CURRENT CONCEPTS REVIEW

Partial Weight-Bearing after Lower Extremity Surgery: A Review of Current Standards, Innovations, and Patient Compliance

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Abstract

Partial weight bearing (PWB) is a cornerstone of post-operative rehabilitation after lower extremity surgery (LES), balancing mechanical stimulation needed for bone, tendon, and cartilage healing with protection against excessive load that precipitates malunion, non-union, or joint dehiscence. This narrative review synthesizes literature to clarify current indications for PWB, evaluate traditional and emerging methods for prescribing and monitoring load, and identify factors influencing patient adherence. Hip, knee, ankle, and foot procedures commonly warrant PWB, yet optimal targets and progression schedules remain surgeon-dependent and inconsistently standardized. Household scales fail to replicate dynamic gait and are associated with poor long-term accuracy when compared to biofeedback devices, although these are the most widely adopted PWB adjuncts. Recent clinical trials demonstrate that wearable pressure-sensing insoles, audio or visual biofeedback, smartphone applications, telerehabilitation platforms, and virtual/augmented reality (VR/AR) or robotic off-loading devices markedly improve PWB precision, range of motion, muscle preservation, and functional scores without increasing complications. Nevertheless, widespread adoption is limited by cost, device sizing, battery life, and the requirement for continuous wear. Across studies that objectively quantified loading, adherence remains suboptimal, particularly among elderly and obese patients, underscoring the need for targeted educational interventions. Formal patient education, integrated into routine follow-up, may enhance understanding of PWB rationale, foster self-efficacy, and amplify the benefits of technology. Future research should prioritize high-quality randomized trials that combine sensor-derived compliance metrics with machine-learning analytics to individualize loading protocols, elucidate the drivers of non-adherence, and determine the cost-effectiveness of digital health solutions. Standardizing PWB guidelines while leveraging wearable, telehealth, and VR/AR technologies holds promise for accelerating recovery, reducing revision surgeries, and improving quality of life in an aging, fracture-prone population.

Level of evidence: III

Keywords: Lower extremity, Patient compliance, Postoperative care, Telemedicine, Virtual reality, Wearable electronic devices, Weight-bearing

Introduction

Bone fractures, particularly those involving the lower extremities, impact a large proportion of the population, with ~50% of the world's population experiencing at least one fracture before reaching sixty-five years old.[1,2] The topic of efficient recovery highlights the importance of mitigating complications that may occur post-operatively, including infection, joint deterioration and complications, muscle imbalances, and unnecessarily prolonged recovery periods.[3,4] Partial weight-bearing—placing a set amount of weight on the post-operative limb

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(i.e., 20% of body weight, 30% of body weight, etc.) throughout activities of daily living—has remained an essential tool in enhancing recovery from many lower extremity surgeries (LES). In well-developed countries, the population of elderly individuals is increasing, highlighting the importance of streamlined and efficient post-operative guidelines to ensure a short post-surgical duration of union and callus formation,[3] while minimizing the risk of non-union, malunion, infection, and prolonged recovery periods. For nearly 40 years, partial weight-bearing has been a cornerstone of recovery from various lower extremity surgeries, with recent innovations enhancing its clinical utility.[5-9]

Main body

Rationale for Partial Weight-Bearing after Lower Extremity Surgery

There are a few different methods of weight-bearing (WB) that a surgeon can prescribe after performing lower extremity procedures [Table 1]: toe-touch weight-bearing (TTWB), partial weight-bearing (PWB), weight-bearing as tolerated (WBAT), and full weight-bearing (FWB).[4,10] Generally, movement after LES provides meaningful utility—allowing for a more anabolic environment in the surrounding musculature, greater blood flow to the tissues near the site of surgery, and prevention of critical deficits in mobility—although, some surgeries necessitate restricted movement and no weight-bearing (NWB).[11-13] A few examples of these surgeries are Achilles tendon repairs, posterior tibial tendon reconstruction, and hip labral reconstruction or repair.

PWB is most commonly employed to facilitate active recovery while minimizing the cumulative distress experienced by the joint capsule or fracture site from overbearing. Full WB can ultimately lead to wound complications, superficial or deep dehiscence, as well as joint deterioration and healing delays, while NWB can contribute to the development of osteoporosis and muscle weakness. When WB exceeds or falls short of the prescribed target, typically up to an expert surgeon's discretion, rates of malunion and non-union increase, while callus formation is at risk of delay.[5] Fortunately, there appears to be no change in infection rates due to a lack of adherence to PWB guidelines,[14] but revision surgeries are often necessary if the healing process is disrupted by these adverse outcomes. PWB aids in facilitating gradual, dynamic loading, which is both concentric and eccentric in nature, allowing for an environment that has been proven to accelerate tendon repair and promote a healthy environment within the articular cartilage.[15] Furthermore, the dynamic movement fostered through PWB protocols is likely to create an articular environment that promotes vascularization and bone tissue remodeling,[16] assuming the load is not of an injurious threshold. Orthopedic surgeons aim to develop clear WB guidelines for each LES to ensure proper recovery and maintenance of patient quality of life.

Table 1. Summary of various types of weight-bearing methods utilized after lower extremity surgeries.

Weight-Bearing Type	Description
Full Weight-Bearing (FWB)	A form of weight-bearing in which no restrictions are applied to a patient, allowing them to place their full weight on their operative limb.
Partial Weight-Bearing (PWB)	A type of weight-bearing in which a patient is assigned a target weight, less than their body weight, to continuously place on their operative limb. Target weight typically increases over time as the patient recovers.
Weight-Bearing as Tolerated (WBAT)	A type of weight-bearing in which a patient places as much weight as tolerable, according to their pain threshold and comfortability, on their operative limb. Typically, it increases over time at the patient's discretion.
Toe-Touch Weight-Bearing (TTWB)	Weight-bearing is when a patient can place a small amount of weight (typically 10-15% of body weight or less) on their operative limb for additional balance.
No Weight-Bearing (NWB)	Complete lack of weight-bearing on the operative limb, typically for a short duration, after highly invasive surgeries or traumatic events.

Surgeries Necessitating Partial Weight-Bearing Post-Operatively

The physiologic rationale for PWB post-operatively is consistent throughout the major complexes of the lower extremity: hip/pelvis, knee, and foot/ankle. Although the biomechanics of specific WB and the typical movement patterns of these joints throughout a normal gait cycle are radically different, the PWB prescription is generally consistent. The goals of avoiding dehiscence, fostering quick improvements in mobility, optimizing tendon and ligament healing with maintenance of peri-articular muscle strength bilaterally, and reduction of overall acute inflammation remain the same throughout any surgery requiring PWB.

Generally, PWB is preferred to NWB; however, although less common, there are numerous examples of surgeries that necessitate NWB for a shorter period after surgery. It is typical of surgeons to prescribe NWB after surgeries to fix traumatic injury sites, while elective joint arthroplasties commonly involve post-operative PWB. Specific examples of hip and pelvic procedures typically requiring PWB post-operatively are pelvic osteotomies, hip fracture fixations, and total hip arthroplasties. In contrast, more extensive pelvic reconstruction surgeries, i.e., internal hemipelvectomy, require strict NWB.[17] Common examples of knee surgeries requiring PWB post-operatively are total knee arthroplasties, meniscal repair, and fixation of tibial plateau fractures.[18] Lastly, ankle surgeries necessitating PWB can include total ankle replacements and ankle fracture fixations.[19,20] Prescriptions of PWB versus NWB are ultimately referred to the expert surgeon's discretion, along with the exact loading parameters of PWB when indicated, but it is important to institute specific recommendations for WB post-operatively.

Bathroom/Household Scales

The most traditional and widespread manner in which PWB is instituted is through the use of bathroom/household scales. These are common in homes across the world, and scales allow a patient to practice PWB on their own time after LES. Patients are often prescribed a target weight by an expert surgeon to be maintained through their operative limb during the recovery period, with the ultimate goal of gradually increasing this weight until reaching normal, full weight-bearing capacity during daily activities. The main advantages of this PWB approach are that patients can practice at their own convenience and that there is minimal cost associated with obtaining a high-quality scale; however, a few notable drawbacks are also present. When a patient practices PWB on a scale, they are in a standing position, which does not accurately mimic dynamic movements. This discrepancy has been shown to negatively impact the adherence and accuracy of PWB, particularly in the long term, in several studies.[2,21,22] This can be countered by repetitive practice on a scale daily, ensuring that patients develop a strong memory for the correct load.[23] Although traditional scales are the most widely used adjunct for partial weight-bearing, there has been tremendous innovation within the past two decades in creating devices with greater utility and quantitative measurement capabilities [Figure 1, Table 2]. These characteristics have benefited patient recovery rates while enhancing analytical tools that expand the realm of quantitative assessment for researchers and clinicians.

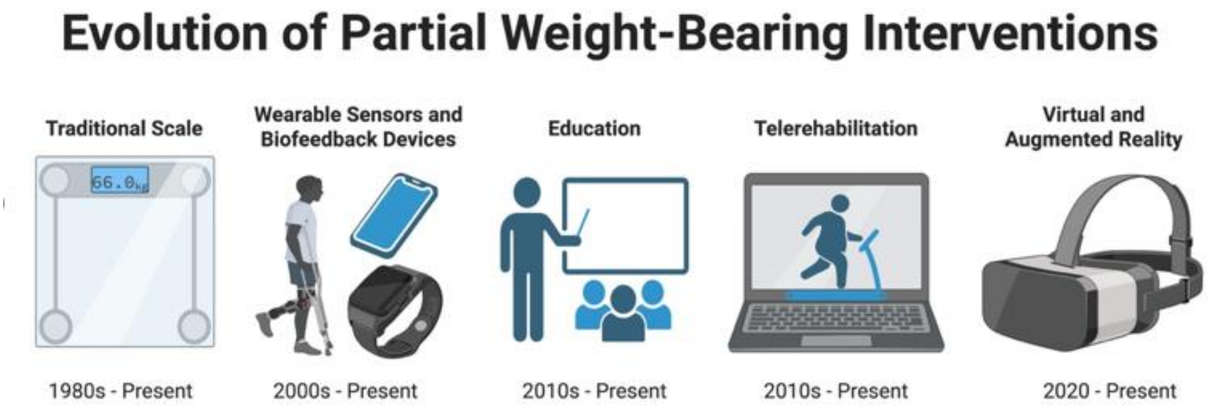

Figure 1. The evolution of partial weight-bearing interventions across time

Table 2. Summary of interventions used in enhancing partial weight-bearing adherence and effectiveness.

Intervention	Description	Benefits	Limitations
Bathroom/Traditional Scale	With support, the patient places one leg on a scale until the prescribed weight-bearing target is reached; ideally repeated often throughout the recovery period to enhance accuracy and precision	Low cost; ability to practice weight-bearing at home	Does not mimic dynamic movement or allow for immediate feedback during daily activities
Wearable Sensors and Real-Time Biofeedback	The use of devices—insoles, specifically, have been studied the most—to allow for real-time audio, visual, and quantitative feedback as a patient performs daily activities (i.e., walking)	Immediate feedback and opportunity for correction; quantitative data measurements; functional benefits realized in many randomized control trials	Limited widespread availability; limited shoe sizes (insoles); low battery life in some devices
Educational Interventions	Periodic teaching and collaborating with patients on their post-operative journey to foster an internal locus of control and adequate knowledge as to the utility of partial weight-bearing throughout their recovery	Increased patient self-efficacy and confidence with weight-bearing; synergizes with technological interventions, which often require more up-front teaching and familiarization	More time requirements placed on healthcare workers

Table 2. Continued

Telerehabilitation	A post-operative program using tools such as apps, internet platforms, and/or video sessions, allowing patients to participate in remote exercise sessions	Remote exercise program, not requiring attendance to a clinic; enhances self-efficacy, functional outcomes, and quality of life	Lack of contact with healthcare personnel while exercising particularly important if patients have multiple, immediate questions
Virtual and Augmented Reality	The most recent technological advancement in post-operative partial weight-bearing involves patients being immersed in a virtual environment that mimics dynamic movement through visual simulators, commonly a headset.	Allows for the practice of weight-bearing in a safe environment; comparable efficacy to home-based programs but with improved functional outcomes reported	Expensive devices; oftentimes performed in a controlled clinical setting, as opposed to at-home

Technological Devices and Recent Innovations

Multiple clinical trials since 2010 have examined technologies to improve post-operative recovery during PWB restrictions in LES [Table 3]. These trials have been invaluable in providing insight into the mechanisms by which researchers and clinicians can enhance compliance and recovery after LES.

Table 3. Studies of technology-assisted rehabilitation after lower extremity surgeries requiring partial weight-bearing (2011–2025).

Study (Year)	Design	Surgery Type	Technological Intervention	Outcomes Measured	Key Findings
Hurkmans et al., 2012	Randomized Control Trial	Total Hip Arthroplasty	In-shoe pressure sensor with audio feedback versus no feedback	Weight-bearing load during training and unsupervised walking; step count	The audio feedback group achieved greater accuracy in meeting assigned weight-bearing goals during supervised training.
Raaben et al., 2018	Pilot Randomized Control Trial	Total Hip Arthroplasty	“SensiStep” wearable insole with visual feedback	Peak load on operative limb; gait performance	Real-time feedback improved postoperative weight-bearing accuracy, allowing patients to walk farther and use fewer assistive devices than the control group.
Avci et al., 2025	Feasibility Randomized Control Trial	Talar Osteochondral Repair (Ankle)	Smart insole and smartphone app with continuous weight load monitoring versus the same insole without feedback	Partial weight-bearing compliance and accuracy at home	Patients receiving real-time alerts stayed within the prescribed load significantly more often than those without feedback.
Henkelmann et al., 2021	Multicenter Randomized Control Trial	Tibial Plateau and Ankle Fractures	Anti-gravity treadmill therapy (partial body weight support) versus standard rehab exercises	Patient-reported joint function; thigh muscle circumference; adverse events	Anti-gravity intervention contributed to less thigh muscle atrophy and better gait symmetry.
Piqueras et al., 2013	Randomized Control Trial	Total Knee Arthroplasty	Interactive virtual telerehabilitation system versus standard outpatient physiotherapy	Knee range of motion; muscle strength; gait speed; functional scores	Both therapies resulted in significant improvements in knee range of motion (ROM) and function, as well as other outcomes.
Zhao et al., 2023	Randomized Control Trial	Total Knee Arthroplasty	Smartphone-based rehabilitation app versus routine home exercise and periodic outpatient visits	Knee range of motion; functional scores; balance tests; complications and readmissions; quality of life	The intervention group had greater knee flexion, performance on balance/strength tests, and self-reported physical function.
Wang et al., 2023	Randomized Control Trial	Total Hip and Knee Arthroplasties	Standard care and rehabilitation program with mobile app versus standard rehabilitation alone	Self-efficacy; patient-reported physical function; pain; anxiety and depression; quality of life	The intervention group showed significantly greater improvements in self-efficacy, physical function, health-related quality of life, and lower anxiety and depression scores than controls.
Zhang et al., 2022	Randomized Control Trial	Hip Fracture Fixation/Replacement	Internet-based telerehabilitation management system versus periodic phone follow-up	Hip function; independence during activities of daily living; mobility; physical performance	The telerehabilitation group showed greater hip function, independence scores, and superior mobility recovery.
Lim et al., 2024	Randomized Control Trial	Anterior Cruciate Ligament Reconstruction	Augmented reality-based telerehabilitation versus standard home program	Knee function; knee range of motion and isometric strength; one-leg hop test; pain	The intervention group achieved greater isometric quadriceps strength gains of the operative limb. All other metrics were not significantly different

Wearable Sensors and Biofeedback Devices

Several innovations have advanced the field of PWB after LES in terms of accuracy and compliance; however, they have not been widely implemented across the orthopedic field. Several studies, paving the way for innovation, have demonstrated the utility of real-time biofeedback in promoting more consistent adherence to PWB regimens among patients.[5,6,14] Biofeedback has been primarily studied through audio feedback,[24,25] and, most importantly, through the use of insole devices.[7,14,26,27] These devices enable patients to continuously monitor and adjust the load on their operative limb during daily activities. An additional benefit of biofeedback devices is that the data obtained from the insole can often be uploaded to a system or app that allows for direct quantification of compliance, which is particularly useful to researchers.[14]

Similar studies have presented a continuous pedobarographic insole that accurately measures adherence, as before, while also providing insight into gait abnormalities.[1,8,9] In this multi-faceted approach, physicians can be kept updated on the condition of their patients while allowing patients to feel involved in their own recovery. In fact, when using continuous biofeedback measures, it has been noted that both physician and patient satisfaction, as well as patient confidence, significantly increase.[5,14] Adding to these benefits in morale and self-esteem are noticeable physiological changes when patients utilize these devices: a lower prevalence of non-union and malunion, shorter recovery periods, and quicker gain of functionality.[5,6,14] The superiority of biofeedback is exhibited when comparing this intervention to traditional scale techniques and physiotherapy, as it demonstrates greater accuracy of PWB when compared to these two interventions.[24,26] Another benefit of biofeedback is that patients using these devices exhibit greater improvement in PWB accuracy over time,[28] likely due to the devices providing real-time feedback that allows users to produce consistent motor patterns gradually.

Wearable sensor systems providing real-time biofeedback have also demonstrated improved compliance with PWB instructions. In a randomized trial of total hip arthroplasty (THA) patients, the addition of audio feedback during supervised gait training led to more accurate offloading compared to standard instruction.[25] However, this effect was mitigated by unsupervised walking. Similarly, a pilot randomized controlled trial (RCT) in THA patients found that visual biofeedback via an insole sensor ("SensiStep") significantly improved early weight-bearing accuracy and enabled longer ambulation distances by 12 weeks.[29] A different study examining recovery from ankle microfracture surgery utilized an innovative insole that transmitted continuous load data to a smartphone, thereby improving physical work capacity (PWB) compliance.[27] Over one week, patients receiving real-time feedback stayed within weight limits significantly better than those without feedback.[27] These findings suggest that wearable pressure sensors with auditory or visual cues can enhance adherence to weight-bearing prescriptions, which is critical for bone and tissue healing. This approach to synergizing patient efforts with innovative and effective technology has provided examples that demonstrate the utility of continuous PWB measures as a cornerstone of increasing patient compliance, thus enhancing measurable outcomes of post-operative functionality.

Machine learning has already made its way into the orthopedic field through wearable devices, where AI can predict recovery trajectories within patients suffering from musculoskeletal injuries.[30] Similarly, machine learning can analyze data collected from pressure-sensing insoles to predict physiological outcomes, optimize weight-bearing planning, and measure patient adherence. This presents an exciting avenue for future PWB research.

There are several concerns with biofeedback devices that should be noted. First, the initial cost of these interventions can be deterring for patients and physicians, particularly when there are other viable alternatives for PWB. Another current limitation is that many of these devices are embedded within insoles, shoes, or boots, which have limited sizes, so there may be portions of the population who do not fit into the given sizes. This is particularly prevalent in patients who are larger in size or who have significant post-operative swelling in their distal extremities. Additionally, battery life is often a consideration when using biofeedback devices, as it is not uncommon for these devices to require charging throughout the day.[31] The last concern is that these devices must be worn at all times when the patient is walking; otherwise, they will not extract the benefits. This presents an extra component that may deter some patients from consistent use over weeks and months.

Mobile Health Applications and Telerehabilitation

Tele-rehabilitation platforms and mobile apps have been tested as alternatives or adjuncts to traditional therapy after lower extremity surgeries. A multicenter randomized controlled trial (RCT) involving 142 patients undergoing total knee arthroplasty (TKA) compared home-based virtual telerehabilitation through an interactive online system to standard outpatient physiotherapy. Both groups achieved equivalent improvements in knee range of motion and strength following a two-week program and at a three-month follow-up visit,[32] indicating that remotely supervised exercise can match in-person rehabilitation outcomes. More recent trials reinforce these findings. Zhao et al. (2023) evaluated a smartphone app for post-total knee arthroplasty (TKA) rehabilitation in 100 patients. At 12 weeks, the app group demonstrated superior knee flexion and better functional test performance, with no increase in complications or readmissions.[33] Similarly, Wang et al. (2023) reported that a six-week mobile app program, as opposed to standard discharge care, significantly improved patients' self-efficacy, physical function, and quality of life after hip or knee arthroplasty while also reducing anxiety and depression.[34] In older adults recovering from hip fracture, Zhang et al. (2022) found that an internet-based telerehabilitation system (video-guided exercises) led to higher Harris Hip Scores and Functional Independence Measure scores at one and three months post-surgery compared to routine telephone follow-ups.[35] Notably, balance and mobility, as measured by the Timed Up-and-Go and Short Physical Performance Battery, also improved with telerehabilitation in patients with hip fractures.[35] These studies demonstrate that telerehabilitation—delivered via apps, video sessions, or dedicated platforms—can safely augment recovery, maintaining and sometimes accelerating functional gains while enabling remote monitoring.

Virtual Reality, Augmented Reality, and Robotic Aids

Emerging evidence suggests that virtual and augmented reality (VR/AR) systems and robotic-assisted exercise devices can enhance rehabilitation after lower extremity surgery. VR-based rehabilitation programs following TKA have demonstrated reductions in pain and improvements in function and range of motion. A 2024 meta-analysis of VR in TKA rehabilitation found significantly lower pain scores, better WOMAC function indices, faster Timed Up-and-Go times, and greater knee flexion in VR-trained groups compared to those receiving conventional therapy.[36] In anterior cruciate ligament reconstruction, an augmented-reality telerehabilitation system (utilizing a motion-tracking camera) was as effective as a standard at-home program for restoring knee stability and patient-reported function; importantly, the AR group achieved faster recovery of quadriceps strength by 6–12 weeks post-op.[37] Robotics and offloading devices have also been explored to facilitate safe weight-bearing. Henkelmann et al. (2021) conducted an RCT using an anti-gravity treadmill after surgical fixation of ankle and tibial plateau fractures. At six weeks, patient-reported outcomes were similar to those of conventional rehabilitation, but the anti-gravity group exhibited less thigh muscle atrophy, suggesting benefits in muscle preservation.[38] A one-year follow-up of this cohort revealed improved gait parameters in individuals who utilized the unloading treadmill.[38] These advanced technologies highlight the potential for optimizing early mobilization: VR/AR can increase patient engagement and possibly expedite functional recovery, while robotic-assisted weight support allows therapeutic exercise with reduced risk, all without compromising safety or outcomes.

Educational Interventions

Due to the room for improvement in compliance rates, previous studies have noted that formal educational interventions can increase patient compliance with PWB prescriptions.[2] This may include education about the reasons PWB is essential for recovery from LES, teaching about how exactly to operate biofeedback devices and wearable devices (particularly important in the elderly),[39] and about the need to practice PWB consistently to ensure that when patients are compliant, they are also accurately achieving their prescribed weight-bearing targets.[2] This intervention primarily presents an issue of opportunity cost since it would take critical and limited time away from surgeons. Still, educating patients at regularly scheduled follow-up appointments could increase their internal locus of control and reduce the need for additional time spent on this critical education. With this intervention, patients are likely to feel more involved in their recovery and more confident that they're adhering to the expert surgeon's exact PWB prescription.

Compliance Rates and the Need for Accurate Measurement

While the benefits of PWB after LES are well-established, there is limited data on how well patients adhere to these protocols. This highlights a significant need to not only assess compliance rates with existing PWB guidelines but also to uncover the reasons behind non-compliance,[1] as a lack of adherence can worsen patient outcomes.

In the few cases where adherence to post-operative PWB plans is measured, results often reveal suboptimal compliance, indicating areas for improvement.[1,5,14] Obese and elderly patients, in particular, have been shown to exhibit lower compliance rates, most commonly overbearing on their affected limb[39-41]; this demonstrates a target population to which specific, tailored interventions should be aimed.[42] Although a few manuscripts have shown insightful trends, compliance rates are rarely examined in a comprehensive manner that would provide valuable insights for surgeons specializing in lower extremity procedures. This highlights the need for further research to accurately determine compliance rates and identify the factors that influence compliance. Without precise measurements, these influencing factors may remain unidentified. Through the advent of consistent data monitoring from wearable devices, physicians are likely to have access to a greater amount of meaningful patient data, which may optimize in-office patient visits through the documentation and analysis of variables that, until recently, have been inaccessible to clinicians. This would also help provide critical data on patient compliance. In the absence of widespread current technological implementation, clinicians may gain insight into their patients' compliance with PWB protocols through brief surveys at follow-up visits.

Conclusion

PWB following LES remains a critical component of recovery, balancing the need to promote bone and soft tissue healing with the preservation of mobility and function. This review highlights the importance of standardizing PWB guidelines to optimize patient outcomes while addressing the challenges posed by adherence variability and the limitations of traditional approaches. In aggregate, the evidence indicates that incorporating wearables, telehealth, VR/AR, or robotic assistive devices can either improve specific recovery parameters or produce outcomes comparable to conventional rehabilitation with greater convenience. Importantly, none of the trials reported higher complication rates with the use of technology. Overall, leveraging technology in PWB rehabilitation can enhance patient engagement and adherence, potentially accelerating functional recovery without compromising safety.[29,37] Educational interventions have emerged as a practical and cost-effective strategy to bridge the gap between innovative technologies and traditional methods, fostering patient confidence and engagement in the recovery process. Moving forward, future research must prioritize the accurate measurement of compliance, identify key drivers of non-adherence to existing PWB protocols, and evaluate the cost-effectiveness of emerging technologies. By combining evidence-based PWB practices with technological and educational interventions, the orthopedic community can further refine recovery protocols to benefit a diverse patient population, ensuring quicker recoveries and enhanced quality of life post-surgery.

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