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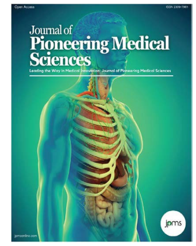

Impact of Gamified Pelvic Floor Muscle Training and Core Stabilization Exercises on Pelvic Floor Dysfunction in Hyperlordotic Osteoporotic Post-Menopausal Women

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Abstract: Objective: Hyperlordotic osteoporotic postmenopausal women (HOP) women are at risk of developing pelvic floor muscle dysfunction (PFD) due to weak pelvic floor muscles, altered spinal alignment and reduced core stability. While pelvic floor muscle training (PFMT) and core stabilization are standard interventions, gamified PFMT (GPFMT) may enhance engagement and outcomes. This study aimed to evaluate the effect of GPFMT combined with core stabilization (CSE) on PFD in this population. **Methods:** A randomized controlled trial was conducted with 74 postmenopausal women from a medical college and hospital in Tamil Nadu,India. Participants were allocated to a GPFMT group (n = 37) or traditional PFMT (TPFMT) group (n = 37). Both groups received their respective PFMT along with CSE for 1 hour/day,4 days/week over 12 weeks. Outcomes assessed were postural alignment using a digital inclinometer, core endurance using plank endurance test, pelvic floor muscle strength using the Modified Oxford Scale and QoL using the IIQ-7 SF. Data was analysed using Wilcoxon Signed Rank and Mann Whitney U tests ($p<0.05$). **Results:** The GPFMT group demonstrated greater improvements across all the outcomes compared to TPFMT, including postural alignment, core endurance, pelvic floor muscle strength and IIQ-7 SF scores ($p<0.05$). **Conclusion:** In HOP women, GPFMT combined with CSE was more effective than traditional PFMT in improving posture, core endurance, pelvic floor strength and quality of life, supporting the value of engaging, interactive rehabilitation approaches for PFD.

Key Words: Pelvic Diaphragm, Osteoporosis, Post-Menopause, Good Health and Wellbeing, Biofeedback, Myofeedback, Muscle Training

INTRODUCTION

Menopause is a natural transition, and many postmenopausal women tend to overlook their health needs, on screening their risk for pelvic flood dysfunction (PFD) [1,2]. PFD may involve hypertonocity or hypotonicity of the pelvic floor muscles (PFM), leading to impaired coordination and symptoms such as urinary or fecal incontinence, obstructive defecation, pelvic organ prolapse and sexual dysfunction, all of which significantly reduce quality of life (QoL) [3-8]. Osteoporosis affects more than 50% of adults over 50 and a large proportion of postmenopausal women, resulting in reduced bone density and a higher risk of fractures [9-11]. Spinal osteoporosis can contribute to postural deformities, particularly lumbar hyperlordosis, furthur disrupting muscular balance [12]. Women with osteoporosis and altered spinal curves frequently demonstrate reduced trunk strength, weak core musculature and degenerative lumbar changes [13-20].

PFMs play a key role in lumbopelvic stability through their synergy with abdominal muscles [21]. Lumbar curvature influences PFM activation patterns in healthy women; optimal spinal alignment supports more efficient PFM contraction during tasks that increase intra-abdominal pressure [22-24]. Hyperlordosis may reduce rectus activation during coughing, subsequently lowering PFM recruitment and impairing continence mechanisms [25]. It also limits spinal mobility and functional capacity, further reducing QoL [26]. In osteoporotic women, impaired posture, weak musculature and balanced deficits heighten the risk of falls and fractures [27].

Rehabilitation strategies for HOP women typically incorporate PFM strengthening, core stabilization exercises (CSE) and postural correction all of which promote better co-contraction and spinal alignment. Emerging evidence suggests muscle training delivered through biofeedback enabled digital platforms can enhance motivation, patient engagement and adherence to therapy [28,29].

Despite growing interest, the relationship between PFD and musculoskeletal alteration in postmenopausal women remains insufficiently understood. Shared mechanisms such as collagen and extracellular matrix changes, may underlie both osteoporosis and PFD, yet current evidence is limited. Research exploring how osteoporosis related hyperlordosis affects PFM function and coordination is scarce. Existing studies often involve small samples, lack long-term follow up or fail to account for lifestyle factors, diet or menopausal timing. Furthermore, few studies directly investigate how weak PFMs combined with hyperlordosis influence continence and daily activities in this specific population [30].

Given these gaps, integrating GPFMT with biofeedback devices such as the NeuroTrac® MyoPlus 4 Pro may offer superior improvements in PFM strength, neuromusclar coordination, adherence and functional outcomes compared with TPFMT. Therefore, this study aimed to evaluate the effectiveness of GPFMT combined with CSE on pelvic floor function, lumbar alignment and core endurance in HOP women compared with TPFMT.

METHODS

Study Design

This is a randomized controlled trial (RCT) with approval obtained from the Institutional Scientific Review Board (ISRB) of a leading medical college in India and followed the Declaration of Helsinki of 1975. The study was conducted at a leading medical college and hospital in Tamil Nadu, India.The inclusion criteria consisted of females aged 50-60, with primary osteoporosis, hyperlordosis, minimum two years post menopause, with a Body Mass Index (BMI) between 18.5 and 24.9, and parous women. The exclusion criteria included females with a history of spinal surgery as they modify the spinal curvature, biomechanics and neural structures which directly affect postural alignment [31], scoliosis as it introduces abnormal spinal curvature in multiple planes which could influence posture, muscle activation and pelvic alignment [32], abdominal girth over 35 inches as larger intra-abdominal girth can alter intra-abdominal pressure, core stability and pelvic floor loading [33],recent use (within one year) of hormonal or thyroid medications as it can influence metabolism, muscle function, and bone density, neurological diseases affecting balance as conditions like Parkinson's, multiple sclerosis, or neuropathies which impair motor coordination, core control, and pelvic reflexes. These would directly impact postural and PF assessments, making it hard to isolate the effect of the intervention [34], musculoskeletal conditions causing lower limb deformities as it alters stance, gait and spinal alignment affecting PF and posture measurements, or any history of cancer as it can cause muscle wasting, fatigue, bone demineralization, pelvic tissue fibrosis or hormonal disruption. This could affect muscular and functional outcomes.

Study Procedure

Simple random sampling was used for participant selection and a total of 122 participants were assessed for eligibility, out of which 48 were excluded based on the inclusion and exclusion criteria. The remaining 74 participants were randomized 1:1 into two groups according to random number table, created by a statistician. The allocation plan was carefully documented in sequence and sealed in opaque envelops. An independent individual, not involved in the study was responsible for opening the envelop to reveal the assigned group. One group was administered Gamified Pelvic Floor Training (GPFMT) and the other was given Traditional Pelvic Floor Muscle Training (TPFMT).

GPFMT Intervention

This group received PFMT using the NeuroTrac® MyoPlus 4 Pro, a multi-channel device integrating neuromuscular electrical stimulation and biofeedback via a vaginal probe. A distinctive feature of this system is its interactive gamified training modules, designed to improve motivation, engagement, and motor learning during PFMT.The sterilized vaginal probe covered with a condom was carefully inserted into the vagina to ensure safety and hygiene. Patients perform specific pelvic floor movements to manipulate on-screen elements, thereby enhancing muscle control, strength, and coordination. A key feature is the Aeroplane Game, which uses real-time EMG signals to control the movement of an on screen aircraft through a track filled with obstacles. The vertical motion of the aircraft corresponds to the intensity of the PFM contraction, the aircraft ascends during contraction and descends upon relaxation. The goal is to navigate through the track without crashing, thereby training the patient to achieve precise control over muscular contractions. As part of a 1-hour session, the biofeedback was incorporated for 40 minutes and CSE for 20 minutes. (Table 1).

TPFMT Intervention

This group received TPFMT in combination with CSE for 40 minutes followed by core stabilization exercises for 20 minutes. (Table 2).

The frequency and duration of sessions were standardized across groups, and each session was supervised by two physiotherapists to ensure consistency in execution. The patients were assessed using an digital inclinometer, plank endurance test, Modified Oxford Scale(MOS) and IIQ-7 before and after the intervention period.

Measures

A digital inclinometer, a reliable instrument for assessing sagittal spinal curvature with good intra-rater reliability and

Table 1: Progression of GPFMT Group

Week	GPFMT (40 mins)	CSE (20mins)	Notes
1-2	Participants performed the Aeroplane game at beginner level using short tracks emphasizing contraction accuracy, relaxation control, and familiarization with EMG feedback.	Bird-dog (static hold), cat-cow, child's pose, and supine hip flexor stretch (10 repetitions × 3 sets).	Emphasis on diaphragmatic breathing, postural awareness, and avoidance of Valsalva maneuver/bearing down.
3-4	Track length was progressively increased, with introduction of speed variations and mild visual challenges to improve coordination and endurance.	Modified plank (knees supported), dynamic bird-dog with alternating upper and lower limb movements, and cat-cow with 5-second isometric holds.	Focus on improving motor coordination and endurance capacity.
5-6	Visual and auditory distractions were introduced to challenge concentration and pelvic floor control under dual-task conditions.	Progression to use of stability ball during bird-dog and modified plank exercises, increased repetitions/hold duration, and introduction of supine bridging with pelvic floor contraction hold.	Integration of cognitive and motor dual-tasking with improved core activation.
7-8	Intermediate-level Aeroplane game with sharper directional changes, complex movement routes, and graded contraction timing tasks.	Unilateral bridging, modified side planks, progression of holds to 10 seconds, and reverse breathing pattern correction exercises.	Development of endurance, postural control, and transition stability.
9-10	Advanced game modes with higher difficulty levels and performance-based progression challenges to enhance motivation and adherence.	Dynamic planks, quadruped hip circles, and side-lying leg lifts combined with pelvic floor muscle contraction.	Simulation of functional activities including coughing and lifting using EMG-guided feedback.
11-12	Final progression included full-length tracks at maximum difficulty with postural variations such as sitting and standing EMG training, where tolerated.	Combined core stabilization exercises performed in circuit format, with addition of mild resistance bands during bridging and bird-dog exercises.	Functional integration of pelvic floor control into daily movement patterns and advanced endurance training.

Table 2: Progression of TPFMT Group

Week	TPFMT (40 mins)	CSE (20 mins)	Notes
1-2	Participants performed basic pelvic floor muscle training including Kegel exercises (5-second hold, 5-second relaxation), reverse Kegels, and quick flick contractions (5 repetitions) to improve initial muscle awareness and control.	Bird-dog (static hold), cat-cow, child's pose, and supine stretching exercises.	Emphasis on pelvic floor muscle identification, coordination, and breathing awareness.
3-4	Hold duration was progressed to 7–10 seconds with increased repetitions (10–12 repetitions), incorporating breath-synchronized contractions to improve endurance and timing.	Modified plank (10-second hold) and bridging with 5-second pelvic floor muscle contraction hold	Focus on endurance development, perineal lift technique, and minimizing accessory muscle activation.
5-6	Training progressed to functional pelvic floor contractions during sit-to-stand activities and other light functional movements.	Unilateral bridging, dynamic bird-dog, and standing core tuck exercises.	Introduction of movement-based pelvic floor training with functional integration.
7-8	Standing pelvic floor contractions were introduced, combining fast and slow contraction patterns to improve motor control and endurance.	Core stabilization combined with posture correction drills, with the addition of resistance band exercises.	Development of postural control and pelvic floor activation during upright activities.
9-10	Functional pelvic floor contractions were practiced during coughing and squatting tasks, with quick flick contractions progressed to 10 repetitions.	Progression of core stabilization and posture correction exercises with increased resistance and endurance demands.	Training pelvic floor recruitment during increased intra-abdominal pressure and dynamic activities.
11-12	Participants practiced pelvic floor engagement during simulated daily activities, such as lifting lightweight objects and transitional movements.	Circuit-based core stabilization program consisting of 5 exercises × 3 rounds, including balance training components.	Assessment and reinforcement of pelvic floor control under dynamic and functional loading conditions.

adequate inter-rater (G = 0.57–0.73) reliability in postmenopausal osteoporotic women, was used to evaluate lumbar lordosis [34]. The Miller & Hughes (2014) procedure was used to assess core endurance using the Plank Endurance Test, which showed good test-retest reliability (ICC = 0.91) [35]. The Modified Oxford Scale (MOS), a 0–5 grading system used for digital vaginal palpation, was used to measure pelvic floor strength. It demonstrated strong inter-rater reliability (Kappa = 0.73–0.81) [36]. With outstanding reliability (ICC > 0.80, Cronbach's α > 0.85), the Incontinence Impact Questionnaire SF (IIQ-7) assessed the impact on quality of life [37]. The data of the subjects was collected before and after the intervention with two clinical therapists not involved in the intervention delivery and blinded to the group to which the participants belonged. A log note was maintained to track the adherence of the participants.

Statistical Analysis

IBM Statistical Package for Social Sciences (SPSS) Statistics for Windows, Version 22 was used for analysis. Normality was assessed using Shapiro-Wilk test and showed an abnormal distribution. Descriptive statistics were used to calculate the mean and standard deviation (SD) for each outcome variable for both groups prior to and following the intervention. Paired t-tests were used for comparisons within groups and the Mann Whitney U test and Wilcoxon Signed Rank Test for comparisons between groups. Additionally, $p<0.05$ was chosen as the statistical significance level.

RESULTS

In the GPFMT group, the mean lumbar lordosis angle measured by the digital inclinometer decreased from 50.62° (±3.41) to 48.75° (±3.53) ($p<0.05$). The plank endurance

Table 3: Mann Whitney U Test Comparison both the Groups

Parameters	Post-test Value of GPFMT group	Post-test value of TPFMT group	p-value
Digital Inclinometer	48.75 ± (3.53)	49.83 ± (3.21)	<0.05
Plank Endurance Test	27±(4.21)	23.72 ± (4.90)	<0.05
MOS	3.5 ± (0.50)	3.4 ± (0.43)	<0.03
IIQ-7 Questionnaire SF	8.7 ± (2.79)	10.02 ± (2.88)	<0.05

time improved from 23.05 (±4.2) seconds to 27 (±4.21) seconds ($p<0.05$), indicating improved core endurance. The Modified Oxford Scale scores rose from 2.51 (±0.55) to 3.5 (±0.50) ($p<0.05$) with improved pelvic floor muscle strength. The IIQ-7 Questionnaire scores dropped from 10.7 (±2.77) to 8.7 (±2.79) ($p<0.05$), indicating a significant reduction in the impact of incontinence on quality of life.

In the TPFMT group, the mean lumbar lordosis angle decreased from 50.81° (±3.27) to 49.83° (±3.21) ($p<0.05$). Plank endurance increased from (22.1 ±5.17) to (23.72 ±4.90) ($p<0.05$), and modified Oxford Scale scores improved from 2.51 (±0.55) to 3.4 (±0.43) ($p<0.008$) IIQ-7 scores decreased to 10.02 (±2.88) from 10.86 (±3.04). Between-group post-test comparisons showed that the BPFMT group performed better than the TPFMT group in all domains evaluated. The between-group analysis revealed a significant decrease in the functional impact of incontinence for the digital inclinometer, plank endurance test, IIQ-7, and modified MOS ($p<0.05$ and $p<0.03$, respectively) (Table 3).

These results suggest that the GPFMT was more effective than TPFMT in improving the muscle strength, postural alignment, core endurance and QOL in HOP women.

DISCUSSION

Both TPFMT and GPFMT, when combined with core stabilization exercises, significantly improved lumbar posture, core endurance, pelvic floor strength and quality of life (QoL) in hyperlordotic osteoporotic postmenopausal women. However, across all outcomes, GPFMT demonstrates superior improvements compared to TPFMT. Participants in the GPFMT group showed greater gains in pelvic floor muscle strength, enhanced trunk endurance and better spinal realignment. These findings are consistent with previous studies highlighting improved adherence associated with biofeedback based training methods, as well as the validity of the plank test as an assessment tool for core endurance [38-39].

Similarly, QoL improvements, as measured by the IIQ-7 questionnaire, were more pronounced in the GPFMT group than in the TPFMT group. This may be attributed to the engaging nature of the gamification, which likely enhanced participant motivation and adherence. This explanation is supported by earlier research emphasizing the role of integration and autonomy in health games as important determinants of patient motivation [39]. In addition, previous studies have confirmed the effectiveness of PFMT in managing stress urinary incontinence; however, concerns regarding long-term adherence to gamified applications remain, with only 41% user retention reported at 90 days [40].

Although PFMT, with or without adjunctive interventions such as biofeedback or electrostimulation, has been shown to facilitate pelvic floor muscle contraction, earlier studies have not consistently demonstrated the superiority of adjunct-based approaches over conventional methods [41]. The discrepancy observed in the present study may be explained by the unique biomedical characteristics of the study population, along with the enhanced motivation associated with gamified biofeedback. While functional improvements were evident, these gains may not necessarily translate into osteogenic adaptions in the absence of adequate load bearing stimuli [42]. this aligns with previous literature suggesting that the effects of exercise on bone health are influenced by exercise intensity, duration and individual patient characteristics [43]. Furthermore, prior evidence indicates that the mere use of technological tools does not guarantee sustained adherence and limited evidence currently supports the superiority of multimodal PFMT over single- technique interventions [44-45].

To ensure internal validity and reliability only participants with ≥90% attendance during the 12-week intervention were included in the final analysis. This adherence threshold helped establish that the observed improvements were attributable to the intervention itself. Notably, no dropouts were recorded throughout the study, suggesting strong participant engagement, particularly within the GPFMT group, which further strengthens the credibility of the findings.

Despite these promising outcomes, several limitations should be acknowledged. First, the relatively short duration of the study may not have been sufficient to evaluate long-term physiological adaptations, such as changes in bone mineral density, or to assess sustained adherence over time. Second, although gamified biofeedback yielded superior functional outcomes, its long-term feasibility and user retention beyond the study period remain uncertain [46]. Third, despite strict exclusion criteria aimed at minimizing confounding variables, factors such as prior exercise, exposure and digital literacy may have influenced performance within the GPFMT group.

Future studies should incorporate longer follow-up periods and include bone mineral density measurements to better explore the potential osteogenic implications and long-term sustainability of functional improvements. Additionally, investigating home-based or app integrated GPFMT programs may offer solutions to long-term adherence challenges. Combining GPFMT with low impact weight bearing exercises my further optimize musculoskeletal and bone related outcomes. Moreover, tailoring gamified interfaces to meet the needs of older adults and evaluating cost effectiveness will be crucial for border clinical implementation.

Overall, the findings of the present study indicate that GPFMT, particularly when pair with biofeedback and core stabilization exercises, improves both participant engagement and clinical outcomes in hyperlordotic osteoporotic postmenopsual women with PFD. This approach appears especially beneficial for individuals with functionl deficits and poor exercise adherence. The results align closely with the primary objective of assessing the impact of GPFMT combined CSE on PFD in this population, demonstrating that the gamified approach is not only more effective than conventional PFMT techniques but also more engaging, as reflected by statistically and clinically significant improvements in posture, core endurance, pelvic floor strength and QoL.

Importantly, this study also addresses a notable gap in the literature. Most previous research has focused either on biofeedback or TPFMT in isolation, often overlooking populations with combined postural dysfunction and osteoporosis. By specifically examining HOP women, the present study provides novel biomechanical insights into the relationship between spinal alignment and pelvic floor outcomes. Furthermore, it integrates modern gamification strategies into physiotherapy management, an emerging area with limited existing evidence. Thus, the study contributes both methodologically and clinically by demonstrating how individualized, technology enhanced PFMT can improve functional outcomes and adherence in this specialized population.

CONCLUSION

This study found that GPFMT and TPFMT, when paired with core stabilization, improved pelvic floor function, core strength, and lumbar angle in HOP women. GPFMT, however, demonstrated better results in every outcome. Rehabilitation is more successful when gamification and biofeedback are used to improve motor learning and adherence. Clinically, including GPFMT into regular physiotherapy protocol may provide a more successful and engaging treatment, particularly for postmenopausal women with PFD and hyperlordosis.

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Institutional Review Board Statement

The study was approved by the institutional review board of Saveetha College of Physiotherapy Approval no: 005/12/2024/ISRB/PGSR/SCPT. All the procedures were conducted I accordance with the Declaration of Helsinki and its alter amendments.

Informed Consent Statement

Written informed consent was obtained from all participants prior to participation in the study. All participants were informed of the study purpose, procedures, associated benefits and their right to withdraw at any time.

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Conflicts of Interest

The authors declare no conflict of interest

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