

Advancing total knee replacement surgery Assessment with Wearable Sensors and AI: A Case Study

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ABSTRACT

Background: India has a higher prevalence of about 20-24% of people suffering from osteoarthritis. Due to the load effect, forces between two and three times body weight are transmitted across the knee joint during a normal stride, which accounts for the higher risk of OA. A Qualitative Analysis of Decision-Making for Total Knee Replacement in Patients with Osteoarthritis. A cutting-edge wearable sensor system called Fitknees delivers a complex arrangement of motion sensors that are carefully placed on the lower limb. These sensors outline thorough kinematic data that include gait analysis, muscle strength, knee range of motion, and balance metrics.

Objective: Utilizing individualised measurements, using wearable sensors and AI tool to assess preoperative evaluations and postoperative rehabilitation programs.

Results: comparing between affected and unaffected side with the normative data provided by the AI. Conclusion: advancement in the medical technologies have made it easier for medial professionals to detect and early diagnose the diseases. Plan a better treatment plan with the aid of artificial intelligence to achieve better results.

Keywords :- OA knee, Total Knee Replacement, wearable sensors, artificial intelligence, advanced diagnostics,

ABBREVIATIONS

OA : Osteoarthritis

TKR- : Total Knee Replacement

TJR : Total joint replacement

INTRODUCTION

Osteoarthritis is the most common degenerative disease, affecting About 16% of the global population. India has a higher prevalence of about 20-24% of people suffering from osteoarthritis.¹ OA risk rises significantly with age and is incredibly uncommon in anyone

under the age of 30. Female sex, obesity, past joint damage (such as an ankle fracture or knee ligament rupture), atypical joint anatomy, and having family members with OA all raise the risk of getting the condition. Why focus more on the knee joint? This is because the lower limbs bear most of the body's weight, and flexible joints like the hip and knee are particularly affected.² Due to the load effect, forces between two and three times body weight are transmitted across the knee joint during a normal stride, which accounts for the higher risk of OA. Therefore, the advancement of OA can occur over many years, with times of rapid progression leading

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to joint failure and total joint replacement (TJR) in the end. According to the incidence of TKR, which increased from 1% to 2% after three years and from 6-9% after 12 years, this population of older women is at a high risk of experiencing joint failure and requiring TJR.³

The OA knee is characterised by a complex combination of biomechanical forces and biochemical changes that lead to the gradual disintegration of articular cartilage. Synovial inflammation, the growth of osteophytes, subchondral bone sclerosis, and the subsequent constriction of joint spaces all exacerbate discomfort and limit mobility. The femur and tibia's diseased cartilage and bone are removed, and then metal and plastic prosthetic parts are inserted as a replacement. The tibial component replaces the top surface of the tibia, and a plastic spacer is inserted between the femoral component and the tibial component. Resurfacing the patellar undersurface is an option. The surgical closure of the joint capsule and incisions complete the surgery, which aims to restore joint stability and alignment. Following surgery, patients go through rehabilitation to restore knee function.

Clinical assessment, medical history review, physical examination, and imaging techniques are currently used in assessments of OA knee patients considering TKR surgery. X-rays can shed light on bone alterations, osteophyte development, and narrowing of joint spaces. Soft tissue structures can be viewed in great detail on an MRI scan. Additionally, diagnostic tools like the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and the Knee Society Score help assess pain, stiffness, and function. Clinical assessment, medical history review, physical examination, and imaging techniques are currently used in assessments of OA knee patients considering TKR surgery. X-rays can shed light on bone alterations, osteophyte development, and narrowing of joint spaces. Soft tissue structures can be viewed in great detail on an MRI scan. The Knee Society Score and Western Ontario and McMaster Universities' diagnostic tools are additional considerations.⁴

A Qualitative Analysis of Decision-Making for Total Knee Replacement in Patients with Osteoarthritis can be decided on the basis of the investigations, which is X-rays, MRIs, and ultrasounds. The suggestion for surgery can be made based on the amount of damage the joint has, the level of pain, any deformities, and the grade of OA the patient is suffering. The amount of degenerative changes through X-ray and MRI. Patients with moderate to severe osteoarthritis may choose to have an elective knee replacement if their condition does not improve with treatment. These procedures are recognized to be highly beneficial to patients, demonstrating efficacy in terms of reducing pain, enhancing function, and enhancing quality of life.⁵

A paradigm change in OA knee evaluation is being presented by the convergence of wearable sensors and AI technology. A cutting-edge wearable sensor system called Fitknees delivers a complex arrangement of motion sensors that are carefully placed on the lower limb. These sensors outline thorough kinematic data that includes gait analysis, muscle strength, knee range of motion, and balance metrics. The combination of these indicators improves the previously limited assessment framework by providing a comprehensive viewpoint.⁶

PATIENT HISTORY AND OBSERVATION

The patient's informed consent was obtained in order to conduct this case study. The entire process for using fitknees was discussed. An 84-year-old retired male complains of having had pain in his left knee for past 2 months. He came to the physiotherapy clinic as there was no pain relief. He was diagnosed with osteoarthritis 10 years back because of negligence, his condition is more severe. He had undergone total knee replacement surgery on his left knee 2 months back. The common symptoms of which he complained were morning stiffness, and crepitations in both limbs, along with numbness in the left lower limb. After being operated 2 months back he was doing basic physiotherapy exercises which helped him in pain relief, improved range of motion, and improved

muscle strength. He had difficulties in complete knee movement, walking, and stair climbing without support. On observation, he has swelling over the knee along with foot, and a healed 12 cm healed scar over knee joint. Left knee slight flexed, left knee in valgus, posteriorly right-sided thoracic scoliosis.

On evaluation, the knee joint tender on the posterior side, and crepitations on both the knee joint. Extension lag was seen on left lower limb.

INVESTIGATIONS

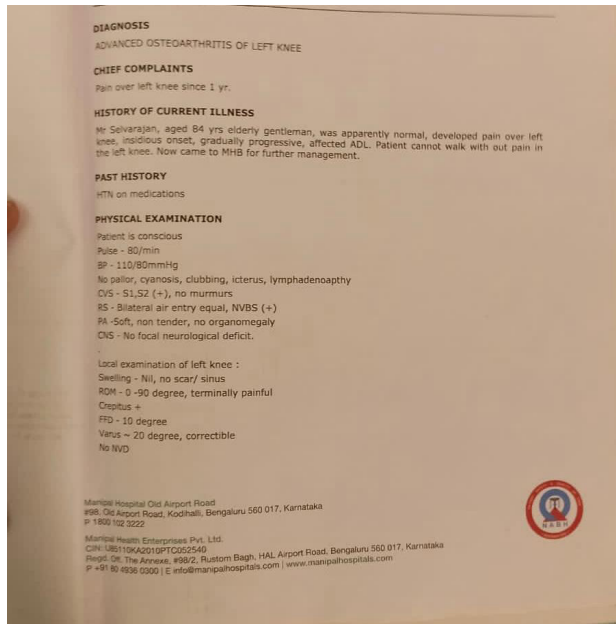


Fig. 1: Medical Diagnosis of patient

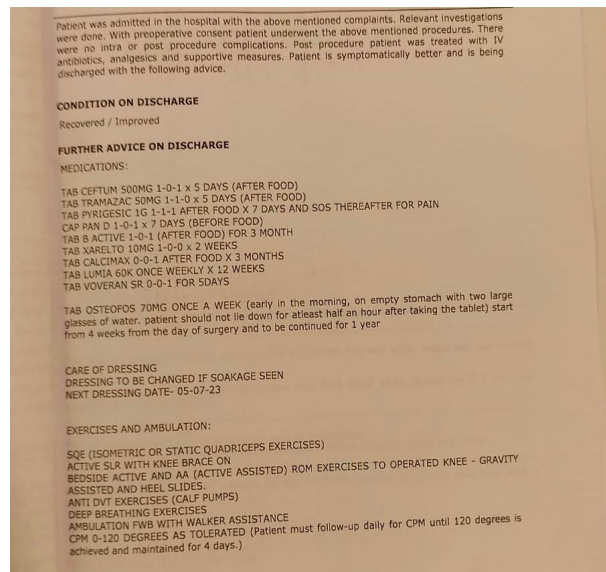


Fig. 2: Medications given to patient

Radiological investigation

Pre- surgery

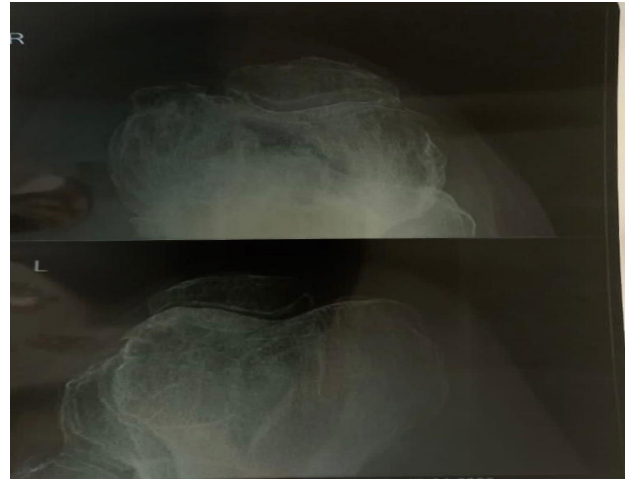


Fig. 3: Patella in knee flexion in anterior view both right and left knee.



Fig 4. Knee joint in anterior and lateral view both right and left knee.

Post- surgery



Fig. 5: Knee joint with implant



Fig 5&6. Knee joint with implant in anterior and lateral view

PHYSIOTHERAPY TREATMENT

- Neuromuscular electrical stimulation - 10 mins for quadriceps muscle.
- Isometric exercises for Quadriceps and hamstrings.
- Strengthening exercises
- Proximal muscles - Hip flexion
- Hip Extension
- Hip Abduction
- Resistance band exercises- gluteus muscle bridges
- Exercises to fixed flexion deformity- passive knee flexion
- Balance training- Spot marching
- Walk standing with hold B/L
- Single leg standing with support B/L
- Gait training- Short hurdles
- Tandon walking
- Side walking
- Backward walking

RESULTS

Comparing both the affected and unaffected with different clinical parameters

Range of motion

Flexion range of motion was calculated for both the sides, where the left limb is an affected limb and right is not affected, this graph shows that the range of rotation on the affected side is reduces as compared to unaffected side where the normal range for knee flexion is >125.

Muscle strength

This graph quantifies the amount of muscle strength. As there is reduced muscle strength in the affected limb as compared to the unaffected limb.

Proprioception

The joint position sense tested actively. This graph shows that the proprioception is more affected on the limb which is operated with TKR.

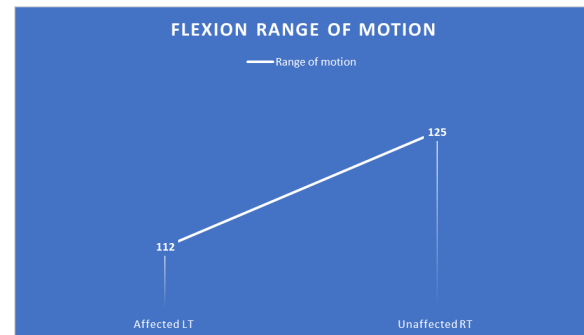


Fig. 7: Comparison between range of motion

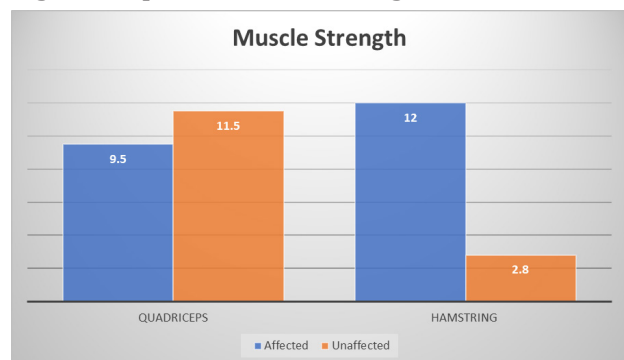


Fig. 8: Comparison between muscle strength

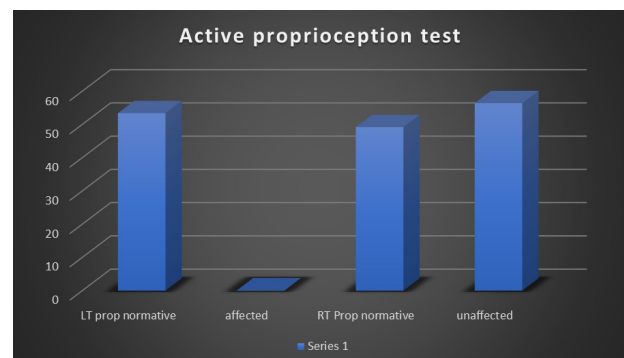


Fig. 9: Comparison between proprioception

Dynamic balance

The graph represents the normal average time taken to complete tug test and the actual time taken by the patient thus more the time taken to complete the test more is the risk of fall.

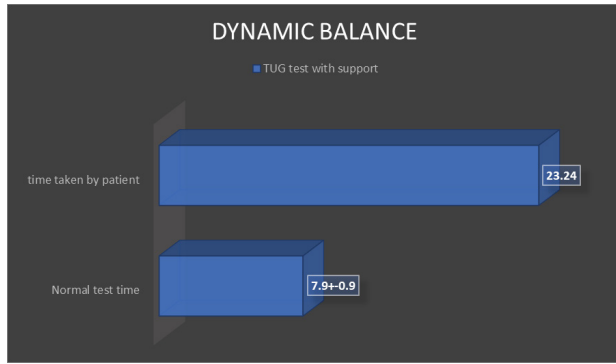


Fig. 10: Comparison between dynamic balance

Gait analysis

Alteration in the gait parameters is seen in the following graphs on the affected and unaffected sides compared to the normative ranges for each of the gait parameters. Which shows us that stance phase, stride length, step length and cadence is reduced as compared to normal.

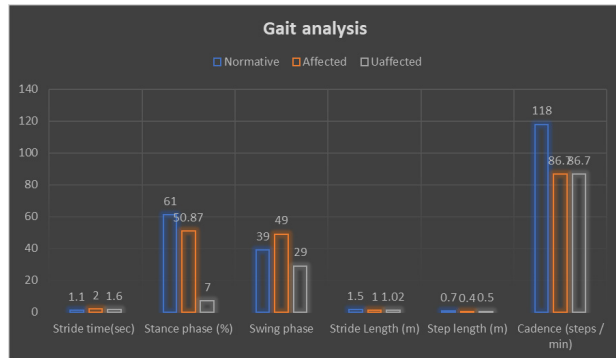


Fig. 11: Comparison between gait

As a result, all of the outcomes are compared to the patient’s actual motions and the normative ranges that the AI offers.

DISCUSSION

The case study, which is explained in medical jargon, and the reference piece highlight the potential advantages of using AI as a tool for assessing post-operative knee arthroplasty. When compared to conventional human evaluations, the AI tool demonstrates increased accuracy,

consistency, and expediency. Additionally, it exhibits a propensity for spotting issues in their early stages, leading to improved patient care.

But integrating AI technologies into clinical settings requires resolving issues with data privacy, algorithmic validity, and the interface between AI and medical specialists. While AI has the potential to enhance evaluations, it is crucial to view it as a supplemental tool that works in concert with medical professionals’ clinical judgment rather than as a replacement for it.

In order to fully realize the promise of AI for post-operative evaluations and other medical domains, it is essential to conduct ongoing research, collaborate synergistically with medical professionals and AI experts, and adhere unwaveringly to ethical standards.⁷

PICTURES



Pic. 1: Lt side affected, swelling present



Pic 2&3: Showing anterior and posterior view

Ethical clearance – Ethical clearance obtained from ST. John’s National Academy of Health sciences

Source of funding: self

Conflict of interest: nil

REFERENCES

1. Cui A, Li H, Wang D, Zhong J, Chen Y, Lu H. Global, regional prevalence, incidence and risk factors of knee osteoarthritis in population-based studies. *EClinicalMedicine* [Internet]. 2020;29–30(100587):100587. Available from: <http://dx.doi.org/10.1016/j.eclinm.2020.100587>
2. Calce SE, Kurki HK, Weston DA, Gould L. The relationship of age, activity, and body size on osteoarthritis in weight-bearing skeletal regions. *Int J Paleopathol* [Internet]. 2018;22:45–53. Available from: <http://dx.doi.org/10.1016/j.ijpp.2018.04.001>
3. Bager CL, Karsdal M, Bihlet A, Thudium C, Byrjalsen I, Bay-Jensen AC. Incidence of total hip and total knee replacements from the prospective epidemiologic risk factor study: considerations for event driven clinical trial design. *BMC MusculoskeletDisord* [Internet]. 2019;20(1). Available from: <http://dx.doi.org/10.1186/s12891-019-2680-3>
4. Halewood C, Athwal KK, Amis AA. Pre-clinical assessment of total knee replacement anterior-posterior constraint. *J Biomech* [Internet]. 2018;73:153–60. Available from: <http://dx.doi.org/10.1016/j.jbiomech.2018.03.042>
5. Suarez-Almazor ME, Richardson M, Kroll TL, Sharf BF. A qualitative analysis of decision-making for total knee replacement in patients with osteoarthritis. *J Clin Rheumatol* [Internet]. 2010;16(4):158–63. Available from: <http://dx.doi.org/10.1097/RHU.0b013e3181df4de4>
6. Root User. Home [Internet]. Ashva - Making Musculoskeletal Healthcare Data-Driven. Ashva; 2022 [cited 2023 Oct 11]. Available from: <https://www.ashva.xyz>
7. Integration of Convolutional Neural Networks for AI-Enhanced Post-Operative Assessment in Knee Arthroplasty: A Comparative Study” by Johnson et al. *Journal of Orthopedic Informatics*. 2023;