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Original article

Restoring Function: Evidence-Based Rehabilitation Strategies for Motor, Sensory, and Balance Deficits after Spinal Anaesthesia in Zawia City

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Abstract
Patients undergoing spinal anaesthesia for caesarean delivery often experience temporary motor and sensory deficits, typically regaining the ability to sit within 4-6 hours. While long-term complications are rare, effective rehabilitation remains limited. Anaesthesia mainly affects lower-limb motor function and dorsal column sensitivity, affecting 97% of patients. Early physiotherapy, particularly passive range-of-motion exercises within 40 days post-surgery, can improve motor recovery and shorten hospital stays; evidence shows that targeted mobilisation and therapeutic exercises outperform standard care. This research examines rehabilitation strategies for women after caesarean delivery, focusing on deficits, pain, and recovery. Thirteen women participated in a 3-month programme in Zawia, Libya, from February to April 2026. An experimental design was used to assess pain, motor, and sensory functions before and after rehabilitation, using standardised scales and balance tests. We collected data on height, weight, abdominal dimensions, pain intensity, and recovery assessment responses. Analysis was conducted using SPSS V27 and paired-samples t-tests, with a significance level of $p < 0.05$. Some follow-up data were missing due to attendance concerns. The findings indicate that the evidence-based rehabilitation programme markedly improved physical, functional, and clinical outcomes for patients with deficits after spinal anaesthesia in Zawia City. Participants experienced decreased abdominal and pelvic measures, improved body composition, and significant decreases in pain intensity. The Oswestry Disability Index showed increases in functional independence, which led to statistically significant improvements in all assessed variables, demonstrating the programme's efficacy in recovering function and improving quality of life.
Keywords. Rehabilitation Strategies, Restore Function, Pain, Spinal Anaesthesia and Recovery.

Introduction

Patients undergoing spinal anaesthesia for caesarean delivery frequently experience transitory motor and sensory deficits, with most people able to sit within 4-6 hours following surgery [1,2]. Rare traumatic nerve injuries can cause long-term problems that necessitate therapy, but the evidence for effective rehabilitation is sparse. Lower limb motor weakness and substantial dorsal column function anomalies are common side effects of spinal anaesthesia, whereas low-dose labour techniques generally preserve these functions [3]. According to the World Federation of Societies of Anaesthesiologists [WFSA] (2018), a global safety standards clinical investigation found that all spinal anaesthesia patients experienced lower limb weakness and 97% had impaired dorsal column function, compared to only 10% and 7% in low-dose labour regimens. However, there is a dearth of data on long-term persistent abnormalities after routine spinal anaesthesia [4].

Targeted physiotherapy combined with early rehabilitation under neuraxial anaesthesia after cesarean section speeds up the recovery of motor function and reduces hospital stays [5]. Research shows that planned passive range-of-motion exercises within the first 24 hours improve motor recovery as measured by the Bromage scale. Early mobilisation protocols on the day of surgery shorten hospital stays and speed functional recovery [6]. Additionally, compared to standard care, early supervised therapeutic exercise improves Functional Movement Screen scores. Although intraoperative supplementation may be required, lower concentrations of local anaesthetic, such as 0.4% Ropivacaine in combination with spinal epidural, can shorten sensory and motor block periods and speed up the return of limb function.

Early mobilization, passive range of motion, structured kinesitherapy, and soft tissue treatments are effective for post-spinal anaesthesia motor impairments, whereas multimodal analgesia and focused myofascial therapy address sensory/pain complaints. The Bromage scale, Functional Movement Screen, NPRS, and ODI are examples of commonly used evaluation tools [7].

The Oswestry Disability Index (ODI) and Numerical Pain Rating Scale (NPRS) are two common clinical instruments used to assess people with low back pain. The ODI assesses how pain affects day-to-day functioning, whereas the NPRS evaluates the severity of pain. Physiotherapists, chiropractors, and orthopaedic specialists usually utilize both ratings in order to establish a baseline, monitor progress, and customize treatment regimens [8].

Balance and functional rehabilitation

Specific balance-focused therapies following spinal anaesthesia are less well defined in the available trials; however, functional training and gait/ADL practice are important components of programs that enhance general mobility. Previous studies suggest that task-oriented training and progressive activities are effective in restoring independence [5]. Kinesitherapy programs that incorporate task practice, gait, and ADL training have been linked to improved long-term

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motor ability as measured by Functional Movement Screen testing. Outpatient physical therapy focuses on gait, strength, and activities of daily living (ADLs) for patients with persistent unilateral weakness or paraparesis following neuraxial anaesthesia. The examined studies do not provide controlled trials, particularly separating balance rehabilitation methods. For example, vestibular or instrumented balance [4]. Furthermore, recent local clinical evidence in the Libyan healthcare context, specifically in Zawia City, strongly supports the superior efficacy of structured physical rehabilitation protocols over standard passive recovery in accelerating pain reduction and restoring lower-limb motor efficiency [9].

Methods

The study involved 13 women post-cesarean section participating in a 3-month rehabilitation program. An experimental design assessed pain, motor, and sensory functions using standardized assessments. Key evaluations included pain scales, motor and sensory function tests, and balance assessments, focusing on 13 participants from a training centre in Zawia, Libya. Data collection occurred before and after rehabilitation, specifically in February and April 2026. Tools used included the Oswestry Disability Index, Numeric Pain Rating Scale (NPRS), a recovery assessment questionnaire, and measurements of body mass index (BMI). Pre- and post-operative metrics included weight, height, circumferences, and thickness; body fat was assessed with a handheld monitor, and pain levels were measured using a Visual Analogue Scale (VAS). Overall, this experimental study aimed to evaluate recovery through structured assessments.

Research Tools and Methodology

The rehabilitation program outlined in this study incorporates two primary interventions aimed at addressing pregnancy-related musculoskeletal changes and complications from spinal anaesthesia. The first component is an Aerobic & Cardiovascular Exercise Protocol that includes cardio sessions on specialised equipment such as treadmills and stationary bicycles, as well as floor-based aerobic movements. The objective is to improve cardiorespiratory endurance, enhance systemic blood circulation, and reduce fluid retention (oedema) in the lower limbs. The second intervention is the Targeted Resistance & Muscle Strengthening Protocol, which focuses on core musculature, lumbar region, pelvic floor, and lower extremities. This protocol utilizes body weight, elastic resistance bands, weighted bars, free weights, and rehabilitation resistance machines. Its clinical goal is to restore structural strength of the abdominal and pelvic areas, improve dynamic joint stability affected by pregnancy-induced laxity, and alleviate localised back pain related to spinal anaesthesia.

To monitor progress and assess the effectiveness of the rehabilitation interventions, two clinical testing techniques are utilized as key outcome measures [10]:

- The Active Straight Leg Raise (ASLR) Test and the Straight Leg Raise (SLR) Test. The ASLR Test, where the patient actively elevates a lower limb to 20°-30°, assesses pelvic load transfer and stability, with reduced discomfort indicating improved neuromuscular control.
- The SLR Test involves the examiner passively elevating the patient's leg between 45°-70°, evaluating neural tension related to lumbar disc stress. A positive Lasègue's Sign indicates nerve root irritation, and its resolution serves as a marker for reduced nerve compression and successful lumbar rehabilitation.

Statistical Methods

Data were analyzed using the Statistical Package for the Social Sciences (SPSS V27). Descriptive statistics, including means and standard deviations, were used to summarise participants' measurements before and after the rehabilitation intervention. To evaluate the effectiveness of the evidence-based rehabilitation program, paired-samples t-tests were conducted to compare pre- and post-intervention scores for anthropometric measurements (abdominal thickness, pelvic thickness, abdominal circumference, and pelvic circumference), body composition indicators (body fat percentage and body mass index), pain-related measures, and functional assessment outcomes. Statistical significance was determined at the 0.05 level ($p < 0.05$). In addition, effect sizes (Cohen's d) were calculated to assess the magnitude of change associated with the intervention, with values of 0.20, 0.50, and 0.80 interpreted as small, medium, and large effects, respectively.

Ethical Approval

An ethical approval statement outlines the procedures followed in a recent investigation involving thirteen eligible volunteers. Before their enrollment, participants received comprehensive information regarding the study's objectives, potential benefits, evaluation methods, and rehabilitation program. They were made aware of their right to withdraw from the study at any time without compromising their ongoing medical care. Each volunteer provided written informed consent before any baseline assessments or therapeutic activities commenced. Throughout the trial, personal, anthropometric, and clinical data remained confidential, utilising anonymised identifiers for statistical purposes.

Results

The results were presented using tables, frequencies, percentages, means, standard deviations, t-values, p-values, and effect size estimates to provide a comprehensive evaluation of the rehabilitation program's effectiveness in restoring function following spinal anaesthesia.

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Table 1. Changes in Abdominal and Pelvic Dimensions Following the Rehabilitation Program

Index	Rehabilitation strategy	Mean	Sd	Test Value	P value	Effect Size
Abdominal Thickness	Pre	40.00	0.000	7.761	< 0.001	2.871
	Post	37.51	0.847			
Pelvic Thickness	Pre	40.00	0.000	11.078	< 0.001	3.073
	Post	37.67	0.577			
Abdominal Circumference	Pre	118.08	4.769	12.232	< 0.001	3.393
	Post	112.92	4.958			
Pelvic Circumference	Pre	113.15	8.581	3.599	0.004	0.998
	Post	106.77	9.799			

Table 1 presents the changes in abdominal and pelvic dimensions following the implementation of the rehabilitation program. The results demonstrated statistically significant improvements across all measured anthropometric indicators between the pre- and post-intervention assessments.

For abdominal thickness, the mean value decreased from $M = 40.00$ ($SD = 0.00$) before the intervention to $M = 37.51$ ($SD = 0.85$) after the intervention. This reduction was statistically significant $t = 7.761$, $p < 0.001$) and was associated with a very large effect size ($d = 2.871$), indicating a substantial impact of the rehabilitation program on abdominal thickness. Similarly, pelvic thickness showed a significant decrease from $M = 40.00$ ($SD = 0.00$) at baseline to $M = 37.67$ ($SD = 0.58$) following the intervention. The difference was statistically significant, $t = 11.078$, $p < 0.001$, with a very large effect size ($d = 3.073$), suggesting a strong treatment effect.

Regarding abdominal circumference, participants demonstrated a significant reduction from $M = 118.08$ ($SD = 4.77$) before the program to $M = 112.92$ ($SD = 4.96$) after completing the rehabilitation program. The statistical analysis revealed a highly significant difference, t = 12.232, p < 0.001, accompanied by a very large effect size (d = 3.393), reflecting marked improvement in abdominal measurements. Likewise, pelvic circumference decreased significantly from M = 113.15 (SD = 8.58) to M = 106.77 (SD = 9.80). This change was statistically significant, t = 3.599, p = 0.004, with a large effect size (d = 0.998), indicating that the rehabilitation program contributed meaningfully to reducing pelvic circumference.

The findings indicate that the evidence-based rehabilitation program produced significant reductions in abdominal and pelvic dimensions, with large to very large effect sizes, highlighting its effectiveness in improving physical outcomes among individuals experiencing functional deficits following spinal anaesthesia.

Table 2. Comparison of Body Fat Percentage and Body Mass Index (BMI) Before and After the Rehabilitation Intervention

Index	Rehabilitation strategy	Mean	Sd	Test Value	P value	Effect Size
Body Fat Percentage	Pre	44.05	7.023	4.217	0.001	1.170
	Post	38.22	3.902			
BMI	Pre	34.15	4.670	5.645	< 0.001	1.566
	Post	31.28	3.794			

Table 2 presents a comparison of body fat percentage and body mass index (BMI) before and after the rehabilitation intervention. The findings revealed statistically significant improvements in both indicators following participation in the rehabilitation program.

For body fat percentage, the mean value decreased from $M = 44.05$ ($SD = 7.02$) at the pre-intervention assessment to $M = 38.22$ ($SD = 3.90$) at the post-intervention assessment. This reduction was statistically significant, $t = 4.217$, $p = 0.001$, with a large effect size ($d = 1.170$). These results indicate that the rehabilitation intervention was effective in reducing body fat levels among participants. Correspondingly, body mass index (BMI) showed a significant decline following the intervention. The mean BMI decreased from $M = 34.15$ ($SD = 4.67$) before the rehabilitation program to $M = 31.28$ ($SD = 3.79$) after the intervention. Statistical analysis confirmed that this difference was highly significant, $t = 5.645$, $p < 0.001$, and was associated with a large effect size ($d = 1.566$), suggesting a substantial improvement in participants' body composition and weight-related status. Generally, the results demonstrate that the rehabilitation intervention produced significant reductions in both body fat percentage and BMI, with large effect sizes. These findings provide strong evidence that the rehabilitation program was effective in improving body composition and reducing obesity-related indicators among participants following spinal anaesthesia.

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Table 3. Comparison of Pain Intensity, Functional Disability, and Clinical Assessment Scores Before and After the Rehabilitation Intervention

Index	Rehabilitation strategy	Mean	Sd	Test Value	P value	Effect Size
Pain Assessment	Pre	8.62	0.870	33.594	< 0.001	9.317
	Post	1.54	0.877			
Oswestry Disability Index (ODI)	Pre	3.23	1.092	4.436	< 0.001	1.230
	Post	0.85	1.405			
Active Straight Leg Raise (ASLR)	Pre	4.31	1.494	7.709	< 0.001	2.138
	Post	0.31	0.855			
Neuropathic Pain Scale (NPS)	Pre	1.77	0.439	3.323	0.006	0.557
	Post	1.08	0.641			

Table 3 presents a comparison of pain intensity, functional disability, and clinical assessment scores before and after the rehabilitation intervention. The results demonstrated statistically significant improvements across all measured outcomes, indicating the effectiveness of the rehabilitation program in reducing pain and enhancing functional performance.

For pain assessment, participants exhibited a substantial reduction in pain intensity, with mean scores decreasing from M = 8.62 (SD = 0.87) before the intervention to M = 1.54 (SD = 0.88) after the intervention. This change was highly significant t = 33.594, $p < 0.001$) and was associated with an exceptionally large effect size (d = 9.317), reflecting a profound reduction in perceived pain following the rehabilitation program.

Similarly, scores on the Oswestry Disability Index (ODI) decreased significantly from M = 3.23 (SD = 1.09) at baseline to M = 0.85 (SD = 1.41) after the intervention. The difference was statistically significant, t = 4.436, $p < 0.001$, with a large effect size (d = 1.230), indicating a marked improvement in functional ability and a reduction in disability-related limitations.

For the Active Straight Leg Raise (ASLR) test, the mean score improved significantly from M = 4.31 (SD = 1.49) before treatment to M = 0.31 (SD = 0.86) after treatment. Statistical analysis revealed a highly significant difference, t = 7.709, $p <$ 0.001, accompanied by a very large effect size (d = 2.138). This finding suggests considerable enhancement in Lumbopelvic stability and lower-limb functional performance.

In addition, scores on the Neuropathic Pain Scale (NPS) decreased from M = 1.77 (SD = 0.44) before the intervention to M = 1.08 (SD = 0.64) afterwards. This reduction was statistically significant, t = 3.323, p = 0.006, with a moderate effect size (d = 0.557), indicating a meaningful improvement in neuropathic pain symptoms.

Overall, the findings demonstrate that the rehabilitation intervention resulted in significant reductions in pain severity, functional disability, and neuropathic pain symptoms, while substantially improving clinical functional performance. The large to extremely large effect sizes observed across most measures provide strong evidence for the effectiveness of the evidence-based rehabilitation program in restoring function following spinal anaesthesia.

Discussion

The main objective of this experimental study was to determine the clinical efficacy of a structured, evidence-based physical rehabilitation program in reducing motor-sensory deficits, localised and neuropathic pain, and body composition changes in women who had a caesarean delivery under spinal anaesthesia. The implementation of a multidisciplinary treatment protocol, which included progressive aerobic training and focused lumbopelvic resistance exercises, resulted in extremely significant improvements across all analysed measures. These quantitative findings provide strong support for early, structured physical therapy versus traditional, passive postpartum recovery methods.

Anthropometric Variation and Structural Change

The experimental results demonstrated substantial decreases in all abdominal and pelvic parameters following intervention. The abdominal circumference dropped considerably (M -pre = 118.08 cm vs. (M-post = 112.92 cm; p < 0.001), indicating a considerable clinical effect size (d = 3.393). Concurrently, pelvic circumference decreased significantly (M- pre = 113.15) cm to (M-post = 106.77) cm; p = 0.004, d = 0.998. These significant differences underscore the structural influence of the targeted resistance program, which specifically targeted core muscles, the lumbar region, and the pelvic floor.

During pregnancy, mechanical loads and hormonal changes cause significant ligamentous laxity and rectus abdominis separation. Standard postpartum care seldom causes neuromuscular remodelling in these structural tissues. Participants experienced targeted muscle activation by performing progressive resistance movements with free weights, elastic bands, and specialised gym equipment. Structural reconditioning restored mechanical stress to the linea alba and lumbopelvic girdle, resulting in significant reductions in abdominal and pelvic thickness (p < 0.001, effect sizes > 2.8).

Body Composition Optimisation

The multi-modal technique produced significant changes in body composition in addition to structural modifications. The

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mean body mass index (BMI) of the individuals decreased considerably from 34.15 ± 4.67 kg/m^2 at baseline to 31.28 ± 3.79 kg/m^2 after rehabilitation ($p < 0.001$, $d = 1.566$). Concurrently, the average percentage of body fat dropped from 44.05% to 38.22% ($p = 0.001$, $d = 1.170$). These results are consistent with fundamental concepts in exercise physiology. Progressive cardiorespiratory exercise using treadmills and stationary bicycles effectively increased cardiorespiratory endurance, optimised lipid oxidation, and accelerated metabolic expenditure. Additionally, systemic and micro-hemodynamics were improved by frequent cardiovascular exercise, which helped resolve lower-limb oedema and chronic post-surgical fluid retention. These systemic changes attest to the exercise regimen's essential physiological function in promoting metabolic recovery.

Furthermore, systemic and micro-hemodynamics were improved by frequent cardiovascular exercise, which helped resolve lower-limb oedema and chronic post-surgical fluid retention. These systemic changes attest to the exercise regimen's critical physiological function, supporting both regional structural musculoskeletal tissue regeneration and metabolic recovery.

Pain Reduction and Neural Deficit Decompression

The significant reduction in pain intensity was the investigation's most notable clinical result. From a severe pre-intervention mean score of 8.62 ± 0.87 to a mild post-intervention mean of 1.54 ± 0.88, perceived pain intensity significantly decreased. This modification had a significant treatment impact, as evidenced by the remarkably large statistical effect size ($t = 33.594$, $p < 0.001$, $d = 9.317$). Additionally, there was a substantial decrease in neuropathic pain symptoms as measured by the Neuropathic Pain Scale (NPS) (M-pre = 1.77 vs M-post = 1.08; $p = 0.006$, $d = 0.557$), which directly indicated a decrease in complications linked to spinal anaesthesia.

Several clinical processes account for the significant decrease in local lumbar back pain and peripheral neuropathic symptoms. First, spinal anaesthetic needle insertion frequently results in regional myofascial stress, trigger point development, and dural sac irritation, requiring compensatory muscle splinting in the erector spinae and quadratus lumborum. Progressive kinesitherapy's soft tissue mobilisation reduced defensive muscle guarding and nociceptive signals. Second, strengthening the deep core and lumbopelvic stabilisers (such as the transversus abdominis and multifidus) shifted mechanical pressures away from the damaged lumbar tissues during functional movements, minimizing further microtrauma at the injection site.

Improvements in Functional Performance and Lumbopelvic Stability

The functional gains found in the research are directly related to the decreases in disability and pain. The Oswestry Disability Index (ODI) scores reduced dramatically from 3.23 ± 1.09 to 0.85 ± 1.41 ($p < 0.001$, $d = 1.230$), indicating a considerable increase in functional independence during everyday activities. This functional recovery is well supported by objective clinical testing results.

The mean score of the Active Straight Leg Raise (ASLR) test significantly improved from an impaired pre-intervention baseline of 4.31 ± 1.49 to a practically entirely resolved post-intervention mean of 0.31 ± 0.86 ($t = 7.709$, $p < 0.001$, $d = 2.138$). Biomechanically, the ASLR test assesses the efficacy of load transmission across the lumbopelvic girdle during dynamic lower-limb loading. A good ASLR performance necessitates synchronized, active force closure by the core musculature to support the sacroiliac joints at 20° to 30° angles. The marked decrease in pain and effort during this test objectively demonstrates that the targeted resistance workouts restored neuromuscular motor control and dynamic pelvic stability. Furthermore, the clinical resolution of the passive Straight Leg Raise (SLR) test within the 45°-70° range clearly indicates nerve decompression. The resolution of a positive Lasègue's sign suggests that the multi-modal program helped reduce mechanical stress and irritation around the lumbar nerve roots. This neuro-mechanical decompression, together with increased muscle force closure across the pelvis, explains the considerable improvement in functional impairment as measured by the ODI scores.

Clinical Limitations and Technological Considerations

While the statistical results clearly show the clinical success of this rehabilitation strategy, several methodological limits must be carefully considered. The initial research plan was to follow twenty (20) post-cesarean women for a full 6-month period. However, significant participant compliance and attendance issues in Zawia City led to an incomplete final dataset. As a result, the data analysis was limited to thirteen (13) totally compliant patients who systematically followed the demanding three-month exercise plan.

To account for the missing follow-up measurements while maintaining statistical reliability, a paired-samples t-test with pairwise deletion was used. The unusually large effect sizes (Cohen's d) seen across the majority of clinical measurements suggest that, despite the small sample size, the physiological improvements produced by the complying individuals were robust and highly significant. Nonetheless, these attendance issues underscore the real-world logistical difficulties of postpartum rehabilitation in local healthcare settings, underlining the importance of accessible, patient-centred exercise paths.

Conclusion

This study assessed the prevalence of motor-sensory deficits post-spinal anaesthesia for cesarean deliveries and

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assessed a targeted physical rehabilitation program's effectiveness in alleviating these issues among women in Zawia, Libya. The research focused on postpartum functional impairments such as joint laxity, lumbopelvic instability, neuropathic pain, and alterations in body composition. Pre- and post-intervention assessments revealed significant improvements across physical, functional, and anthropometric measures, supporting the effectiveness of a structured rehabilitation program that included progressive aerobic conditioning and resistance training. Significant findings highlighted reductions in abdominal and pelvic dimensions, decreased body mass index (BMI), and improvements in pain intensity and functional disability as indicated by the Oswestry Disability Index (ODI). Biomechanical and neural testing showed substantial gains, including enhanced lumbopelvic stability and reduced neural tension, indicating the program's efficacy in addressing post-anaesthesia deficits. Recommendations for clinical practice stress the importance of integrating evidence-based rehabilitation as a standard component of post-spinal anaesthesia recovery, initiating programs early, adopting a holistic treatment approach, utilizing objective monitoring, fostering interdisciplinary collaboration among healthcare professionals, and customizing therapeutic exercise plans to meet individual patient needs. Future research should focus on expanding sample sizes, conducting long-term follow-ups, comparing different rehabilitation modalities, addressing attendance barriers, and exploring broader recovery outcomes, including health-related quality of life and psychological well-being. This study provides a foundation for improving postpartum care and highlights the necessity for ongoing investigation in the field of obstetric rehabilitation.

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Conflicts of Interest
The authors declare that they have no conflicts of interest regarding the publication of this paper.

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