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Wearable Sensor Guided Physiotherapy after Total Knee Arthroplasty: Clinical Applications, Opportunities and Implementation Barriers - A Narrative Review

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Abstract:

Background: Total knee arthroplasty (TKA) reduces pain for many people with end-stage knee osteoarthritis, yet postoperative recovery varies and access to supervised physiotherapy is uneven. Wearable sensors offer objective monitoring of activity, joint motion and exercise performance outside the clinic. Objective: To synthesize evidence published from 2012 through 2021 on wearable sensor–guided and digitally supported physiotherapy after TKA, with emphasis on clinical applications, interpretation, safety and implementation. Methods: A structured narrative review considered peer-reviewed English-language studies and reviews published between January 2012 and December 2021. Priority was given to accelerometers, inertial measurement units, smartwatches, sensor-based biofeedback and remote rehabilitation systems used after knee arthroplasty. Results: Wearables can quantify steps, sedentary time, range of motion, exercise repetitions and selected gait features; paired platforms can deliver prompts, feedback and clinician dashboards. Trials through 2021 suggest that sensor-supported home rehabilitation can be feasible and may achieve outcomes comparable to conventional pathways in selected patients. However, heterogeneous devices, algorithms and outcome definitions limit comparison. Sensor accuracy in controlled tasks does not guarantee clinical validity at home, and high data volume does not replace examination or therapeutic reasoning. Digital literacy, connectivity, privacy, adherence and workflow integration remain major barriers. Conclusion: Wearable technology is best viewed as an adjunct that extends physiotherapy observation between visits. Safe implementation requires validated measures, individualized thresholds, human oversight and alternatives for patients unable or unwilling to use technology.

Keywords: total knee arthroplasty; wearable sensors; physiotherapy; telerehabilitation; inertial measurement units; remote monitoring; digital health

Introduction

Total knee arthroplasty is a common operation for end-stage knee osteoarthritis. It can produce substantial pain relief and improvement in function, but the postoperative trajectory is heterogeneous. Early deficits in knee motion, quadriceps strength, walking speed, balance and confidence may restrict independence. Some patients recover steadily with a home programme, whereas others need closer review because pain, swelling, weakness or low adherence impedes progress.

Physiotherapy traditionally relies on periodic face-to-face assessment and patient report. This model captures performance during a short clinic visit but provides limited information about daily activity or exercise technique at home. Patient-reported outcome measures are essential but do not always correspond closely to objectively measured activity (Small et al., 2019). A patient may report improvement while remaining sedentary, or may demonstrate adequate range in clinic but avoid stairs and community walking.

Wearable sensors create an opportunity to extend observation beyond the clinic. Accelerometers, gyroscopes, inertial measurement units (IMUs), smartwatches and pressure or joint-angle sensors can record movement, repetitions, activity and selected gait features. When linked to a mobile application, a wearable can deliver exercise instructions and feedback, while a clinician dashboard can display trends and adherence.

The appeal is especially strong in TKA pathways characterized by shorter hospital stays and variable outpatient access. Remote monitoring may support rural patients, reduce unnecessary travel and help therapists identify delayed recovery. Yet technology also introduces risks: inaccurate measurement, data overload, false reassurance, privacy concerns, digital exclusion and substitution of automated prompts for needed clinical care.

Research from 2012 through 2021 moved from measurement studies toward rehabilitation trials. A scoping review documented increasing but methodologically inconsistent use of wearable motion sensors after knee arthroplasty (Small et al., 2019). Pilot and randomized studies evaluated sensor-supported remote systems and smartwatch-based self-directed rehabilitation (Bell et al., 2020; Tripuraneni et al., 2021). This review examines how physiotherapists can interpret and implement that evidence responsibly.

Review Aim and Method

The aim is to synthesize clinical applications, opportunities and barriers associated with wearable sensor–guided physiotherapy after TKA. The review addresses what sensors measure, how information may influence exercise prescription, which patients are suitable, how safety and privacy should be managed, and where evidence remains insufficient.

The evidence period was restricted to January 2012 through December 2021. Peer-reviewed English-language trials, cohorts, measurement studies, reviews and clinically relevant digital-rehabilitation publications were considered when they involved knee arthroplasty, postoperative physiotherapy, wearable movement sensing, activity monitoring, biofeedback or remote rehabilitation. Publications outside the specified dates were excluded.

A narrative method was selected because devices, algorithms, interventions and outcomes are heterogeneous. No new participant data were collected and no meta-analysis was performed. Evidence was interpreted at the level supported by study design. Technical accuracy was distinguished from clinical effectiveness; feasibility was distinguished from equivalence; and reduced visits were not assumed to represent lower total cost without economic analysis.

Post-TKA Rehabilitation Needs

Postoperative rehabilitation addresses a cluster of interacting impairments. Pain and swelling inhibit quadriceps activation and knee motion. Weakness affects transfers, stairs and gait. Reduced flexion can restrict sitting and stair use, while loss of extension influences stance and walking efficiency. Balance, confidence and aerobic capacity also affect participation.

The early pathway includes education, safe transfers, assistive-device use, knee motion, muscle activation, gait and a home programme. Progression depends on wound status, pain, swelling, medical stability and preoperative function. Later phases emphasize strength, endurance, balance, stairs and return to meaningful activities. Wearable data should map to these clinical goals rather than be collected because a device is available.

Recovery is nonlinear. Activity may decrease on painful or swollen days, and a temporary reduction does not necessarily represent failure. Conversely, high step count can coexist with poor gait quality or excessive joint irritability. Sensor interpretation therefore requires context, including symptoms, medication, sleep, environment and the nature of activity.

Red flags remain clinical priorities. Fever, wound drainage, rapidly increasing swelling, calf pain, chest symptoms, acute loss of motion or sudden functional deterioration require appropriate medical review. A device cannot rule out infection, thromboembolism, fracture or mechanical complication. Automated reassurance must never delay escalation.

The value of a wearable lies in supplementing the physiotherapist's picture. Objective trends can trigger questions, demonstrate improvement and support shared decisions. They should not replace joint examination, manual strength testing, observation, patient goals or clinical communication.

Wearable Technologies and Their Outputs

Accelerometers measure linear acceleration and are widely embedded in watches, phones and dedicated activity monitors. Algorithms translate signals into steps, activity counts, intensity categories, sedentary time or sleep estimates. Accuracy varies by placement, gait speed, assistive-device use and algorithm. Slow or asymmetric gait after TKA may be misclassified.

Gyroscopes measure angular velocity. Combined accelerometer and gyroscope units form IMUs that estimate segment orientation and movement. Sensors placed on the thigh and shank can characterize knee angle, exercise repetitions and movement quality. Magnetometers may contribute orientation but can be affected by environmental interference.

Smartwatches offer convenience because users may already understand the device. They can record activity and deliver reminders or exercise applications. A randomized 2021 study paired a smartwatch with a mobile application for self-directed rehabilitation and reported no clinically meaningful compromise in postoperative outcomes compared with formal physiotherapy in the studied population

(Tripuraneni et al., 2021). Generalization requires attention to eligibility, compliance and the content of the application.

Pressure sensors, instrumented insoles and force-sensitive systems can estimate loading and gait symmetry. These measures may help patients who underload the operated limb, but calibration, footwear and walking surface influence results. Smart implants can produce detailed load information but are not routine rehabilitation tools.

Camera-based systems are sometimes grouped with wearable rehabilitation platforms although the sensing mechanism is external. Phones or tablets can provide pose estimation, video guidance or teleconsultation. Privacy and space requirements differ from body-worn sensors.

Outputs should be transparent. “Activity score” or “quality percentage” may conceal proprietary calculations. Clinicians need to know what was measured, sampling method, wear time, missing-data handling and validation population. A precise number is not automatically a valid clinical construct.

Clinical Applications

Activity monitoring is the simplest application. Step count and sedentary time can show whether daily mobility is increasing. Trends may identify patients who complete exercises but remain inactive. Goals can be individualized to baseline and symptoms rather than using universal step targets. Sudden decline should prompt contact, but minor day-to-day variability is expected.

Range-of-motion monitoring can supplement goniometry. IMUs may estimate knee flexion and extension during exercise or gait. Repeated home measurements could reveal plateau, but sensor placement and soft-tissue movement affect accuracy. Clinicians should confirm concerning readings with direct assessment.

Exercise recognition systems count repetitions and identify movement patterns. Feedback can cue speed, range or alignment. This may improve home-program fidelity and allow therapists to adjust dose remotely. Algorithms must be validated for postoperative movement, which differs from healthy performance. A compensated movement may be counted as successful even when clinically undesirable.

Gait monitoring can estimate cadence, step time, asymmetry and walking bouts. Laboratory gait analysis is detailed but resource intensive; wearables offer ecological information. Yet interpretation is complex. Symmetry is not always the immediate goal, and forcing symmetry during pain may be counterproductive. Gait data should inform observation, not dictate treatment alone.

Adherence monitoring records whether prescribed sessions were completed. It can support discussion but should not become surveillance or blame. Non-completion may reflect pain, misunderstanding, caregiving, technology failure or fear. Physiotherapists should explore barriers and adjust the programme.

Remote triage is a promising application. Dashboards can flag low activity, declining motion, missed sessions or symptom reports. The service must define who reviews alerts, how quickly and what action follows. An alert without a response pathway creates false security.

Patient education and motivation can be integrated through videos, reminders and progress displays. Feedback should be specific, achievable and linked to meaningful function. Gamification may engage some users and irritate others. Personal choice matters.

Evidence for Sensor-Supported Rehabilitation

The evidence through 2021 suggests feasibility and possible equivalence for selected pathways, but it does not support unrestricted replacement of physiotherapy. Device studies differ in sensor placement, intervention content, clinician contact and comparator care.

Bell et al. (2020) evaluated a portable remote rehabilitation system after total knee replacement. IMUs, a mobile application and a clinician portal were used to supplement outpatient rehabilitation. The pilot randomized study reported acceptability and feasibility, with participants and therapists indicating willingness to use the system again. The small sample limited conclusions about clinical effectiveness and cost.

Tripuraneni et al. (2021) conducted a multicentre randomized trial of a smartwatch paired with a self-directed rehabilitation application. Range of motion, manipulation rates and patient-reported outcomes were not meaningfully different from formal physiotherapy in the reported sample. The findings demonstrate that a digital pathway can be an appropriate alternative for some patients, not that formal physiotherapy is unnecessary for all.

Broader telerehabilitation studies during the period reported outcomes comparable with face-to-face models in selected TKA populations. These programmes often included therapist interaction rather than automated monitoring alone. The distinction matters: technology may change the channel of care while preserving professional oversight.

Small et al. (2019) identified 45 studies using accelerometers and IMUs after knee arthroplasty and found substantial inconsistency in methodology and reported variables. This limits pooled interpretation and emphasizes the need for standardized protocols.

Overall, wearable-supported care may reduce travel, extend monitoring and support home exercise. Evidence is strongest for feasibility and selected clinical non-inferiority findings. Evidence for long-term superiority, universal cost savings and prevention of complications remains limited.

Physiotherapy Assessment and Prescription

A wearable pathway begins with a conventional assessment. Baseline function, pain, swelling, range of motion, strength, gait, balance, assistive-device use, home environment and patient goals are documented. Digital literacy, vision, hearing, hand function and access to a compatible device or internet are also assessed.

The physiotherapist selects measures that answer a question. Step count may support activity progression; knee-angle data may support motion goals; repetition recognition may support adherence. Collecting every available metric increases burden without necessarily improving decisions.

Exercise prescription follows tissue response and function. Early exercises may include quadriceps activation, knee extension positioning, flexion, sit-to-stand and walking. Later progression incorporates resistance, step tasks, balance and endurance. Sensor feedback should reinforce correct technique and appropriate dose.

Thresholds must be individualized. A fixed daily increase can be inappropriate for an older patient with comorbidity or for someone already highly active. Progression should consider pain and swelling during and after activity. A symptom diary can add context to sensor trends.

Remote review should include scheduled contact, not only exception alerts. The therapist asks about confidence, wound status, medication, sleep and meaningful activities. Video may help inspect technique, but camera angle and connectivity limit accuracy. In-person review is arranged when findings are uncertain.

Discharge from monitoring should be planned. Patients need to know whether they may continue using consumer metrics and what constitutes a reason to seek care. Data collection should not continue indefinitely without purpose or consent.

Feedback and Behaviour Change

Wearables can make behaviour visible. A progress graph may demonstrate that walking bouts are becoming longer or that sedentary time remains high. Feedback can support self-efficacy when it is understandable and connected to goals such as walking to a shop or climbing stairs.

Automated reminders are useful only when timely and controllable. Excessive notifications can cause fatigue. Systems should allow preference settings and quiet periods. Patients should be able to pause an exercise for symptoms without being labelled noncompliant.

Goal setting should use baseline data and shared decisions. A step goal based on healthy-population norms may be unrealistic early after surgery. Weekly ranges and functional goals can accommodate variation. Positive feedback should reward safe participation rather than maximum volume.

Adherence data can improve conversations. The therapist may learn that instructions were unclear, the strap was uncomfortable or internet access failed. A supportive approach treats low adherence as information. Punitive monitoring may reduce honesty.

Family support can help with setup and encouragement, but consent and privacy remain with the patient. Caregivers should not gain unrestricted access automatically. Systems must also avoid transferring excessive technical responsibility to families.

Safety and Escalation

Wearables do not independently establish medical safety. Predefined escalation criteria should cover wound concerns, fever, increasing erythema, acute calf symptoms, chest pain, breathlessness, falls, sudden loss of function and uncontrolled pain. Patients need direct instructions that override the application.

Exercise alerts should distinguish routine symptoms from urgent concerns. Over-sensitive alerts burden clinicians; under-sensitive systems create risk. Thresholds need clinical validation and periodic review. The person responsible for monitoring and response time must be explicit.

Sensor-related harms include skin irritation, trip hazards, distraction and incorrect exercise caused by faulty feedback. Devices should be easy to clean and secure. Battery failure and lost connectivity require a backup plan.

Falls may occur when patients focus on a screen while walking. Feedback should not require visual attention during challenging tasks. Balance or stair exercises should not be progressed remotely unless safety has been established.

Data absence is ambiguous. It may mean inactivity, non-wear, technical failure or hospitalization. Systems should not infer deterioration automatically. Human contact resolves uncertainty.

Measurement Validity and Data Interpretation

A wearable measure is useful only when it is sufficiently valid, reliable and interpretable for the decision being made. Validation against laboratory equipment may show that a sensor estimates knee angle accurately during a standardized task. This does not guarantee accuracy during slow, guarded home movement, with loose clothing, altered placement or use of a walking frame. Ecological validity must be tested in the intended population.

Reliability concerns whether repeated measurements under stable conditions produce similar results. A device may be accurate on average yet too variable to detect change in an individual. Clinicians should know measurement error and, where available, minimal detectable change. Small fluctuations below error should not trigger treatment changes.

Placement is a major source of error. IMUs on the thigh and shank require consistent orientation. If patients attach sensors differently each day, an apparent range-of-motion change may reflect placement rather than recovery. Clear markings, shaped straps, setup videos and automated calibration can reduce variability. The therapist should verify technique during onboarding.

Wear time influences activity metrics. One high-activity hour cannot represent a day if the device was removed during the remainder. Dashboards should display wear time and missing data. Imputation methods may be reasonable for research but can obscure uncertainty in clinical care. The safest interpretation is often to contact the patient.

Step-count algorithms may undercount slow gait, shuffling or short indoor bouts. Walking aids alter arm movement and can reduce wrist-device accuracy. A thigh- or trunk-worn device may perform differently. Services should avoid comparing numbers across devices as if they are interchangeable.

Range-of-motion estimates also require context. Functional flexion during a sit-to-stand or step may not equal passive range measured with a goniometer. Both can be valuable but answer different questions. A wearable trend may indicate increasing use of available motion even when maximal clinical range changes little.

Gait asymmetry can be expressed through step time, stance time, loading or joint motion. These variables may not normalize at the same rate. A composite “gait quality” score hides this complexity. Physiotherapists should request interpretable variables and examine whether changing the variable is a meaningful treatment goal.

Data presentation affects decisions. Longitudinal trends with symptom annotations are more useful than isolated daily scores. Reference zones can support interpretation, but population norms should not replace individualized baselines. The system should allow clinicians to see raw or summarized components behind alerts.

Clinical validity means that the measure relates to patient status or predicts an outcome. Predictive models may identify delayed recovery, but false positives can create unnecessary visits and false negatives can delay care. Models need external validation in different hospitals, ages, body sizes and rehabilitation pathways before routine use.

Finally, technology should be audited after deployment. If sensor alerts rarely change management, data collection may be unnecessary. If clinicians repeatedly override recommendations, the algorithm or workflow requires review. Measurement is valuable when it leads to an appropriate action, clearer shared decision or improved understanding—not merely because it produces a number.

A Phase-Based Sensor-Guided Rehabilitation Pathway

A phase-based pathway can connect sensor data with clinical priorities. Phase 1 begins before discharge. The physiotherapist assesses transfers, walking, device use, knee motion, quadriceps activation and understanding of warning signs. The wearable is fitted, calibrated and tested during prescribed exercises. The patient demonstrates charging, attachment and application use through teach-back.

Early home recovery constitutes Phase 2. Priorities include safe mobility, swelling control, extension, gradual flexion, quadriceps activation and adherence. Useful metrics may include exercise completion, walking bouts and symptom reports. High step targets are inappropriate at this stage. Scheduled human contact should occur even when data appear normal because wound and systemic concerns may not be captured.

During Phase 3, usually after acute irritability decreases, the programme progresses strength, sit-to-stand, step tasks and walking duration. Sensor feedback can identify whether repetitions reach the prescribed range and whether activity is distributed through the day. The therapist reviews pain and swelling after increased load. A steep activity rise followed by decline may suggest overloading.

Phase 4 emphasizes gait, balance, stairs and community participation. Wearables may quantify walking duration, cadence and real-world bouts. In-person assessment remains important for movement quality and fall risk. Exercise can include progressive resistance, step-down control, directional tasks and endurance appropriate to the patient.

Phase 5 prepares for independent self-management. Goals relate to work, recreation and general physical activity. Monitoring may become less frequent and focus on agreed outcomes rather than daily compliance. The patient should be able to progress exercise, recognize excessive joint response and seek review when needed.

Progression between phases is not determined by postoperative day alone. Criteria include wound status, symptoms, motion, strength, gait safety and capacity to complete current tasks. Sensor data contribute but do not make the decision independently. Complications or manipulation procedures may require regression and a revised pathway.

A typical remote review follows a structured sequence: confirm general health and red flags; examine pain and swelling pattern; review wear time and missing data; discuss exercise performance; inspect relevant trends; observe one or two key tasks by video when appropriate; agree on modifications; and document the plan. This prevents the consultation from becoming a tour of dashboard metrics.

Visit substitution should be selective. A patient with stable progress, reliable use and simple goals may need fewer in-person sessions. A patient with limited extension, marked weakness, poor balance, escalating pain or uncertain data needs direct examination. The model should intensify care when necessary, not merely reduce contact.

The pathway also requires exit criteria. Monitoring may stop when goals are met, when data no longer influence treatment, or when the patient prefers standard care. Equipment return and data retention are explained. A planned ending supports autonomy and avoids indefinite surveillance.

Patient Selection and Personalization

Suitability is determined by clinical and practical factors. A good candidate is medically stable, able to understand the plan, capable of fitting the device or supported by a consenting caregiver, and willing to engage. Suitability does not require high technical expertise when onboarding and support are effective.

Patients who may need more face-to-face care include those with significant balance impairment, cognitive difficulty, severe visual or hand limitation, complex comorbidity, poor wound progress or substantial preoperative disability. Technology can still supplement care, but should not be the primary channel without adequate support.

Personalization begins with goals. A younger worker seeking return to a physically demanding role requires different monitoring from an older adult aiming for household independence. Step count may be central for one person and sit-to-stand performance or stair practice for another. The dashboard should reflect the plan rather than force every patient into the same metrics.

Comorbid conditions affect interpretation. Cardiorespiratory disease may limit walking independent of the knee. Contralateral joint pain can reduce step count and alter gait. Obesity can influence sensor attachment and algorithm performance. Neurological conditions may produce asymmetry unrelated to the operation. Baseline assessment prevents misattribution.

Preferences should be revisited. Some patients enjoy data and self-directed progress; others experience anxiety or feel watched. A patient may initially accept monitoring and later request less frequent feedback. Respecting choice supports therapeutic alliance.

Language and health literacy influence usability. Instructions should use clear wording, pictures and demonstration. Applications should not rely on colour alone or small text. Accessibility testing with the actual population is more informative than assumptions made by designers.

Personalization also applies to alert thresholds. Low activity may be concerning for a previously active patient but expected for someone with substantial baseline limitation. Pain scores have individual meaning. Combining multiple trends and clinical context is safer than a single universal cutoff.

The therapist should avoid technological enthusiasm that overrides patient need. A wearable is justified when it adds actionable information, supports engagement or improves access. If it increases burden without changing care, a conventional pathway is preferable. Person-centred selection is therefore the first implementation safeguard.

Implementation and Workflow

Technology succeeds when embedded in care. Referral, onboarding, device fitting, education, data review, alerts, documentation, technical support and return of equipment all require ownership. Without workflow design, wearable data becomes an additional inbox.

Clinicians need training in both technology and interpretation. A dashboard should present trends and exceptions rather than raw signals. Integration with health records reduces duplicate documentation, but interoperability was limited in many systems during the evidence period.

Services should pilot implementation and measure enrolment, wear time, adherence, technical failures, response time, visits, outcomes and patient experience. They should report who declines or cannot participate. High satisfaction among enrolled users may conceal exclusion.

Cost evaluation includes devices, software, connectivity, staff review, replacement, cybersecurity and technical support. Fewer visits do not automatically mean lower cost. Savings may arise through targeting visits, but evidence should be measured rather than assumed.

Vendor relationships require transparency. Proprietary algorithms and changing platforms complicate validation. Contracts should address data ownership, access, retention, export and device

discontinuation. Clinical services should avoid dependence on a system that cannot provide interpretable data.

Equity, Privacy and Ethics

Digital rehabilitation can improve access for rural patients and people with transport difficulty, but it can also widen inequality. Older adults may have limited digital confidence, impaired vision or no smartphone. Language, literacy and household connectivity affect use. Technology should be offered, not imposed.

An equivalent non-digital pathway must remain available. Declining monitoring should not reduce access to physiotherapy. Training, simplified interfaces and loan devices can improve inclusion, but some patients still need face-to-face care.

Movement data can reveal routines and location-related patterns. Consent should explain what is collected, who sees it and how long it is retained. Only data necessary for care should be collected. Patients should be able to withdraw without penalty.

Cybersecurity is a clinical issue because breaches undermine trust and system failure can disrupt care. Secure authentication, encrypted transfer and role-based access are important. Clinicians should use approved platforms rather than personal messaging accounts.

Ethical use also requires avoiding algorithmic bias. Devices validated in healthy, faster walkers may perform poorly in older adults using frames. Performance should be evaluated across relevant populations before decisions rely on it.

Rural and Resource-Limited Applications

Wearables could extend physiotherapy where distance and workforce shortages restrict follow-up. A patient may receive initial in-person assessment and device training, followed by remote review and scheduled local care. This hybrid model preserves safety while reducing travel.

Connectivity limitations require offline functionality and delayed synchronization. Systems should not assume continuous broadband. Low-cost sensors and phone-based applications may be practical, but device compatibility and maintenance matter.

Community health workers or local physiotherapists can support setup and escalation. Remote specialists should communicate clearly and avoid duplicating instructions. Care pathways need local emergency contacts.

Cost must be considered from the patient perspective, including data charges, travel and time. A platform that shifts cost to the patient may not improve access. Evaluation should include participation by socioeconomic group.

Simple monitoring can be more sustainable than high-dimensional data. Steps, exercise completion and scheduled calls may deliver greater value than complex gait analytics that nobody reviews. Technology should match the decision capacity of the service.

Limitations and Research Priorities

Evidence through 2021 is limited by small pilots, heterogeneous platforms and selected participants. Device accuracy, adherence and clinical outcomes are not consistently reported. Comparator physiotherapy varies, making claims of equivalence context dependent.

Future trials should describe sensors, placement, algorithms, missing-data rules, feedback and clinician contact. Standard outcome sets should include pain, range, strength, mobility, activity, patient-reported function, complications, adherence and adverse events.

Research should determine which patients benefit from automated self-management, hybrid care or intensive in-person therapy. Predictive algorithms require external validation and should support rather than replace clinical judgment.

Long-term studies should examine whether activity gains persist after monitoring stops. Economic evaluation should include total service and patient costs. Qualitative research can identify burden, trust and reasons for non-use.

Interoperability, privacy and equity should be evaluated as outcomes, not afterthoughts. A clinically accurate system that excludes patients or cannot integrate into workflow may have little real-world value.

Conclusion

Wearable sensors can extend physiotherapy observation after TKA by measuring activity, exercise performance, motion and selected gait characteristics. Evidence from 2012 through 2021 supports feasibility and indicates that digital or sensor-supported home rehabilitation can produce outcomes comparable to conventional care in selected patients.

Wearables are adjuncts, not autonomous therapists. Their outputs require validation, symptom context and professional interpretation. Safe pathways include conventional baseline assessment, individualized targets, scheduled human review, escalation rules and non-digital alternatives.

Future work must standardize measures, clarify cost effectiveness and address privacy, workflow and equity. The most useful technology is not the device collecting the most data, but the system that helps a physiotherapist and patient make safer, timely and meaningful rehabilitation decisions.

For current practice, a phased hybrid model is the most defensible overall approach. Initial assessment and device training establish safety and baseline function; remote monitoring then supports exercise and activity progression; scheduled reassessment confirms recovery; and in-person care is intensified when symptoms, function or data quality raise concern. This model preserves professional accountability while using technology to extend reach. Its success should be judged by patient outcomes, access, workload, experience and clinical sustainability rather than adoption rate alone.

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