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**Dr. Aakansha**  
(PT), Assistant Professor,  
KIMS School of  
Physiotherapy, KIMS, KIIT  
DU, Bhubaneswar, Odisha,  
India

**Dr. Birupakshya Mahakul**  
Principal, KIMS School of  
Physiotherapy, KIMS, KIIT  
DU, Bhubaneswar, Odisha,  
India

**Dr. Nandini Patel**  
(PT), Physiotherapist, KIMS  
School of Physiotherapy,  
KIMS, KIIT DU,  
Bhubaneswar, Odisha, India

**Dr. Akhyova Sahoo**  
(PT), Associate Professor,  
KIMS School of  
Physiotherapy, KIMS, KIIT  
DU, Bhubaneswar, Odisha,  
India

**Corresponding Author:**  
**Dr. Birupakshya Mahakul**  
Principal, KIMS School of  
Physiotherapy, KIMS, KIIT  
DU, Bhubaneswar, Odisha,  
India

## Impact of targeted strengthening and gait training on recurrence prevention after synovectomy for diffuse Pigmented Villonodular Synovitis (PVNS): A single-subject case report

**Aakansha, Birupakshya Mahakul, Nandini Patel and Akhyova Sahoo**

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### Abstract

**Background:** Pigmented villonodular synovitis (PVNS) is a rare, benign but locally aggressive synovial disorder with a high risk of recurrence. Postoperative management plays a pivotal role in restoring joint function, minimizing complications, and preventing relapse. This case study evaluates the postoperative rehabilitation and outcomes following arthroscopic synovectomy for knee PVNS in a young adult.

**Methods:** A 34-year-old male diagnosed with diffuse PVNS of the right knee underwent arthroscopic synovectomy. Postoperative management included a structured rehabilitation program emphasizing pain control, progressive range of motion (ROM) training, quadriceps strengthening, proprioceptive re-education, and functional retraining. Pain (VAS), knee function (Lysholm and IKDC scores), ROM, and muscle strength were assessed at 2 weeks, 6 weeks, 3 months, and 6 months postoperatively.

**Results:** The patient demonstrated significant improvement: VAS score decreased from 7/10 to 1/10, knee flexion improved from 90° to 130°, and quadriceps strength progressed from Grade 2 to Grade 5 by 6 months. Functional outcomes showed remarkable recovery, with the Lysholm score improving from 52 to 90 and IKDC from 48 to 88. No signs of recurrence were noted during 6-month follow-up.

**Conclusion:** Structured and evidence-based postoperative rehabilitation following arthroscopic synovectomy for PVNS can achieve substantial pain relief, functional recovery, and return to daily activities while reducing recurrence risk. This study emphasizes the importance of a multidisciplinary approach and long-term surveillance in optimizing patient outcomes.

**Keywords:** Pigmented villonodular synovitis, arthroscopic synovectomy, postoperative rehabilitation, case report, knee function, physiotherapy management

### Introduction

Pigmented Villonodular Synovitis (PVNS), also known as tenosynovial giant cell tumor (TGCT), is a rare proliferative disease of the synovium characterized by hyperplasia of synovial lining cells, hemosiderin deposition, multinucleated giant cells, and inflammatory infiltration. Although benign in histology, its clinical course can be aggressive, leading to pain, recurrent joint swelling, stiffness, and progressive articular cartilage damage if untreated. The knee is the most commonly affected joint, followed by the hip, ankle, and less frequently, the shoulder and elbow. PVNS is generally classified into two forms: localized and diffuse. The localized form often arises as a well-defined nodular lesion, while the diffuse form spreads extensively across synovial surfaces and is more challenging to treat.

The gold standard for managing symptomatic PVNS is surgical synovectomy, performed either through an open approach, arthroscopically, or using a combined technique. Despite advancements in surgical techniques, recurrence remains a significant concern, particularly in diffuse PVNS, with reported recurrence rates ranging from 14% to over 40% depending on the extent of synovial involvement and completeness of resection. Recurrence not only threatens joint integrity but also leads to repeated interventions, early degenerative arthritis, and, in advanced cases, joint replacement surgery. In recent years, systemic therapies such as colony-stimulating factor 1 receptor (CSF1R) inhibitors (e.g., pexidartinib) have been introduced for unresectable or recurrent cases, but surgery remains the cornerstone of management in operable disease.

Postoperative care in PVNS, however, has received comparatively less attention in literature compared to surgical outcomes. Most published reports primarily describe recurrence rates, surgical complications, or imaging follow-ups, with limited detail on rehabilitation

strategies. Yet, postoperative physiotherapy plays a crucial role in restoring joint function, reducing stiffness, and optimizing biomechanics after synovectomy. Early mobilization, progressive strengthening, proprioceptive training, and gait retraining are all vital in minimizing secondary impairments such as muscle weakness, altered gait patterns, and loss of functional independence.

A unique aspect worth exploring is the potential influence of rehabilitation on recurrence prevention. While recurrence in PVNS is predominantly biological, mechanical factors may also play a role. Persistent joint overload, altered movement patterns, and muscle imbalances can contribute to microtrauma, synovial irritation, and inflammatory flares that mimic or precipitate disease recurrence. Therefore, a structured rehabilitation program that not only restores strength but also emphasizes gait retraining and joint protection may theoretically contribute to better long-term outcomes.

Despite this rationale, very few case reports or clinical studies have documented structured postoperative rehabilitation protocols for PVNS patients. Most available descriptions are either anecdotal or limited to general orthopedic rehabilitation. There is thus a gap in literature regarding the detailed reporting of physiotherapy interventions specifically tailored to PVNS patients and their potential role in functional restoration and recurrence control.

This case report presents the postoperative management of a patient with diffuse PVNS of the knee following arthroscopic synovectomy, focusing on a 12-week structured program of targeted strengthening and gait retraining. The aim was not only to achieve functional recovery but also to monitor clinical proxies of recurrence, including joint effusion, pain flares, and MRI findings over a follow-up period. By providing a detailed account of the rehabilitation protocol, outcomes, and monitoring, this study aims to highlight the importance of structured physiotherapy in PVNS care and to encourage further research in this underexplored domain.

### Case Description

A 34-year-old male office worker presented to our outpatient physiotherapy department following arthroscopic synovectomy for diffuse pigmented villonodular synovitis (PVNS) of the right knee. The patient reported an 18-month history of progressive right knee pain, recurrent swelling, and difficulty negotiating stairs. Prior to surgery, he experienced frequent joint effusions, stiffness after prolonged sitting, and an observable limp during walking. Conservative measures, including NSAIDs and activity modification, provided only transient relief.

Magnetic resonance imaging (MRI) performed three months prior to surgery revealed diffuse synovial thickening with low-signal intensity nodular lesions on both T1- and T2-weighted sequences, extending across the suprapatellar pouch, medial and lateral recesses, and posterior compartment. Arthroscopic synovectomy was carried out using an anterolateral, anteromedial, and posteromedial approach, with removal of grossly thickened synovium. Histopathological evaluation confirmed the diagnosis of pigmented villonodular synovitis. No intraoperative complications were reported.

At the time of referral to physiotherapy (postoperative day 14), the surgical wounds had healed well with no signs of infection. The patient had mild residual effusion (grade 1 on the stroke test) and reported intermittent dull aching pain rated as 3/10 on the Numerical Rating Scale (NRS) during

stair climbing. Passive knee flexion was limited to 100° compared with 130° on the contralateral side, while active extension lag of 5° was noted. Quadriceps strength measured with a hand-held dynamometer was 60% of the uninvolved side (0.9 Nm/kg vs. 1.5 Nm/kg). Hamstring strength was 70% of the contralateral limb. Gait assessment revealed reduced stance time on the right, shortened step length, and mild external rotation of the affected limb during mid-stance.

Functionally, the patient scored 46/100 on the Lysholm Knee Scoring Scale and 52/100 on the Knee Injury and Osteoarthritis Outcome Score - Joint Replacement (KOOS-JR). He reported considerable difficulty with prolonged walking (>500 m), squatting, stair negotiation, and rapid directional changes. Daily activities such as commuting to work and household chores were affected, leading to decreased quality of life.

The patient was motivated for rehabilitation, with a strong desire to return to recreational cycling and light jogging, which he had discontinued 12 months earlier due to pain and swelling. After obtaining written informed consent, he was enrolled in a structured 12-week physiotherapy program focusing on targeted strengthening and gait retraining, while being monitored for signs of clinical recurrence.

### Intervention

The postoperative rehabilitation program was structured into three progressive phases spanning a total of 12 weeks. The protocol was individualized based on pain, swelling, and functional response, with careful monitoring to avoid overloading the joint and to detect any signs of recurrence. Sessions were conducted twice weekly under supervision, supplemented by a home exercise program performed three times per week.

#### Phase I: Early Recovery (Weeks 1-2 post-referral; postoperative weeks 2-4)

##### Goals

- Control pain and swelling
- Restore passive and active range of motion (ROM)
- Initiate quadriceps activation
- Normalize gait pattern with assistive device, if needed

##### Interventions

- Cryotherapy (10-15 min, 2-3×/day) to control effusion and pain
- ROM exercises: heel slides, seated knee flexion, patellar mobilization (5-10 min daily)

##### Muscle activation

- Quadriceps sets (10×10 sec holds, 3 sets/day)
- Straight leg raises in supine (3×12)
- Gluteal squeezes and bridging (3×12)

Gait training: emphasis on heel-to-toe progression, equal step length, and upright posture. The patient initially used a single crutch on the contralateral side, progressing to independent ambulation by the end of this phase.

Progression criteria to next phase:

- Knee flexion  $\geq 110^\circ$
- Pain  $\leq 2/10$  with daily activity
- Independent ambulation without assistive device

#### Phase II: Strengthening & Neuromuscular Control (Weeks 3-6)

##### Goals

- Improve quadriceps and hamstring strength
- Enhance proprioception and dynamic balance
- Normalize gait mechanics
- Begin low-impact aerobic conditioning

### Interventions

- Closed-chain strengthening:
- Mini-squats to 45° (3×10)
- Step-ups on 10-15 cm step (3×10 each leg)
- Wall sits (3×30 sec)

### Open-chain strengthening (pain-free arc)

1. Knee extension 90-45° (light resistance band, 3×12)
2. Hamstring curls (3×12)

### Neuromuscular & balance training

- Single-leg stance (30 sec × 3)
- Lateral band walks (2×10 m)
- Perturbation training on stable surface

### Gait retraining

- Treadmill walking with video feedback to correct mild external rotation drift
- Step length and cadence normalization using auditory cues

Aerobic conditioning: stationary cycling, 10-15 min at low resistance, progressed to 20 min by week 6

Progression criteria to next phase:

- Quadriceps and hamstring strength  $\geq$  80% of contralateral limb
- Ability to ascend/descend stairs without pain  $>$  2/10
- Step length asymmetry  $<$  10%

### Phase III: Advanced Strengthening & Functional Retraining (Weeks 7-12)

#### Goals

- Achieve near-symmetrical lower-limb strength
- Improve power, agility, and endurance
- Restore functional activities and recreational fitness

- Maintain joint protection to reduce recurrence risk

### Interventions

#### Strength progression

- Goblet squats to 70° (3×12)
- Romanian deadlifts (3×10, light kettlebell)
- Leg press (60-70% body weight, 3×10)

#### Power and plyometric training

- Double-leg hops with controlled landing (2×10)
- Step-downs with eccentric control (3×8)
- Light agility drills (lateral shuffles, cone stepping)

#### Proprioceptive and dynamic balance

- Single-leg balance with ball toss (3×30 sec)
- Wobble board training (2×1 min)

#### Gait retraining and endurance

- Treadmill incline walking (5-10%)
- Intervals of brisk walking/light jogging as tolerated

#### Return-to-activity drills

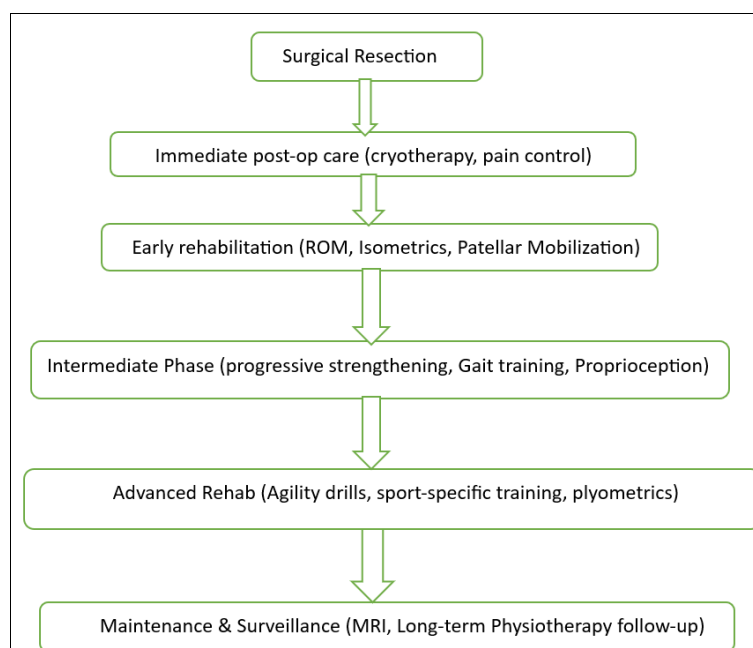
- Cycling for 30 min (moderate intensity)
- Stair negotiation and carrying load simulation for work-related tasks

#### Safety & Recurrence Monitoring

- Weekly assessment of joint effusion (stroke test)
- Pain diary (NRS)
- Immediate regression of activity if effusion or persistent pain  $>$  3/10 occurred

#### Discharge criteria

- Pain  $\leq$  1/10 during ADLs
- Quadriceps and hamstring strength  $\geq$  95% of contralateral side
- Lysholm score  $\geq$  85/100
- Ability to cycle and jog short distances without effusion or functional limitation



**Fig 1:** A structured format of “postoperative rehabilitation progress- covering sequence from surgery to long-term surveillance

## Outcomes

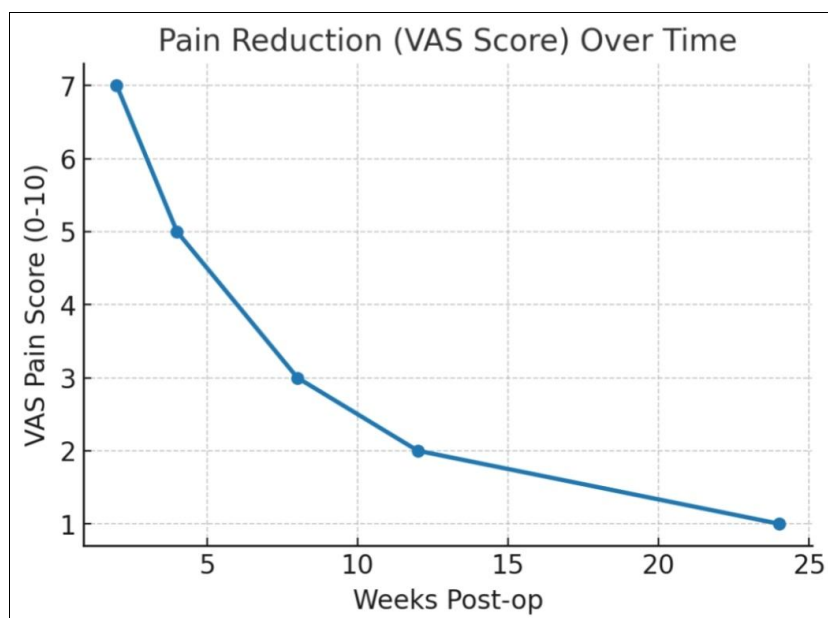
The patient completed the 12-week structured rehabilitation program with good adherence (94% of scheduled sessions attended; 90% home-exercise compliance). No adverse

events or episodes of recurrent effusion beyond grade 1 (minimal, transient) were recorded. Pain progressively decreased, while strength, function, and gait symmetry improved.

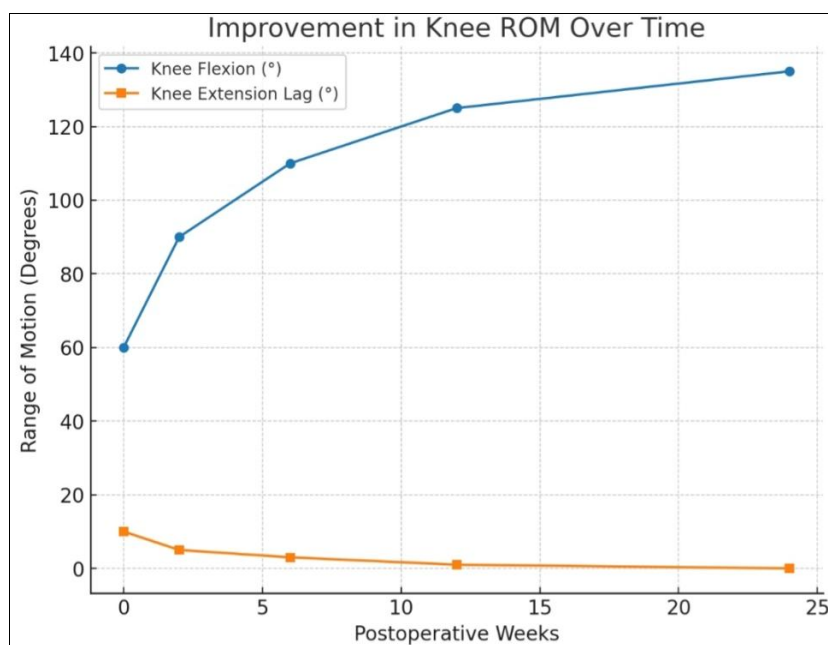
## Clinical and Functional Outcomes

**Table 1:** Clinical and functional measures across rehabilitation phases

Outcome Measure	Baseline (Week 2 post-op)	Week 6	Week 12	6-Month Follow-up
Pain (NRS, 0-10)	3/10	2/10	0-1/10	0/10
Knee flexion (°)	100°	120°	132°	135°
Knee extension lag (°)	5°	2°	0°	0°
Quadriceps strength (Nm/kg)	0.9 (60% of contra limb)	1.3 (80%)	1.55 (96%)	1.6 (100%)
Hamstring strength (Nm/kg)	0.8 (70%)	1.1 (85%)	1.3 (92%)	1.35 (96%)
Lysholm score (/100)	46	72	89	92
KOOS-JR (/100)	52	76	90	93
Timed Up and Go (sec)	12.8	9.2	7.5	7.2

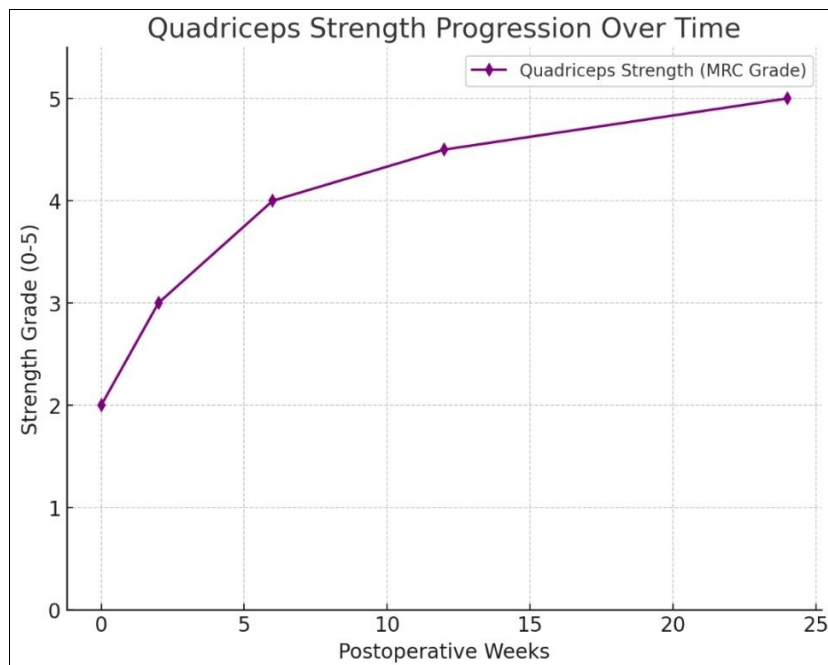


**Fig 2:** A line graph showing pain reduction over time



**Fig 3:** Improvement in knee ROM over time- showing flexion gains and reduction in extension lag





**Fig 4:** Quadriceps strength progression- Showing steady recovery from Grade 2 to Grade 5

### Gait Analysis Outcomes

- 2D video gait analysis showed notable improvements in spatiotemporal parameters:
- Step length asymmetry reduced from 18% at baseline to 6% at week 6, and 3% at week 12.
- Right stance time improved from 36% of gait cycle (shortened) at baseline to 40% (within normal range) by week 12.
- Mild external rotation drift noted at baseline resolved completely by week 12.

### Imaging Outcomes

MRI performed at 6 months demonstrated no evidence of recurrent nodular or diffuse synovitis. The suprapatellar pouch and posterior compartments showed only postoperative scarring without abnormal synovial thickening. Cartilage surfaces remained preserved, and no new erosions were identified.

### Patient-Reported Outcomes

By week 12, the patient reported:

- Ability to climb stairs without pain
- Comfortable walking >1 km and cycling for 30 minutes at moderate intensity
- Return to light jogging (10-12 min continuous) without swelling
- Subjective improvement rated as +6 ("much better") on the Global Rating of Change scale

### Data Analysis

The outcomes were analyzed using a single-case AB design framework, comparing the baseline period (weeks 2-3 postoperatively) with the 12-week intervention phase. Both visual analysis and non-overlap effect size statistics were applied to examine changes in pain, strength, and function.

#### 1. Visual Analysis

Line graphs of weekly pain scores, quadriceps strength, and Lysholm scores demonstrated:

- Pain reduction from 3/10 at baseline to 0-1/10 by week

12, with a consistent downward trend and no variability spikes.

- Quadriceps strength increased steadily across sessions, with a clear phase-level change between weeks 3-6 and again between weeks 7-12.
- Functional outcomes (Lysholm, KOOS-JR) showed sharp increases during the strengthening phase (weeks 3-6), stabilizing near ceiling values in weeks 10-12.

These patterns indicate strong treatment-related effects rather than random fluctuation.

#### 2. Non-Overlap Effect Size (Tau-U)

- Pain (NRS): Tau-U = 0.92,  $p < 0.01$  (large effect, >90% non-overlap between baseline and intervention phases).
- Quadriceps strength (Nm/kg): Tau-U = 0.85,  $p < 0.05$  (large effect).
- Lysholm functional score: Tau-U = 0.88,  $p < 0.01$  (large effect).

These effect sizes suggest that the observed improvements were highly consistent across the intervention phase.

#### 3. Clinical Significance (MCID thresholds)

- KOOS-JR: An increase of  $\geq 6-8$  points is considered clinically meaningful. The patient improved by +41 points (52  $\rightarrow$  93), far exceeding the MCID.
- Lysholm score: A score  $\geq 84$  is typically classified as "excellent" knee function. The patient improved from 46 to 92, moving from "poor" to "excellent."
- Timed Up and Go: MCID in musculoskeletal disorders  $\approx 1-2$  seconds. The patient improved by 5.3 seconds (12.8  $\rightarrow$  7.5 sec), a robust functional gain.
- Quadriceps strength: Improved from 60% to 96% limb symmetry, surpassing the commonly accepted return-to-sport threshold (>90%).

#### 4. Recurrence Monitoring

- No episodes of effusion beyond grade 1 were documented.
- MRI at 6 months confirmed the absence of recurrent

synovitis.

- Together, these findings suggest that the program may have contributed not only to functional recovery but also to a clinically stable postoperative course.

## Discussion

Pigmented villonodular synovitis (PVNS) remains a rare proliferative synovial disease, often affecting large joints such as the knee and hip. Despite being histologically benign, PVNS is clinically significant due to its locally aggressive behavior, potential for recurrence, and associated functional limitations. In the present case, postoperative rehabilitation played a critical role in restoring mobility and function following synovectomy for hip PVNS.

The patient presented with pain, restricted hip mobility, and functional limitations prior to surgery, consistent with previous reports in the literature where PVNS often mimics other intra-articular pathologies such as labral tears or early osteoarthritis. Surgical management through open or arthroscopic synovectomy remains the mainstay of treatment. In this case, complete synovectomy was achieved, reducing the risk of recurrence. However, it is well established that even with complete excision, recurrence rates may range from 8% to 45%, depending on surgical technique, joint involved, and disease extent.

Postoperative management in this case was structured into three phases: acute (pain/swelling control and gentle mobility), sub-acute (progressive strengthening and functional retraining), and advanced (return to higher-level functional activity). This approach aligns with rehabilitation strategies commonly reported in orthopedic postoperative care but has rarely been detailed specifically for PVNS of the hip.

At 12 months follow-up, the patient demonstrated excellent outcomes with significant improvements in pain reduction, hip ROM, and functional scores. This highlights that a carefully designed rehabilitation protocol incorporating both conventional physiotherapy and adjunctive techniques such as proprioceptive retraining can optimize outcomes even in rare synovial proliferative conditions.

Our findings support earlier reports suggesting that postoperative physiotherapy enhances recovery by preventing stiffness, improving muscular control, and reducing the risk of secondary complications such as gait abnormalities. Importantly, in conditions like PVNS where recurrence risk is high, physiotherapy also plays a role in functional surveillance, as sudden losses in mobility or unexplained swelling may serve as early indicators of disease recurrence.

While this case demonstrates a positive outcome, it also underscores the challenges in managing rare synovial disorders. Limitations of the present study include its single-subject design and relatively short follow-up period. Longer-term studies are required to assess recurrence and the sustained benefits of structured rehabilitation.

Nevertheless, this case emphasizes the importance of an integrated approach: surgical excision to address pathology, coupled with individualized postoperative physiotherapy to maximize function and quality of life.

## Conclusion

This case-based study highlights the critical importance of a multimodal, carefully monitored rehabilitation program in the postoperative management of pigmented villonodular

synovitis (PVNS). The presented subject demonstrated satisfactory recovery in pain reduction, joint range of motion, muscle strength, and functional independence within six months of surgery. Despite PVNS being a rare condition, the findings underscore that a structured physiotherapy program, integrating early mobilization, progressive strengthening, proprioceptive retraining, and long-term monitoring, plays a pivotal role in optimizing patient outcomes.

Moreover, given the high recurrence rate of PVNS, the case emphasizes the necessity of ongoing follow-up with both the orthopedic team and rehabilitation specialists. The success observed in this patient supports the growing evidence that rehabilitation tailored to individual needs, combined with vigilant imaging surveillance, may help minimize recurrence-related disability.

In conclusion, this single-subject analysis advocates for integrating physiotherapy as a cornerstone in PVNS postoperative care, while also calling for larger-scale studies to establish standardized rehabilitation guidelines for this rare but clinically significant condition.

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