (color-coded yellow, black, and red) were employed for the procedure. The yellow and red electrodes were positioned bilaterally adjacent to the perineum, whereas the black electrode was affixed to a selected site on the posterior aspect of the thigh.
- To ensure stability and prevent displacement during the intervention, each electrode was firmly secured using a layer of thick adhesive plaster **[11]**.

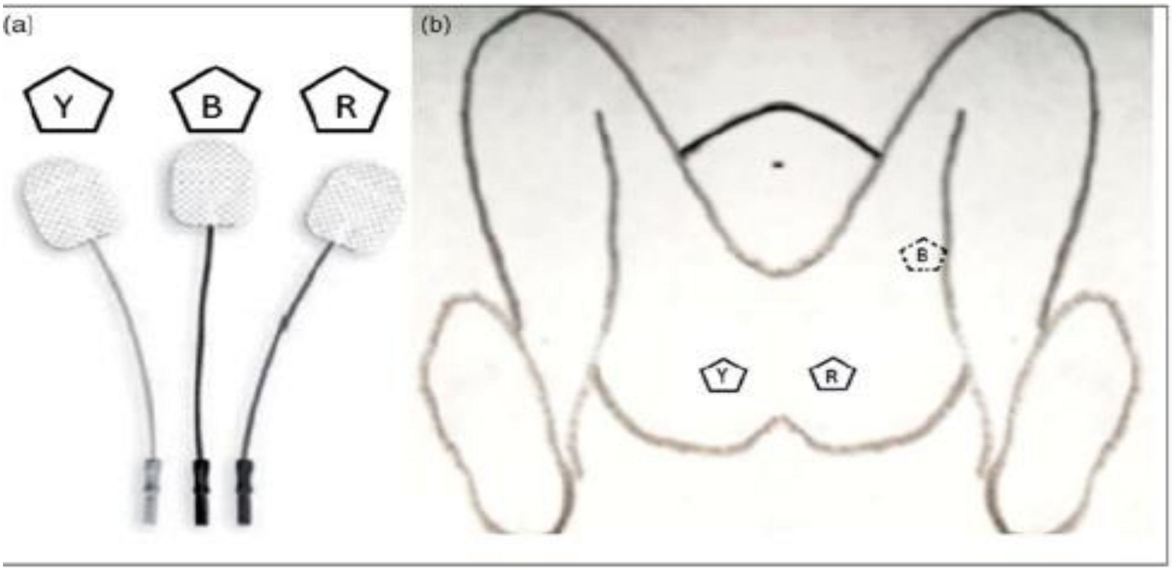

Figure 4: EMG electrodes placement for pelvic floor muscles [11].

Statistical analysis:

Before the final analysis, data were screened for extreme values and tested, using ShapiroWilk test, for normality. Screening for normality showed that all dependent variables were normally distributed and not violates the parametric assumption to evaluate the treatment effect (the mean difference between the groups at baseline), we used unpaired sample t-test while within groups comparison with paired sample t-tests. The descriptive statistics (mean, and standard deviation) were calculated for the main treatment outcomes

The alpha level was 0.05. Data was analyzed using Statistical Package for Social Science (SPSS) version 22 for Windows. Outcome assessors were blinded to group allocation to reduce observer bias during data analysis

3. Results:

Subject characteristics:

Both groups demonstrated similar characteristics in age, weight, height, BMI, and time since spinal cord injury, with no statistically relevant disparities observed (**Table 1**).

Table 1: Baseline characteristics of the two studied groups

	PEMFT Group n=20	**PFE Group n=20**	**p-value**
Age (years)	38.4±4.3	37.5±4.3	0.982
Weight (kg)	84.5±8.7	85.4±8.7	0.836
Height (cm)	171±4	172±3	0.355
Body mass index (kg/m²)	26.2±2.5	25.3±2.5	0.827
Duration of SCI (Months)	4.8±1.1	4.7±2.1	0.634

In the initial assessment, both groups demonstrated comparable values for maximum cystometric capacity (MCC), first desire (FD) to void, and peak urinary flow rate, with no statistically significant differences detected **(Table 2).** These initial MCC, FD to void, and flow rate measurements were low, indicating features of overactive bladder. After the intervention, significant improvements were observed in all three parameters in both groups; however, the PEMFT group achieved notably higher post-treatment MCC and FD to void values than the PFE group ($p < 0.001$ for both).

The Revised Urinary Incontinence Scale (RUIS) scores decreased significantly in both groups, with the PEMFT group showing a greater degree of improvement **(Table 2**). This pattern was confirmed in **Table 3**, which showed a more substantial change in RUIS for the PEMFT group compared to the PFE group. Additionally, a positive association was identified between RUIS scores and urodynamic measures **(Table 4).**

Table 2: Urodynamic measurements pre and post treatment in both groups.

	PEMFT Group n=20	PFE Group n=20	p-value**
The maximum cytometric capacity of the bladder			
Baseline	219.33±29.49	220.2±29.35	0.831
After treatment	268.53±28.59	237.47±28.17	< 0.001
p-value*	< 0. 01	< 0. 01	
First desire to void the patients			
Baseline	154.33±19.3	155.53±19.6	0.898
After treatment	178.6±19.7	162.87±18.9	< 0.001
p-value*	< 0.001	0.001	
The maximum flow rate of patients' urination			
Baseline	5±1.8	5.17±1.9	0.822
After treatment	8.5±1.86	6.4±1.84	0.001
p-value*	0.0001	0.0001	

* Change post treatment compared to pre treatment

** Difference between the two groups

Table 3: the revised urinary incontinence scale at pre and post treatment in the both groups

	PEMFT Group n=20	PFE Group n=20	p-value**
RUIS			
Baseline	9.1±1.2	8.87±1.3	0.687
After treatment	4.9±1.1	7.47±1.2	< 0.001
p-value*	< 0.0001	0.01	

* Change post treatment compared to pre treatment

** Difference between the two groups

Table 4: Correlation of post-treatment urodynamics measurements with post-treatment of the revised urinary incontinence scale in the whole studied group (n=40)

	the revised urinary incontinence scale	
	Pearson Correlation	**p-value**
Maximum cytometric capacity	0.711	0.003
First desire to void	0.387	0.112
The maximum flow rate of patients' urination	0.560	0.001

5. Discussion:

The result of this study shows no significant differences in the maximum cytometric capacity, first desire to void, and maximum flow rate of urination between the two groups. but there the maximum cytometric capacity post treatment in PEMFT group show significant increase (percent of change 22%) more than pelvic floor muscle exercise group (percent of change 7%) (P< 0. 001).

there was significant increase in the first desire to void post treatment in PEMFT group (percent of change 15.7%) more than pelvic floor muscle exercise group (percent of change 4.7%) (P< 0.01).

The maximum flow rate post treatment in PEMFT group show significant increase (percent of change 41%) more than pelvic floor muscle exercise group (percent of change 23.7%) (P< 0.01).

There was significant decrease in the revised urinary incontinence scale (RUIS) after treatment in PEMFT group (percent of change 46%) more than pelvic floor muscle exercise group (percent of change 15.8%) (P< 0.001)

PEMFT is a completely non-invasive, safe, tolerable, and effective treatment option for urge and/or stress urinary incontinence and OAB (especially neurogenic detrusor overactivity). As showed in our study improve urodynamic parameter as maximum cytometric capacity, first desire to void and improve the flow rate of urine.

And the current study came in line with the following study which show the effect of pulsed electromagnetic field therapy on overactive bladder.

PEMFT improves local blood flow and activates the efferent neurons and motor endplates of the pelvic floor muscle, enhancing muscular strength and endurance. It may also influence the firing rate of the somatic nerve, which controls pelvic muscle and sphincter tone **[10].**

As the bladder fills, there is an increase in urethral sphincter activity accompanied by relaxation of the detrusor muscle, facilitating urinary retention. Afferent neural signals from the bladder engage central pathways that stimulate the sympathetic nervous system, promoting storage and suppressing voiding, particularly during stress or fight -or-flight responses. Additionally, certain anorectal nerve branches contribute to the inhibition of the micturition during defecation **[13]**.

FMS has been observed to induce urination, possibly by stimulating parasympathetic efferent to the bladder and exploiting the fatigue response of the detrusor and periurethral sphincter muscles. Although it may be more effective than sacral nerve root electrical stimulation for bladder evacuation, evidence of direct parasympathetic activation in humans is absent. The prevailing explanation is that detrusor contractions or bladder emptying occur as a rebound effect following the release of bladder inhibition **[14].**

FMS may suppress overactive detrusor activity, offering a straightforward and well-tolerated approach to neuromodulation. This technique could represent a more effective substitute for implanted-electrode electrical stimulation. **[15].**

In individuals with neurogenic overactive bladder secondary to suprasacral spinal cord injury, PEMFT produced more favorable urodynamic results than TENS, with a greater capacity to suppress neurogenic detrusor overactivity **[16].**

In children with voiding dysfunction, FMS was observed to produce an immediate relaxation effect on the pelvic floor. The proposed explanation attributes this to the attenuation of acute detrusor hyperreflexia. Such inhibition, conveyed via efferent bladder nerves, may alter interneural signaling within the bulbospinal reflex arc, thereby suppressing the C-fibers that predominate after neurological injury. Activation of the afferent sacral nerves through this pathway may, in turn, help mitigate bladder overactivity **[17].**

These findings may translate into sustained clinical benefits over time, a phenomenon referred to as the carry-over effect. This effect could be attributed to the influence of electrical stimulation on pelvic floor function. Adequate stimulation parameters are likely to induce such changes, indicating that bladder reflexes possess sufficient adaptability to be reconditioned or restored **[18].**

The levator ani and puborectalis muscles make up the pelvic floor. The contraction of these two muscles is considered to be included in PFM contraction **[19]**.

The levator ani, when contracted, supports evacuation during defecation and urination. In contrast, the puborectalis functions as a continence muscle, sealing the posterior urethra and anal canal through its own contraction and by assisting the external urethral and anal sphincters. Forming a U-shaped sling around both passages, it raises intraurethral and anal pressures and coordinates simultaneous tightening of the two sphincters, resulting in closure **[20].**

A recent study reported that contraction of the puborectalis muscle, together with the external anal or urethral sphincters, can inhibit detrusor activity in both the rectum and bladder. Normally, the micturition reflex is triggered when bladder filling reaches the threshold of desire, leading to detrusor contraction, internal sphincter relaxation, and urination. However, if the puborectalis and external urethral sphincter are voluntarily contracted—through intentional squeezing or pelvic floor muscle activation—internal sphincter relaxation can be prevented. This inhibition prompts a reflex detrusor relaxation, allowing the bladder to accommodate its contents. Such coordinated muscle activity is thought to suppress the micturition reflex through what is termed the "voluntary urinary inhibition reflex" **[21].**

In daily physiotherapy practice, PEMFT may be considered as an adjunct in managing neurogenic overactive bladder in patients with partial SCI above T12. However, it should not be used in individuals with pacemakers, active tumors, or undiagnosed pelvic pain.

Follow-up: after 3 months shows still improvement in maximum cytometric capacity and first desire to void and maximum flow rate and a score of revised urinary incontinence scale

5. Conclusions:

From the results, it was clear that pulsed electromagnetic field therapy (PEMFT) is a completely safe, effective, for the treatment of patients' complaints of overactive bladder after partial spinal cord injury above T12 in age group 40-30 years and no have and other disease cause neurogenic bladder.

Ethics approval statement:

Ethical approval for this research was granted by the Faculty of Physical Therapy, South Valley University, Egypt (Code: P.T-NEUR-503). The trial was additionally listed in the Pan African Clinical Trial Registry with the registration number PACTR202306754593717.

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Conflict of interests:

The authors confirm the absence of any conflicts of interest in relation to this work

Informed consent:

Informed consent has been obtained from all individuals included in this study.

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