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Digital Rehabilitation through Play: Improving Core Stability in Post-Abdominal Surgery Patients Using Gamified Balance Platform

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ABSTRACT

Background: Core muscle dysfunction is a common complication after major abdominal surgeries, often leading to delayed recovery, postural instability, and an increased risk of hernia recurrence. Conventional physiotherapy, though effective, may lack the engagement required for long term adherence. Integrating gamification into rehabilitation introduces an interactive and motivating approach that enhances neuromuscular coordination and patient participation. This study evaluates the effectiveness of a gamified digital balance platform in improving core stability among post abdominal surgery patients compared to traditional physiotherapy.

Objective: To evaluate the effectiveness of a gamified digital balance board in improving core stability in patients recovering from abdominal surgery by integrating interactive play based therapy with conventional rehabilitation.

Methods: A quasi experimental study was conducted on 30 participants aged 30–40 years who had undergone elective or emergency abdominal laparotomy. Participants were purposively assigned to two groups: Group A (digital rehabilitation using a gamified balance board, n = 15) and Group B (conventional core exercises, n = 15). Both groups trained thrice weekly for six weeks. Core stability was assessed using McGill's Core Endurance Tests, including trunk flexor, extensor, and side bridge endurance. Statistical analysis was performed using paired and independent t tests at a significance level of $p < 0.05$.

Results: Among the 30 participants (median age 35.5 years, 20 women), both groups showed significant improvement ($p < 0.05$), but Group A demonstrated greater gains in core stability.

Conclusion: Gamified rehabilitation using the MEND digital balance board significantly enhanced core stability compared to conventional methods. This approach presents a valuable adjunct to traditional physiotherapy, promoting better engagement and improved outcomes in post surgical recovery.

1. Introduction

Core muscle dysfunction following major abdominal surgeries is a common postoperative complication resulting from the incision into the abdominal cavity (Boden, 2016). Up to 30–50% of patients may experience prolonged postoperative weakness following abdominal surgery (Hodges, 1996). Core muscle weakness leads to delayed functional recovery and increased risk of complications such as recurrent hernia and low back pain (Kato, 2019). Core training with a balance board creates an unstable surface, forcing the body to engage deep core muscles (such as transversus abdominis, multifidus, and oblique) to maintain balance through reflexive core engagement, which is crucial after surgery (Oliva Lozano, 2020). The integration of gamification into physiotherapy has revolutionized post operative rehabilitation, offering patient centered strategies that emphasize engagement and interactive play sessions (Rehabindia, n.d.; Rehabtronics, n.d.). The MEND balance board, developed by Rymo, exemplifies this transition by fusing traditional core stability training with digital game based therapy. Unlike conventional rehabilitation, in which many suffer from monotony and low patient adherence, MEND utilizes multi directional games and progressive task difficulty to stimulate active participation and sustained motivation during recovery. Its user friendly design, rapid setup, and portability enable tailored interventions both in clinical settings and at patients' homes, facilitating

broader access to high quality therapy. It also offers an innovative approach by combining functional core training with interactive, play based tasks supported by real time visual feedback, which likely contributes to improved neuromuscular coordination, proprioception, and overall core activation (Park, 2018). Studies on similar digital devices demonstrate enhanced consistency in exercise routines, greater compliance, and measurable gains in functional outcomes compared to standard rehabilitation modalities (Arbuckle, 2025). MEND's integration of playful elements such as point scoring and rewards transforms therapy into a motivating experience that not only accelerates physical recovery but also addresses psychological barriers to adherence. As surgical volumes increase and patient needs diversify, digital gamified boards represent a promising paradigm for personalized, efficient, and enjoyable rehabilitation that meets the evolving expectations of modern healthcare delivery (Khaleghi, 2021).

Core stability plays a vital role in postural control, functional mobility, and overall recovery following abdominal surgeries (Huxel Bliven & Anderson, 2013). Traditional physiotherapy remains the mainstay of rehabilitation, but it may lack the motivational and sensory engagement necessary to maintain long term adherence and active participation. As surgical volumes increase, especially for procedures like hernia repair, cholecystectomies, and for diagnostic purpose, there is a growing demand for innovative, patient centered rehabilitation strategies that not only restore physical function but also sustain interaction. There is limited clinical evidence comparing the effectiveness of gamified balance platforms versus traditional physiotherapy in improving core stability in post abdominal surgery patients in the Indian context, leaving a research gap in the post operative abdominal surgery domain and necessitating the need for the study.

The aim of the study is to determine whether interactive, game based balance board exercises can effectively improve core stability in patients following abdominal surgical procedures. The objective of the study is to evaluate and compare improvements in core stability between the digital rehabilitation group and the conventional physiotherapy group over the intervention period.

2. Methodology

2.1. Study Design

A quasi experimental study was conducted in the Physiotherapy Department of Sri Ramakrishna Multispecialty Hospital. A total of 30 participants were recruited using a purposive non random sampling method, and the study was carried out over a period of six months. The materials required for the intervention included a gamified balance platform, connectivity equipment such as tablets, exercise mats, a plank hold timer, a BMI chart, and informed consent forms to ensure ethical participation.

2.2. Criteria for Selection of Participants

Participants included in the study were individuals aged between 30 and 40 years who had undergone either elective or emergency abdominal laparotomy with a minimum of three months of post operative period. Eligible participants were required to have the ability to ambulate independently for at least 5 meters and must have completed a minimum of three months following their operative period. Core instability was confirmed using McGill's Core Endurance Test ratios, specifically a flexor to extensor ratio ≥ 1.0, a right to left side bridge ratio within ±0.05 of 1.0, and a side bridge each side to extension ratio ≥ 0.75. Additionally, participants needed to demonstrate the ability to understand instructions and actively engage in game based digital interaction without cognitive impairments.

Patients were excluded if they had a history of neurological or neuromuscular disorders that could affect balance or coordination. Individuals with a body mass index BMI ≥ 25 kg/m² who were unable to safely use the balance board platform were also excluded. Further exclusion applied to those with pre existing musculoskeletal conditions that significantly limited mobility or balance, such as severe osteoarthritis. Patients with severe cardiopulmonary conditions that contraindicated physical exertion, or those with severe visual or vestibular impairments affecting participation in balance based digital activities, were not eligible. Finally, participants engaged in any other concurrent core stability rehabilitation program were excluded from the study.

2.3. Procedure

The outcome measure of this study focused on core stability, which was assessed using McGill's Core Stability and Endurance Tests. Participants were divided into two intervention groups, each comprising 15 individuals. Group A received digital rehabilitation through a gamified balance platform, while Group B underwent conventional physiotherapy exercises. In this design, core stability was considered the dependent variable, as it reflected the effectiveness of the interventions. The independent variables included the two types of interventions: digital gamified balance board exercises for Group A and conventional physiotherapy exercises for Group B. This structure allowed for a comparative evaluation of whether gamified digital rehabilitation provides greater improvements in core stability than standard physiotherapy approaches.

Baseline and post intervention assessments were conducted using McGill's Core Endurance Test, which evaluates trunk flexor endurance, trunk extensor endurance, and side bridge performance. Each participant was allowed to perform one short practice trial to familiarize themselves with the test position, followed by a single actual test trial per position. The outcome measure was defined as the maximum duration, in seconds, for which the participant was able to maintain the static position.

The intervention consisted of core instability training delivered for 40 minutes per session, three times per week, over a total period of six weeks amounting to approximately 120 minutes of training per week. This structured program ensured uniformity across both groups, allowing for reliable comparison of intervention outcomes. Figure 1 illustrates the flowchart of the study protocol, including patient recruitment, eligibility screening, and purposive non random allocation into Group A gamified balance board training and Group B conventional physiotherapy. The reporting of this quasi experimental study followed the TREND guidelines, and the intervention description was structured according to the TIDieR checklist for non pharmacological interventions to ensure transparency and replicability.

2.4. Ethical Issues and Informed Consent

Ethical approval was obtained from the Institutional Ethics Committee of Sri Ramakrishna Hospital, Coimbatore, Tamil Nadu, India (Approval No.: COPT/MPT/ETHICS/01/2024). All participants who underwent the study provided informed consent. The committee members reviewed the protocol, and participants signed the consent form after complete explanation of the study.

2.5. Determination of Sample Size

The technique used for sample size calculation was a reference based method adopted from the article by Alves *et al.* (2025).

$$n = 2\left(Z1-\alpha/2 + Z1-\beta\right)^2 / d^2$$

Two sided $\alpha = 0.05$
$Z1-\alpha/2 = 1.96$
Power = 90%
$Z1-\beta = 1.281$
$Z1-\alpha/2 + Z1-\beta = 3.241$
Standardized effect size Cohen's $d \approx 1.15$

Sample size was calculated using the mean difference ($\Delta \approx 11.5$) and pooled standard deviation ($\sigma \approx 10$) derived from Alves *et al.* (2025). Assuming a two sample t test, two sided $\alpha = 0.05$ and 90% power, the required sample size was 16 per group (total N = 32).

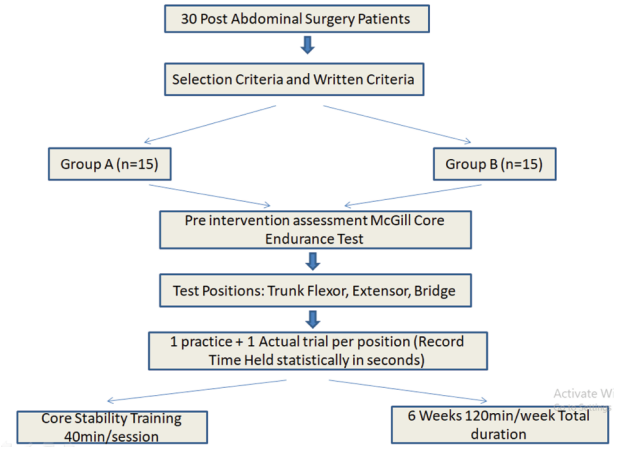


Figure 1: Flowchart of the Study Protocol, including Patient Recruitment, Eligibility Screening, and Purposive (non-random) Allocation into Group A and Group B.

2.6. Intervention Protocol for Group A

All participants underwent a standardized warm-up and cool-down phase consisting of 5 minutes each of general body stretches, including spinal twisting and flexion, to ensure safe muscle activation and relaxation.

For Group A (Gamified Balance Board Training), patients were trained across six multidirectional tasks with three progressive difficulty levels in each direction. The exercises included: (1) standing balance on the board, (2) squatting on the board, (3) crunch position, and (4) arms extended forward with knees flexed on the board. Static balance training was administered over a period of 3 weeks (9 sessions), with each session lasting 5 minutes, a radius setting of 6 degrees, and support provided with foam cushioning. Patients experiencing more than two falls during training were excluded from the study.

Subsequently, dynamic balance training was provided for another 3 weeks (9 sessions) at difficulty levels 1, 2, and 3, with a set time of 5 minutes per session, a radius range set at 10 degrees, and a 2 minute rest period between exercises to prevent fatigue and ensure safety.

Figure 2A demonstrates how the MEND device integrates interactive gaming in both the frontal and sagittal planes, targeting recruitment of all abdominal muscles. The games are designed to promote multidirectional movement and muscle activation, supporting rehabilitation or training objectives.

The frontal plane gaming (image on the left) focuses on movements that engage muscles responsible for lateral or side to side actions, such as the obliques and lateral abdominal wall. The sagittal plane gaming (image on the right) involves forward and backward motions, targeting muscles such as the rectus abdominis and deeper core stabilizers.

Figure 2B displays the record of a participant performing a "Static Balance Mode" using a digital balance platform. The interface summarizes several important parameters:

- Total Time: 00:38 seconds
- Balance Time: 00:11 seconds spent in a steady, stable position
- Imbalance Time: 00:25 seconds spent outside the stable threshold
- No. of Falls: 10, indicating the number of times the participant lost balance or exceeded a set stability limit
- Frontal or Sagittal Angle: 03° or 00°, indicating deviation from a neutral standing posture

In the center, a trace map shows the participant's center of pressure movement, with the red dot likely indicating the mean or reference position. The blue line demonstrates postural sway, representing how much the participant's balance fluctuated during the test.

Figure 2D displays six different game modes available for patients in the Rymo rehabilitation system, designed to make therapy engaging and interactive.

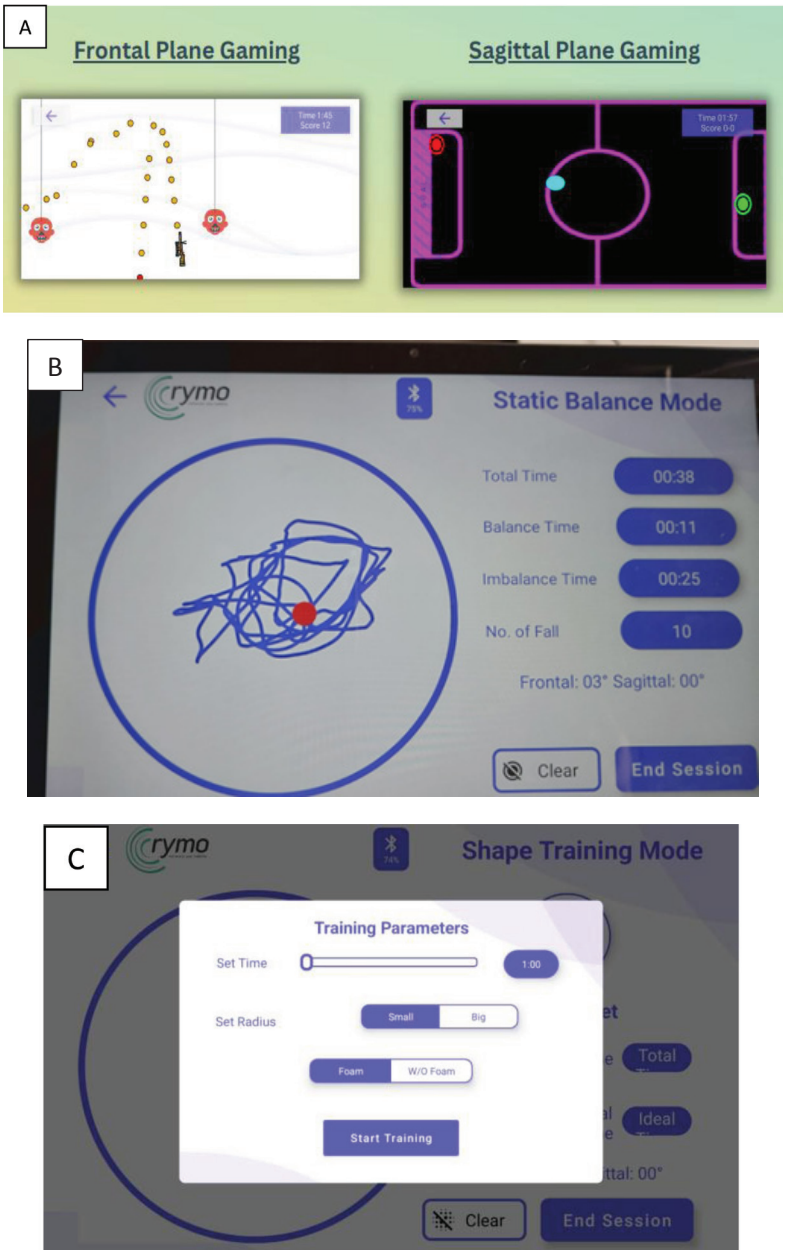


Figure 2. Gamified Balance Training using the MEND Digital Balance Board. (A) Integrative gaming tasks performed in both the frontal and sagittal planes. (B) Performance record of a participant in Static Balance Mode. (C) Adjustable training parameters, including set time and set radius. (D) Overview of the six available game modes used during the intervention.

Figure 3A illustrates the flowchart of the training protocol for Group A.

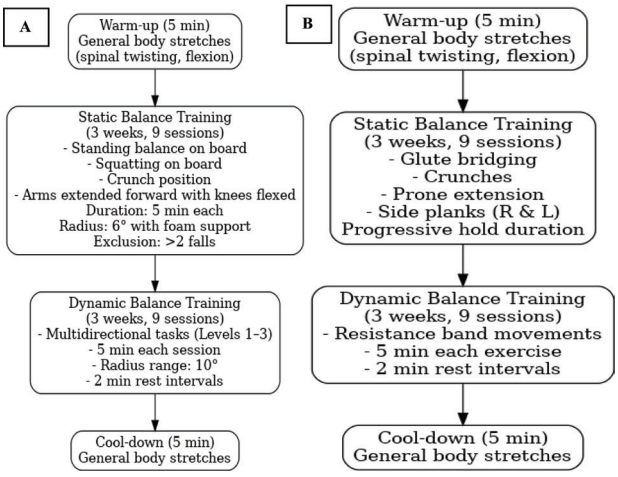


Figure 3: Flowcharts Illustrating the Training Protocols. (A) Training protocol for Group A, gamified digital balance board intervention. (B) Training protocol for Group B, conventional core training intervention.

Overview of Game Modes: The screen is titled "Let's play, Raj H," indicating a personalized approach to patient engagement. Six game modes are shown, with each represented by a colored card (yellow or red), which may denote levels or categories of play.

Listed Game Modes:

- Zombie Attack
- Star Boat
- Hot Air Balloon
- Snow Surfer
- Space Invasion
- Neon Hockey

Game Functionality: Each game likely targets specific motor skills, reaction time, and engagement for patient rehabilitation. The cards may allow selection and adjustment of difficulty or mode, supporting personalized therapy plans.

2.7. Intervention for Group B

For Group B (Conventional Core Training), patients performed a series of core stabilization exercises, including glute bridging, crunches, prone extension, and side planks (right and left). Static balance training was conducted over 3 weeks (9 sessions), with progressive increases in hold duration to enhance endurance and stability. Following this, dynamic balance training was administered for an additional 3 weeks (9 sessions), incorporating resistance band–based movements to challenge core control and coordination. Each exercise was performed for a duration of 5 minutes, with a 2-minute rest interval between exercises to allow recovery and minimize fatigue.

3. Results

3.1. Participant Demographics and Baseline Characteristics

A total of 30 participants (median age: 35.5 years; 20 women, 10 men) were enrolled and allocated into two groups using purposive (non-random) assignment: Group A (gamified digital balance platform, n = 15) and Group B (conventional core training, n = 15). Group comparability was ensured by recruiting participants who met the same inclusion criteria during the same time period and then distributing them into the two intervention arms so that the overall distribution of age, gender, type of surgery, and baseline core stability values remained similar between groups. Core muscle weakness was confirmed for all participants by McGill's Core Endurance Test ratios at entry.

3.2. Within-Group Analysis: Pre- and Post-Intervention

- **Group A: Gamified Balance Board Training**

The mean pre-intervention core stability score for Group A was 14.00 seconds. After the six-week intervention with the MEND gamified platform, post-test scores rose significantly to an average of 25.70 seconds. The mean improvement was 11.70 ± 4.62 seconds. Statistical testing revealed a highly significant change ($t = 9.83$, $p < 0.05$), indicating robust gains in core endurance and control among participants receiving digital gamification.

- **Group B: Conventional Core Training**

Group B started with a mean core stability score of 14.60 seconds. Following conventional static and dynamic balance exercises, post-test scores increased to 21.33 seconds. The mean improvement was 6.73 ± 2.26 seconds, with significant results ($t = 5.822$, $p < 0.05$), demonstrating effectiveness of conventional rehabilitation, though less pronounced than the gamified intervention.

3.3. Between-Group Analysis: Comparative Effectiveness

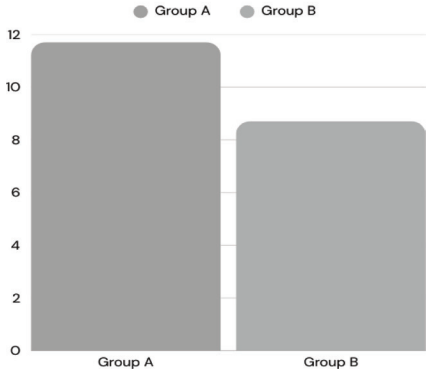
The difference in mean improvement between Group A (11.70 ± 4.62 seconds) and Group B (6.73 ± 2.26 seconds) was statistically significant ($t = 3.077$, $p < 0.05$). Group A exhibited greater absolute improvement in post-intervention core stability scores, supporting the enhanced efficacy of the gamified balance platform over traditional core training. These results remained consistent after adjustment for baseline imbalances and participant adherence.

The percentage improvement in Group A was nearly double that of Group B, suggesting the gamified approach is not only statistically superior but also clinically meaningful for restoring core stability post-abdominal surgery. Participants in Group A demonstrated better trunk flexor, extensor, and lateral endurance, as measured by McGill's Core Endurance Tests. No serious adverse events or dropouts were reported in either group throughout the intervention period. Group A had three participants who experienced more than two falls in the initial training sessions, but all completed therapy safely and without injury after adjustment of session difficulty and added foam pads for support. Overall compliance rate exceeded 95% for both groups, confirming high participant engagement and adherence to the regimen.

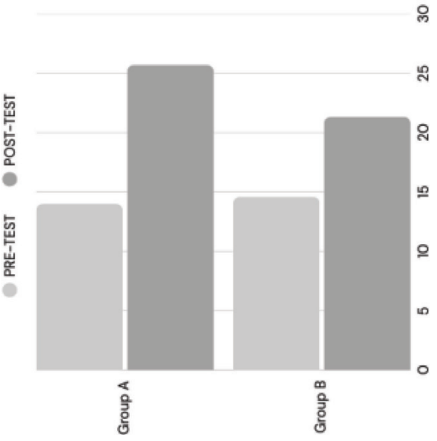
Qualitative feedback from therapists noted higher patient motivation, engagement, and enjoyment during gamified training compared to conventional modalities. Participants in Group A reported that interactive elements—such as point scoring and progressive difficulty—contributed to sustained interest and perceived challenge, which may have played a role in enhanced outcomes.

As shown in the bar graph, Group A (gamified balance board training) demonstrated a marked improvement from a baseline mean of 14.00 seconds to 25.70 seconds after the six-week program. In contrast, Group B (conventional core training) improved from 14.60 seconds to 21.33 seconds. The visual trend supports the statistical findings reported earlier, indicating that although both interventions were effective, the improvement was more pronounced in Group A.

Graph 2 shows the comparative improvement scores between the two groups. Group A achieved a mean improvement of 11.70 seconds, whereas Group B improved by 6.73 seconds. This graphical comparison reinforces the between-group analysis, where the difference in improvement was statistically significant ($t = 3.077$, $p < 0.05$). The larger bar height for Group A visually confirms the superior effectiveness of the gamified platform in enhancing core endurance.



Graph 1: Difference in Mean Improvement between Group A and Group B



Graph 2: Mean Pre and Post Intervention Core Stability between Group A and Group B

Table 1: Demographic Data of the Participants

S.no	Variables	Gender	Training Group	Control Group
1	Gender (n)	Male Female	6 9	7 8
2	Age (years)	Male Female	36.2 ± 2.8 34.4 ± 3.2	36.2 ± 2.4 36.4 ± 3.2
3	Weight (kg)	Male Female	80.63 ± 13.71 54.3 ± 3.79	72.81 ± 5.18 59.94 ± 7.13
4	BMI (kg/ m^2)	Male Female	24.4 ± 2.51 23.5 ± 6.03	22.39 ± 1.97 22.46 ± 2.49
5	Surgery (n)	Male Female	2 - Herniotomy 4 - Cholecystectomy 5 - Cesarean 4 - Hysterectomy	6 - Herniotomy 1 - Appendicectomy 3 - Cesarean 5 - Cholecystectomy

4. Discussion

Core stabilization exercises strengthen the deep muscles of the back area, such as multifidus and transversus abdominis muscles, enhancing coordination and trunk stabilization (Aldhuhoori, 2021). A significant challenge in balance training is maintaining engagement and motivation, particularly for individuals undergoing long-term rehabilitation (Barry, 2014). Balance exercises can often be repetitive and monotonous, causing patients to lose interest. This lack of engagement can result in poor adherence to the training regimen, ultimately slowing progress (Deltombe, 2017).

The findings of this study clearly demonstrate that gamified balance board rehabilitation using MEND led to significantly greater improvements in core stability compared to conventional physiotherapy for post-abdominal surgery patients. Psychological barriers, such as fear, often prevent individuals from pushing their limits or attempting more challenging exercises, which is essential for improvement (Fitton Davies, 2024). Critically, integrating game elements such as scoring and progressive challenges—helped overcome typical barriers in rehabilitation, notably boredom and poor adherence, which often hinder sustained engagement during recovery (Jorge Fernando, 2010).

Recent evidence from neurorehabilitation, orthopedic, and balance disorder research affirms the superiority of gamified platforms in promoting consistent patient participation and meaningful functional outcomes (Sulfikar Ali, 2021). Gamified systems adapt dynamically to the patient's skill level, maintaining motivation through personalized feedback and attainable challenges, which is a proven strategy for enhancing adherence and accelerating progress (Jorge Fernando *et al.*, 2023). Techniques like point scoring, leader boards, and rewards can motivate patients to actively participate in their rehabilitation process (Fitton Davies, 2024).

Core stability exercises initiated three months postoperatively for abdominal surgery patients have shown greater collagen and tensile strength without the risk of fascial dehiscence (Stéphanie Perrodin, 2023). Research shows that exercises like squatting with an unstable load can activate core muscles more effectively and increase balance and center of pressure (COP) displacement. The unstable load condition results in greater displacement in the COP, whereas the unstable surface condition has a more significant impact compared to stable conditions (Sardi, 2017).

Therefore, the training method of this study using the MEND digital balance board is beneficial for improving both dynamic and static core endurance and stability in abdominal surgery patients, enhancing functional ability and preventing future complications such as hernia. Risk of injury was minimized using foam pads. Future recommendations include larger, randomized samples and extended follow-up periods to validate and expand upon these findings. Investigations into the specific components of gamification that most influence clinical outcomes, as well as cost-effectiveness, will further guide the integration of digital rehabilitation tools into mainstream physiotherapy.

5. Conclusion

The findings of this study demonstrate that post-abdominal surgery patients who underwent gamified digital rehabilitation using the MEND balance board achieved significantly greater improvements in core stability compared to those receiving only conventional physiotherapy. The interactive, game-based digital approach not only produced superior objective outcomes on validated endurance tests but also fostered higher participant engagement and adherence throughout the recovery process.

The evidence supports the use of digital rehabilitation tools to enhance both the effectiveness and experience of core stability training, potentially leading to faster and more

sustainable functional recovery in this population. Future research involving larger, randomized samples and extended follow-up is recommended to confirm these findings and further explore the role of gamified digital therapies in routine postoperative care.

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Authorship Contribution

Methodology, Data Collection, Data Analysis: K. Sowndarya
Writing, Review & Editing: K. Saravanan
Supervision / Guidance: A. Ahamed Thajudeen

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Ethical Approvals

Ethical approval was obtained from the Institutional Ethics Committee of Sri Ramakrishna Hospital, Coimbatore, Tamil Nadu, India (Approval No.: COPT/MPT/ETHICS/01/2024).

Declarations

The authors declare that this work is original and has not been submitted elsewhere for publication. All data, methodologies, and system components have been developed and reported in adherence to academic standards. All referenced materials have been duly cited, and the authors accept full responsibility for the integrity and accuracy of the findings presented.

Conflict of Interest

The authors declare no conflict of interest related to this study.

Data Availability Statement

The authors declare that the data supporting the conclusions of this study can be obtained upon request from the corresponding author. The data are not publicly accessible due to restrictions, as they contain information that may compromise the privacy of the research participants.

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