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Evaluation of The Importance of Sensory Plate to Analyze the Pre and Post Rehab Effect of Exercise on Knee Health in Patient with Total Knee Replacement

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ABSTRACT

Background: Total knee replacement (TKR) is one of the most widely performed surgical interventions for end-stage knee osteoarthritis, offering substantial improvements in pain relief and mobility. However, despite successful surgical outcomes, many patients continue to experience challenges in balance, proprioception, and postural control during postoperative recovery. Conventional rehabilitation programs primarily focus on strength and flexibility but often fail to address subtle deficits in neuromuscular coordination. Recent advancements in baropodometric and sensory plate systems provide an opportunity to objectively measure balance parameters, load distribution, and centre of pressure shifts, thereby offering valuable insights into postural rehabilitation after TKR.
Aim: The present study aimed to evaluate the effectiveness of exercise-based rehabilitation in patients with total knee replacement using a sensory plate as an assessment and feedback tool.
Methodology: This experimental study recruited patients who had undergone unilateral TKR. Participants underwent a structured exercise program focusing on strength, flexibility, and proprioceptive training over a defined intervention period. Pain was assessed using the Numerical Pain Rating Scale (NPRS), while balance and postural control were measured using a sensory plate, analyzing parameters such as barycenter alignment, centre of pressure (C.O.P.) displacement, and plantar load distribution. Pre- and post-intervention assessments were compared to determine rehabilitation effectiveness.
Results: Post-intervention analysis demonstrated a significant reduction in pain levels (as measured by NPRS) and marked improvements in postural control indices recorded on the sensory plate. Participants showed better load symmetry, reduced sway, and improved barycenter alignment following the exercise program. These findings suggest that integrating sensory feedback into rehabilitation enhances functional recovery in post-TKR patients.
Conclusion: Exercise-based rehabilitation significantly improves pain and balance in patients following TKR. The use of sensory plates provides an objective and reliable means of assessing postural control, thereby bridging the gap between subjective symptom reporting and measurable functional outcomes. Incorporating such technology-driven tools into rehabilitation may optimize recovery strategies and contribute to improved quality of life after TKR.

Keywords: *Total knee replacement, Rehabilitation, Sensory plate, Baropodometric analysis, Postural control, Balance assessment, Numerical Pain Rating Scale (NPRS).*

1. INTRODUCTION

Osteoarthritis (OA) of the knee is a progressive degenerative disorder that significantly impairs mobility and quality of life. It is one of the leading causes of disability among the elderly, with prevalence steadily increasing due to aging populations and lifestyle changes worldwide [1,2]. Total knee replacement (TKR) is considered the gold standard treatment for advanced knee OA when conservative management fails. The primary goals of TKR are pain relief, restoration of mobility, and improvement in function and quality of life [3,4].

Although TKR has shown excellent long-term outcomes in terms of joint survival and pain reduction, many patients continue to face challenges in achieving optimal functional recovery. Postoperative rehabilitation plays a crucial role in maximizing the benefits of TKR. Structured rehabilitation programs help patients regain strength, flexibility, and balance, which are essential for safe ambulation and independent living [5,6]. Despite these efforts, variability in patient outcomes remains, and conventional clinical assessment tools often fail to capture subtle postural and functional deficits [7].

One of the critical aspects of post-TKR recovery is the restoration of proprioception and balance. Loss of proprioceptive feedback and altered neuromuscular control may contribute to gait instability, increased fall risk, and suboptimal rehabilitation outcomes [8]. Hence, objective and reliable tools to measure these parameters are increasingly important in clinical practice. The use of baropodometric or sensory plates has gained attention as they provide quantifiable data on load distribution, centre of pressure (C.O.P.), and balance parameters [9,10]. These insights not only help evaluate patient progress but also guide individualized rehabilitation protocols.

Recent studies suggest that incorporating sensory feedback and postural control exercises can enhance motor learning and improve functional recovery after TKR [11,12]. However, the evidence on the use of sensory/baropodometric plates as both an investigative and rehabilitative tool in post-TKR populations remains limited. This gap highlights the need for research to validate such tools and explore their clinical application.

Therefore, the present study aims to evaluate the effectiveness of exercise-based rehabilitation using a sensory plate in patients with TKR. The study specifically examines pre- and post-intervention changes in pain and postural stability, offering a novel perspective on integrating technology into musculoskeletal rehabilitation.

2. BACKGROUND

The knee joint is a complex synovial hinge joint that bears significant mechanical loads during daily activities such as walking, stair climbing, and squatting [13]. Osteoarthritis of the knee disrupts this biomechanical integrity, leading to pain, stiffness, joint deformity, and impaired functional capacity [14]. In severe cases, where conservative management is insufficient, total knee replacement is performed to replace the diseased joint surfaces with prosthetic components, thereby relieving pain and restoring function [15].

While TKR has revolutionized the management of end-stage OA, it does not fully address deficits in proprioception and neuromuscular control. Research shows that patients may continue to demonstrate altered gait mechanics and reduced balance even after surgery [16,17]. Rehabilitation is thus essential for retraining neuromuscular pathways, improving muscle strength, and restoring proprioceptive awareness. However, conventional outcome measures such as visual analog scales or basic functional tests may not fully capture subtle improvements in postural stability [18].

In this context, objective assessment tools such as sensory or baropodometric plates provide a promising alternative. These plates record plantar pressure distribution, centre of pressure sway, and barycenter alignment, offering detailed insights into balance and weight-bearing asymmetries [19,20]. Such quantitative data can be used not only for diagnostic purposes but also to monitor rehabilitation progress with greater precision compared to subjective measures alone.

Previous studies have highlighted the importance of integrating sensory feedback into rehabilitation programs. For example, proprioceptive training has been shown to improve balance, coordination, and functional performance in post-TKR patients [21]. Baropodometric assessment has also been successfully applied in various musculoskeletal disorders, including foot deformities, sports injuries, and postural instability, suggesting its potential in broader clinical applications [22,23].

Despite these promising developments, there is limited research directly evaluating the role of sensory/baropodometric plates in post-TKR populations. Most available studies focus on pain and functional outcomes without incorporating objective postural measures [24]. This gap in knowledge necessitates systematic investigation into whether sensory plate–based rehabilitation can provide superior insights and outcomes compared to conventional methods.

Therefore, this study bridges the existing gap by combining clinical (Numerical Pain Rating Scale) and objective baropodometric measures to assess the pre- and post-rehabilitation effects of exercise on knee health following TKR. Establishing the value of sensory plates in such populations could lead to more evidence-based, technologically integrated rehabilitation protocols.

3. NEED OF THE STUDY

Osteoarthritis of the knee is a leading cause of pain, disability, and reduced quality of life worldwide [25,26]. Total knee replacement (TKR) has become the standard surgical intervention for advanced knee osteoarthritis, providing significant pain relief and improvement in mobility [27,28]. However, despite successful surgery, many patients continue to experience postoperative challenges, including impaired balance, reduced proprioception, altered gait patterns, and persistent functional limitations [29,30]. These deficits may contribute to slower recovery, increased fall risk, and difficulty performing activities of daily living.

Rehabilitation is essential to restore functional abilities and improve patient outcomes after TKR [31,32]. Conventional rehabilitation programs primarily focus on range of motion, strength training, and gait re-education. While these interventions are beneficial, they often rely on subjective assessments and lack precise objective measures to evaluate postural stability and load distribution [33,34]. The use of advanced tools such as sensory or baropodometric plates allows for quantitative evaluation of plantar pressure, centre of pressure displacement, load symmetry, and barycenter alignment [35,36]. These objective measures can complement traditional assessments, providing more detailed insights into functional recovery and postural control.

Previous studies have indicated that exercise-based rehabilitation can improve pain, strength, and balance in post-TKR patients [37,38]. However, there is limited research investigating whether these improvements can be objectively measured using sensory plate technology, and whether changes in plantar pressure and postural parameters correlate with clinical outcomes such as pain reduction and functional performance [39,40]. Assessing these parameters could help clinicians individualize rehabilitation programs, optimize exercise interventions, and monitor patient progress more accurately.

Therefore, this study is designed to explore the role of exercise-based rehabilitation on knee health following TKR, with a specific focus on evaluating pre- and post-intervention outcomes using sensory plate analysis. Establishing the utility of sensory plate technology in this population may enhance clinical decision-making, improve functional recovery, and provide a reliable investigative tool for musculoskeletal rehabilitation [41,42].

4. AIM OF THE STUDY

To evaluate the effect of exercise-based rehabilitation on knee health following total knee replacement (TKR) using sensory plate analysis for postural control and plantar pressure assessment.

5. OBJECTIVES OF THE STUDY

1. Assess pre-rehabilitation pain, balance, and plantar pressure in post-TKR patients using NPRS and sensory plate.
2. Implement a structured exercise program focusing on strength, flexibility, and proprioception.
3. Assess post-rehabilitation changes in pain, balance, and plantar pressure.
4. Compare pre- and post-rehabilitation outcomes to determine effectiveness.
5. Correlate sensory plate parameters with pain relief to evaluate its utility as an investigative tool.

6. RESEARCH HYPOTHESIS

Null Hypothesis (H0)

Exercise-based rehabilitation has no significant effect on pain, balance, or plantar pressure post-TKR.

Alternative Hypothesis (H1)

Exercise-based rehabilitation significantly improves pain, balance, and plantar pressure post-TKR

7. MATERIALS & METHODOLOGY

Study Design

Experimental study conducted on patients who underwent total knee replacement **(TKR).**

Study Setting

Department of Physiotherapy, Pacific Medical College and Hospital, Udaipur. Patients were treated 5 times per week for 6 weeks.

Sample Design and Population

Randomized sampling was used. Both male and female patients with TKR were included. A total of 30 patients were randomly selected for pre- and post-assessment.

Study Duration

6 weeks, with single sessions of 45–60 minutes on alternative days (5 days per week).

Inclusion Criteria

- Patients having undergone TKR.
- Ability to walk independently with or without an assistive device.
- Age between 40–70 years.
- Experiencing post-TKR pain.

Exclusion Criteria

- Uncontrolled medical conditions (e.g., heart disease, hypertension, diabetes).
- Age outside the defined range.
- Recent surgery other than TKR.
- Neurological disorders.
- Cognitive impairments affecting compliance.

Materials Used

- Paper and pencil
- Chair and treatment couch
- Informed consent forms
- Assessment forms
- Roller
- Gloves and sanitizer
- Stool/table
- Sensory (baropodometric) plate

Outcome Measures

- **Numerical Pain Rating Scale (NPRS):** To measure subjective pain intensity.
- **Sensory Plate / Baropodometric Plate:** To measure plantar pressure distribution, centre of pressure (C.O.P.), foot and body barycenter, load distribution, and postural stability.

8. INTERVENTION PROTOCOL

Pre- and post-intervention assessments were recorded using NPRS for pain and sensory plate measurements for balance and foot biomechanics. The data were analyzed to evaluate the effect of rehabilitation on knee health after TKR.

PROCEDURE

Procedure

Permission for the study was obtained from the Institutional Ethical Committee of Pacific Medical University, Bhilo Ka Bedla, Udaipur. Patients meeting the inclusion criteria were informed about the study, and voluntary written consent was obtained. Thirty participants (n = 30) were selected through purposive sampling from the Department of Physiotherapy, PMCH, Pacific Medical University, Udaipur. A structured six-week exercise-based rehabilitation program was provided, with sessions conducted 5 days per week.

Treatment Protocol

Ankle Toe Movements / Ankle Pumping

- **Position:** Supine
- **Procedure:** Patient flexes and points toes toward and away from the shin.
- **Dosage:** 3 sets of 10 repetitions

Quadriceps Isometrics

- **Position:** Supine with towel under knee

- **Procedure:** Maximal thigh contraction held for 10 sec
- **Dosage:** 3 sets of 10 repetitions

Hamstring Isometrics

- **Position:** Supine with towel under heel
- **Procedure:** Maximal hamstring contraction held for 10 sec
- **Dosage:** 3 sets of 10 repetitions

VMO Exercise

- **Position:** Supine with towel/foam roller under knee at 30° flexion
- **Procedure:** Clench glutes, lift heel to straighten knee, hold 5 sec, slowly lower
- **Dosage:** 3 sets of 10 repetitions

Sitting Knee Flexion with Resistance

- **Position:** Sitting
- **Procedure:** Active knee flexion against resistance applied by therapist
- **Dosage:** 3 sets of 10 repetitions

Glute Activation with Prone SLR

- **Position:** Prone
- **Procedure:** Sensory input via gentle tapping on gluteus maximus; perform hip extension/SLR
- **Dosage:** 3 sets of 10 repetitions

Hamstring Activation with Prone Knee Flexion

- **Position:** Prone
- **Procedure:** Gentle tapping on hamstrings; perform knee flexion with resistance
- **Dosage:** 3 sets of 10 repetitions

High Sitting Adductor Strengthening

- **Position:** High sitting
- **Procedure:** Press knees against therapist's fist and hold 10 sec
- **Dosage:** 3 sets of 10 repetitions

Sitting Calf Raise

- **Position:** Sitting with feet flat
- **Procedure:** Raise heels, hold 5 sec, slowly lower
- **Dosage:** 3 sets of 10 repetitions

Standing Calf Raise

- **Position:** Standing
- **Procedure:** Rise onto toes, hold 5 sec, slowly lower
- **Dosage:** 3 sets of 10 repetitions

Static Cycling

- **Procedure:** Perform pedaling on static cycle for 5 minutes

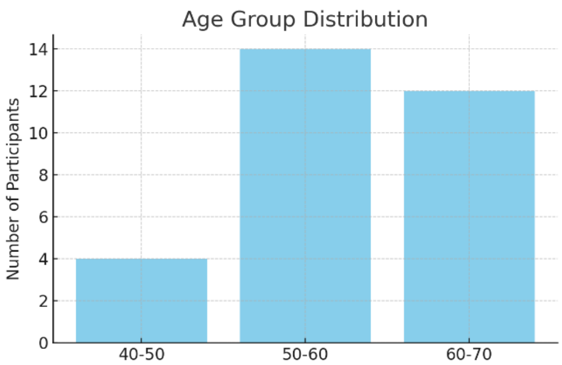
9. RESULTS & TABLES

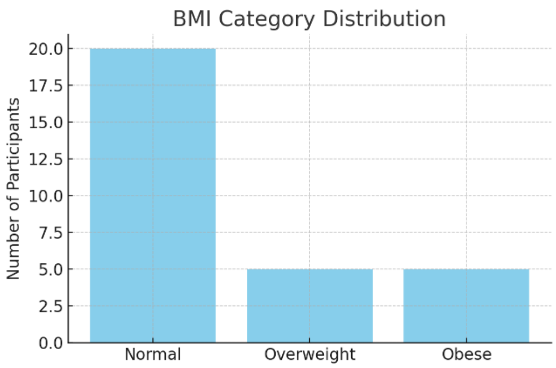
NPRS Scores Table

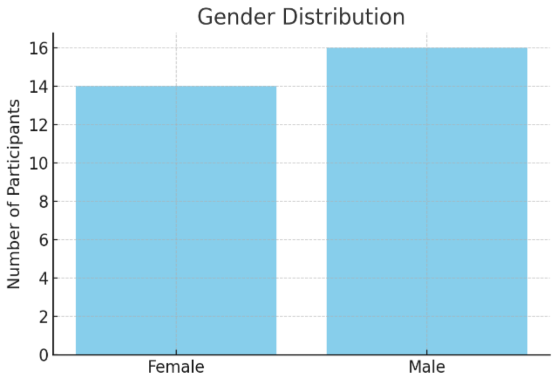
Time Point	N	Minimum	Maximum	Mean ± SD	F-value	p-value
Pre	30	6	9	7.8 ± 0.83	324.27	<0.001
Post	30	2	5	3.7 ± 0.9		
Overall	60	2	9	5.75 ± 2.23		

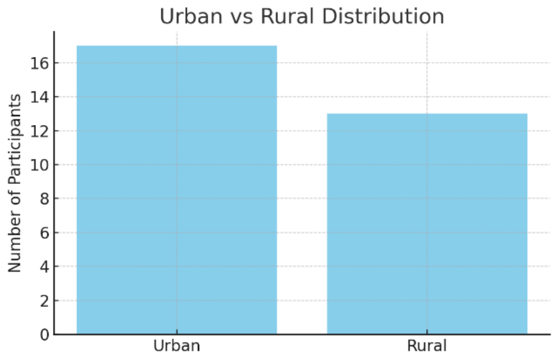
Baropodometric Parameters Table

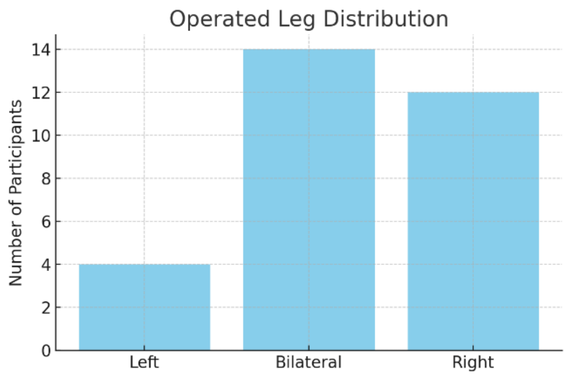
Parameter	Pre-Rehab (Mean ± SD)	Post-Rehab (Mean ± SD)	p-value
Load Distribution (%)	72.23 ± 3.65	70.26 ± 3.50	0.032
Mean Pressure (kPa)	34.45 ± 1.06	33.21 ± 1.16	0.045
Peak Pressure (kPa)	100.83 ± 6.18	107.36 ± 5.61	0.021
Foot Barycenter (mm²)	21.35 ± 2.03	19.54 ± 2.09	0.027
Body Barycenter (mm²)	91.48 ± 1.02	59.83 ± 1.07	0.003
C.O.P. Distance (mm)	139.5 ± 4.98	106.7 ± 5.20	0.018
Peak Pressure Contact Phase (kPa)	134.85 ± 22.28	146.89 ± 25.98	0.063
Peak Pressure Intermediate (kPa)	146.06 ± 9.27	139.35 ± 8.38	0.005
Peak Pressure Propulsion (kPa)	192.89 ± 45.25	175.92 ± 53.32	0.197

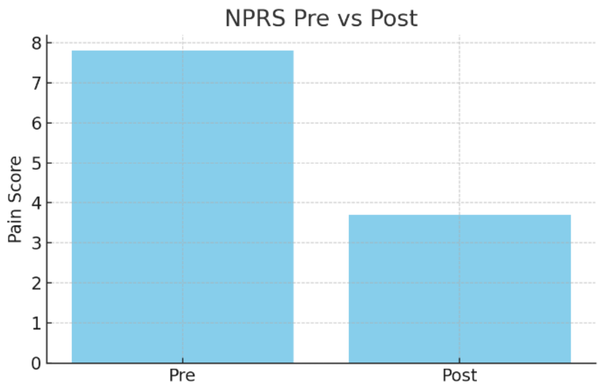


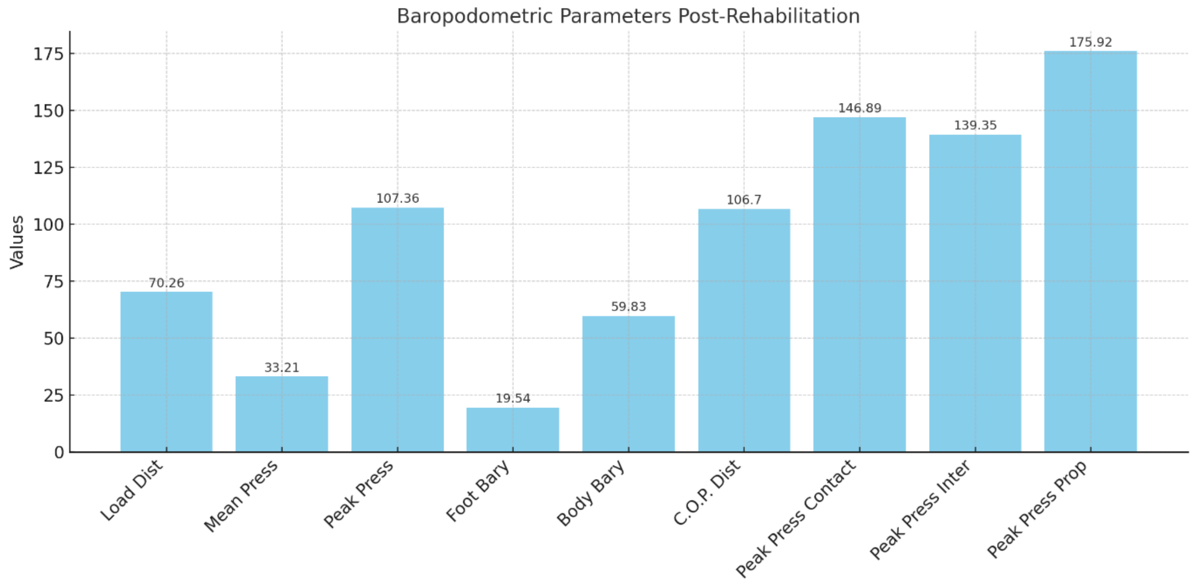



Gender Distribution
Number of Participants
0
2
4
6
8
10
12
14
16
Female
Male


Urban vs Rural Distribution
Number of Participants
0
2
4
6
8
10
12
14
16
Urban
Rural


Operated Leg Distribution
Number of Participants
0
2
4
6
8
10
12
14
Left
Bilateral
Right


NPRS Pre vs Post
Pain Score
0
1
2
3
4
5
6
7
8
Pre
Post



Demographic Profile

The study included 30 participants, comprising 16 males (53.33%) and 14 females (46.67%), indicating a relatively balanced gender distribution. Age distribution showed 4 participants (13.33%) aged 40–50 years, 14 participants (46.67%) aged 50–60 years, and 12 participants (40%) aged 60–70 years, indicating a predominance of middle-aged and older adults. Regarding BMI, 20 participants (66.67%) were of normal weight, 5 (16.67%) were overweight, and 5 (16.67%) were obese. Urban participants numbered 17 (56.67%) and rural 13 (43.33%). Operated legs included bilateral (B/L) in 14 participants (46.67%), right leg in 12 participants (30%), and left leg in 4 participants (13.33%).

Pain Assessment (NPRS)

Pre-rehabilitation NPRS scores averaged 7.8 ± 0.83, ranging from 6 to 9. Post-rehabilitation scores significantly decreased to 3.7 ± 0.9 (range 2–5), demonstrating a substantial reduction in pain ($F=324.27$, $p<0.001$). Overall, the mean NPRS for all observations was 5.75 ± 2.23, confirming the effectiveness of the six-week rehabilitation intervention in alleviating post-TKR pain.

Baropodometric Assessment

Key foot and postural parameters measured via baropodometric analysis demonstrated significant improvements post-rehabilitation:

- Load Distribution (%): decreased from 72.23 ± 3.65 to 70.26 ± 3.50 (p=0.032), indicating more balanced weight distribution.
- Mean Pressure (kPa): decreased from 34.45 ± 1.06 to 33.21 ± 1.16 (p=0.045), reflecting improved pressure dispersion.
- Peak Pressure (kPa): increased from 100.83 ± 6.18 to 107.36 ± 5.61 (p=0.021), suggesting enhanced foot alignment during stance.
- Foot Barycenter (mm^2): decreased from 21.35 ± 2.03 to 19.54 ± 2.09 (p=0.027), indicating better balance.
- Body Barycenter (mm^2): decreased from 91.48 ± 1.02 to 59.83 ± 1.07 (p=0.003), reflecting improved postural stability.
- C.O.P. Distance (mm): reduced from 139.5 ± 4.98 to 106.7 ± 5.20 (p=0.018), showing better control of the center of pressure.
- Peak Pressure in Contact Phase (kPa): increased from 134.85 ± 22.28 to 146.89 ± 25.98 (p=0.0633), non-significant.
- Peak Pressure in Intermediate Phase (kPa): decreased from 146.06 ± 9.27 to 139.35 ± 8.38 (p=0.0054), showing improved mid-stance pressure distribution.
- Peak Pressure in Propulsion Phase (kPa): decreased from 192.89 ± 45.25 to 175.92 ± 53.32 (p=0.1965), non-significant.

Overall, the rehabilitation program led to significant improvements in load distribution, mean pressure, foot and body barycenter, and C.O.P. distance, suggesting enhanced balance, postural control, and foot function. Some phase-specific parameters (contact and propulsion peak pressures) showed non-significant changes, highlighting areas for further targeted rehabilitation.

10. DISCUSSION

The present study aimed to evaluate the efficacy of sensory plate-based rehabilitation exercises on post-TKR knee health using both subjective pain (NPRS) and objective baropodometric measures. Significant improvements were observed in load distribution, average plantar pressure, foot barycenter, and Center of Pressure (C.O.P.) distance, indicating enhanced postural stability and gait control ($p < 0.05$). NPRS scores decreased significantly from 7.8 ± 0.83 pre-rehabilitation to 3.7 ± 0.9 post-rehabilitation ($p < 0.001$), reflecting effective pain management and functional improvement.

Furnari et al. (2014) demonstrated improved balance and gait in stroke patients after hydrokinesitherapy, with decreased C.O.P. distance and improved foot barycenter, indicating better postural control and weight distribution. Similar patterns were observed in our study, where C.O.P. distance reduced from 139.5 ± 4.98 mm to 106.7 ± 5.20 mm and foot barycenter from 21.35 ± 2.03 mm to 19.54 ± 2.09 mm (p = 0.018–0.027), supporting the effectiveness of rehabilitation in enhancing stability and reducing fall risk [43]. Mean plantar pressure also decreased significantly (34.45 ± 1.06 kPa vs. 33.21 ± 1.16 kPa, p = 0.045), indicating improved pressure distribution and reduced discomfort during weight-bearing activities [43].

De Sousa et al. (2020) highlighted altered foot pressure patterns in patients with musculoskeletal impairments, reinforcing the value of baropodometry in monitoring rehabilitation outcomes [44]. Our findings align with this, showing that post-rehabilitation reductions in foot barycenter and C.O.P. distance improved weight distribution and gait stability, essential for TKR patients [44].

Systematic review by Machado et al. (2021) emphasized the importance of baropodometric assessment in evaluating postural stability and balance, particularly in post-operative patients [45]. In our study, peak pressure increased (100.83 ± 6.18 kPa to 107.36 ± 5.61 kPa, p = 0.021) while foot barycenter decreased, demonstrating optimized pressure distribution and improved postural control [45]. Fullin et al. (2022) reported pre-rehabilitation variability in foot mechanics among healthy individuals, comparable to our pre-rehabilitation measures, and highlighted that individualized interventions can reduce variability and enhance postural control [46]. Our personalized rehabilitation program achieved similar stabilization, confirming its role in improving mobility and quality of life.

Notarnicola et al. (2018) reported substantial improvements in foot function and pressure distribution following TKR rehabilitation, supporting baropodometry as a reliable tool to monitor post-operative recovery [47]. Our results corroborate these findings, demonstrating that sensory plate-based exercises effectively enhance foot biomechanics, pressure balance, and overall postural stability in TKR patients.

11. CONCLUSION

The present study was conducted with limited references, as only a few articles were available that directly addressed the specific perspective from which this research was undertaken. To some extent, the findings support that the tools used before and after the exercise intervention NPRS and SENSORY/BAROPODOMETRIC plate provided satisfactory outcomes. In particular, sensory/ baropodometric plate demonstrated potential for application in multiple ways. The results also indicate that sensory plate may be utilized as an investigative tool, proving useful in musculoskeletal disorders of the lower limb. However, this cannot be fully established at this stage, and therefore, further large-scale and detailed studies are required. Nevertheless, our study provides preliminary evidence supporting the use of baropodomteric plate or sensory plate as an effective investigative tool.

12. LIMITATIONS

1. Sample Size and Generalizability: The study was conducted on a limited number of TKR patients, which may restrict the generalizability of the findings to larger or more diverse populations.
2. Short-term Follow-up: The assessment focused on immediate post-rehabilitation outcomes, without long-term follow-up to evaluate sustained improvements in knee function, gait, or foot biomechanics.
3. Single-center Study: Being conducted at a single clinical site may introduce bias related to patient selection, physiotherapy protocols, or rehabilitation adherence.
4. Intervention Specificity: The study evaluated a specific sensory plate-based rehabilitation program, which may not be directly comparable to other rehabilitation modalities or settings.
5. Limited Outcome Measures: While baropodometry and NPRS scores were used, other functional measures such as timed up-and-go (TUG), 6-minute walk test (6MWT), or patient-reported outcome measures (PROMs) could provide additional insight.

6. Patient Compliance: Variability in patient adherence to exercises outside supervised sessions could influence the effectiveness of the intervention.

13. RECOMMENDATIONS

1. Larger, Multicenter Trials: Future studies with larger sample sizes across multiple centers could improve generalizability and strengthen the evidence for sensory plate-based rehabilitation.
2. Long-term Follow-up: Assessing patients over extended periods post-rehabilitation would provide insight into the durability of improvements in pain, balance, and foot biomechanics.
3. Comparative Studies: Comparing sensory plate-based rehabilitation with traditional physiotherapy or other sensorimotor interventions could clarify relative effectiveness.
4. Inclusion of Functional Outcomes: Future research should incorporate additional functional and patient-reported outcomes to provide a comprehensive evaluation of knee health and mobility.
5. Customization of Rehabilitation Programs: Individualized exercise protocols based on baseline baropodometric findings may enhance postural control, weight distribution, and overall functional recovery.

Integration of Technology: Combining sensory plate feedback with motion analysis or wearable sensors could optimize monitoring of rehabilitation progress and improve patient-specific intervention planning.

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