American Journal of Advanced Multidisciplinary Innovation and Research (AJAMIR)

E-ISSN: XXXX-XXXX ● Website: www.ajamir.com ● Email: editor@ajamir.com

Home-Based Rehabilitation Adherence Through Adaptive Mobile Support

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Abstract

Home-based rehabilitation extends therapeutic activity beyond supervised clinical encounters, but its effectiveness depends substantially on whether patients perform prescribed exercises consistently, correctly, and for an adequate duration. Conventional home programs frequently rely on printed instructions, patient memory, and occasional follow-up, leaving clinicians with limited information regarding missed sessions, exercise difficulty, symptom fluctuations, or declining motivation. Mobile health technologies offer an opportunity to strengthen rehabilitation continuity through reminders, instructional media, progress recording, feedback, and remote professional support. The present study develops a simulation-based model of adaptive mobile support in which rehabilitation guidance responds within clinician-defined boundaries to adherence history, reported difficulty, symptoms, progress, and missed-session patterns.

A hypothetical sample of 360 adults participating in home rehabilitation was divided equally among adaptive mobile support, static mobile support, and usual home-program conditions. All numerical findings are synthetic because no original clinical dataset was supplied. At eight weeks, mean simulated adherence was approximately 77% in the adaptive-support pathway, 65% in the static mobile pathway, and 54% under usual home rehabilitation.

The adaptive pathway also demonstrated higher modeled program completion, greater confidence in completing prescribed exercises, and earlier identification of adherence decline. Prior evidence shows that applications combined with remote support can improve home-exercise adherence compared with paper instructions, while systematic research identifies motivation, self-efficacy, social support, perceived effectiveness, and therapeutic relationships as relevant determinants of adherence.

Keywords: home-based rehabilitation; exercise adherence; mobile health; adaptive support; telerehabilitation; physiotherapy; rehabilitation technology; patient engagement; therapeutic exercise; digital health

1. Introduction

Home-based therapeutic exercise is an important component of rehabilitation across musculoskeletal, neurological, cardiopulmonary, postoperative, and chronic health conditions. It enables patients to continue rehabilitation between supervised appointments and provides opportunities for repeated practice within their everyday environment. The clinical value of a technically appropriate exercise prescription, however, depends on implementation. Patients who perform exercises inconsistently,

abandon the program early, misunderstand instructions, or reduce activity because of uncertainty may receive a substantially smaller therapeutic dose than intended. Reviews of home-based physical rehabilitation have identified a wide range of adherence-related influences, including self-efficacy, motivation, social support, perceived treatment effectiveness, psychological characteristics, and program-related factors.

Traditional home-exercise delivery frequently involves verbal instruction supplemented by printed diagrams or written sheets. Such methods can be clinically appropriate, but they provide limited capacity for ongoing observation after the patient leaves the rehabilitation setting. Palazzo and colleagues' qualitative study among people with chronic low back pain documented barriers to home-exercise adherence and explored patients' expectations regarding technology-supported rehabilitation. More broadly, adherence research has shown that reminders alone are unlikely to address every barrier because patients may also encounter pain, uncertainty about technique, competing responsibilities, lack of supervision, reduced motivation, fear of injury, or difficulty perceiving progress.

Mobile health creates a different opportunity because support can continue throughout the interval between clinical visits. Lambert and colleagues conducted a randomized trial in people with musculoskeletal conditions and reported better adherence when a mobile application was combined with remote support than when home exercises were provided through paper handouts. Bennell and colleagues subsequently found that a web-based exercise programming system improved home-exercise adherence and confidence in exercise performance, although the clinical importance of the differences required careful interpretation. Research in stroke rehabilitation has likewise suggested that mobile technology can support home physical-activity adherence, while also demonstrating the importance of continued support and guidance for some users.

A limitation of many digital rehabilitation systems is that they remain essentially static. A patient may receive videos, reminders, or digital exercise instructions, but the system does not meaningfully respond when adherence declines, exercises become too difficult, symptoms change, or the patient repeatedly reports uncertainty. A 2020 review of home-based telerehabilitation systems identified functions including exercise-plan management, scheduling, patient education, statistics generation, and remote supervision, while also concluding that substantial diversity remained across systems and that further evaluation in real clinical settings was required. This provides a foundation for developing more responsive digital rehabilitation models without assuming that technology itself guarantees adherence.

The present study proposes adaptive mobile support as a structured extension of clinician-prescribed rehabilitation. Adaptation refers to changes in reminders, educational prompts, motivational feedback, progress visualization, clarification requests, and clinician escalation based on patient interaction and adherence patterns. It does not imply unrestricted autonomous alteration of rehabilitation intensity or clinical treatment. Exercise progression, regression, or suspension should remain within predefined professional protocols and require clinician oversight when clinically significant symptoms or functional changes occur. The study uses transparent synthetic data to compare adaptive mobile support, static mobile support, and conventional home rehabilitation and thereby provides a methodological model for future clinical evaluation.

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2. Objectives of the Study

2.1 To Examine Home-Rehabilitation Adherence Under Adaptive Support

The primary objective is to examine whether an adaptive mobile pathway could theoretically improve adherence to prescribed home rehabilitation compared with static digital instructions and conventional home-program delivery. Adherence is conceptualized as the proportion of prescribed rehabilitation sessions completed within an agreed time frame rather than simply the number of times a participant opens an application. This distinction is important because digital engagement metrics do not necessarily represent performance of clinically meaningful rehabilitation activity.

The analysis also considers adherence as a trajectory rather than a single end-point measurement. Rehabilitation engagement may be relatively strong immediately after an appointment and decline as initial motivation diminishes, symptoms fluctuate, competing obligations increase, or progress becomes less visible. Adaptive support is therefore designed to identify emerging disengagement and respond before complete program abandonment.

2.2 To Evaluate Personalized Feedback and Clinician Connectivity

The second objective is to examine how patient-specific feedback, goal tracking, and access to rehabilitation professionals may support adherence. Existing evidence indicates that adherence is influenced by psychological and interpersonal factors as well as exercise prescription itself. Essery and colleagues identified multiple predictors associated with adherence to self-managed physical therapies, while Moore and colleagues highlighted the role of therapeutic alliance in longer-term exercise engagement among older adults receiving physiotherapy for knee pain.

Adaptive support therefore retains a visible clinician relationship. The mobile system is conceptualized as a communication and self-management tool rather than a replacement for rehabilitation professionals.

2.3 To Develop a Safe and Scalable Digital Rehabilitation Framework

The third objective is to formulate an adaptive support model capable of functioning within diverse home environments while maintaining patient safety. Home rehabilitation differs from supervised exercise because clinicians cannot continuously observe movement quality, environmental hazards, fatigue, or symptom progression. Digital support must consequently incorporate clear boundaries concerning what can be managed remotely and when direct reassessment is necessary.

Scalability is similarly important. A model that requires therapists to review every completed exercise in real time may increase access but produce an unsustainable professional workload. The proposed framework therefore uses routine automated support for low-risk adherence functions while reserving clinician attention for meaningful deviations, repeated difficulty, concerning symptoms, and cases requiring treatment modification.

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3. Review of Literature

3.1 Adherence Challenges in Home-Based Rehabilitation

Exercise adherence has long been recognized as a major challenge in self-managed rehabilitation. Picorelli and colleagues reviewed exercise-program adherence among older people and found considerable variation in how adherence was measured, including attendance and dropout-based measures. Essery and colleagues later reviewed predictors of adherence to home-based physical therapies and identified patient, psychological, social, and treatment-related factors associated with adherence. These findings indicate that adherence is better understood as a behavioral and contextual outcome than as a simple expression of patient willingness.

Qualitative research provides additional detail. Palazzo and colleagues found that individuals undertaking home exercises for chronic low back pain described practical and motivational barriers and expressed expectations regarding new technologies that could support exercise performance. Moore and colleagues subsequently showed that supervision, monitoring, motivation, and the quality of the therapeutic alliance remained relevant to long-term exercise behavior among older adults with knee pain. Together, these studies suggest that adherence-support technologies should address uncertainty, feedback, connection, and motivation rather than merely transferring existing paper instructions to a screen.

Adherence also matters because rehabilitation effectiveness can depend on sufficient participation in the prescribed activity. Gunnes and colleagues reported that greater adherence to a physical-activity and exercise intervention after stroke was associated with better functional recovery across several outcome measures after adjustment for selected covariates. Although such observational associations cannot prove that adherence independently causes every improvement, they reinforce the clinical importance of understanding and supporting treatment participation.

3.2 Mobile Technology and Telerehabilitation

Telerehabilitation research demonstrates that rehabilitation can be delivered or supported outside conventional face-to-face settings. Hwang and colleagues' systematic review of cardiopulmonary telerehabilitation found outcomes broadly comparable with other delivery models and reported indications of higher adherence in some telerehabilitation programs. Cottrell and colleagues later concluded that real-time telerehabilitation for musculoskeletal conditions appeared effective and comparable with conventional health-care delivery for physical-function outcomes. These findings support remote rehabilitation while also emphasizing that effectiveness depends on program design and clinical context.

More direct evidence concerning home-exercise adherence was provided by Lambert and colleagues. Their randomized trial showed that an application combined with remote support achieved greater adherence to home exercise than paper handouts among people with musculoskeletal conditions. Bennell and colleagues similarly found improved adherence and exercise confidence using a web-based exercise programming system. Importantly, these studies imply that digital intervention can influence adherence but do not establish that all applications or all technological features are equally effective.

Valenzuela and colleagues reviewed technology-based exercise programs among older adults and concluded that such interventions demonstrated generally good adherence while also emphasizing the

need for additional research on longer-term feasibility, acceptability, and effectiveness. Hosseiniravandi and colleagues' 2020 review of home-based telerehabilitation software further identified common features such as exercise-plan management, educational material, scheduling, monitoring, and reporting. These findings establish a technological foundation but leave an important question regarding how support should change when a patient's adherence or rehabilitation experience changes.

3.3 Adaptive Support and the Remaining Research Gap

The principal gap concerns the distinction between digital delivery and adaptive digital support. A static application may reproduce exercise instructions and provide scheduled reminders regardless of whether the patient is progressing well, missing sessions, or experiencing difficulty. Adaptive support instead uses patient-generated and adherence-related information to modify the type and intensity of support while maintaining clinician-defined treatment boundaries.

Behavior-change research provides a theoretical basis for this approach. Meade and colleagues reviewed behavior-change techniques associated with adherence to prescribed exercise and physical activity and identified intervention components potentially relevant to sustained exercise behavior. Peek and colleagues similarly reviewed interventions intended to improve adherence to physiotherapist-prescribed self-management strategies and found multiple potentially useful adherence-support techniques. The evidence indicates that adherence interventions are likely to require combinations of strategies rather than reliance on a single reminder mechanism.

The research gap is therefore both technological and clinical. Digital systems are capable of collecting repeated information, but rehabilitation research must determine how this information should influence support without creating unsafe autonomous treatment changes, excessive alerts, or additional burden for patients and therapists. The present study addresses this gap through a simulated adaptive model that links adherence monitoring with differentiated reminders, feedback, educational reinforcement, and professional escalation.

4. Research Methodology

4.1 Research Design and Simulated Study Population

The study adopts an eight-week simulation-based comparative design involving a hypothetical sample of 360 adults undertaking clinician-prescribed home rehabilitation. Participants were distributed equally among three conditions: adaptive mobile support (n = 120), static mobile support (n = 120), and usual home rehabilitation using conventional instructions (n = 120). The population is intentionally condition-neutral because adaptive support may eventually be tested across multiple rehabilitation populations rather than being restricted to a single diagnosis.

The current analysis contains no real patient observations. Synthetic data were generated to demonstrate the structure of a future randomized or pragmatic clinical evaluation. A real trial would require a clinically defined population, condition-specific eligibility criteria, standardized exercise prescription, ethics approval, informed consent, adverse-event procedures, and prespecified criteria for exercise modification or discontinuation.

Potential baseline covariates would include age, sex, diagnosis, duration of symptoms, previous rehabilitation experience, baseline physical function, pain or symptom severity, self-efficacy, digital

literacy, caregiver support, employment responsibilities, and previous home-exercise adherence. These variables could influence both engagement with mobile technology and adherence independently of the intervention.

4.2 Adaptive Mobile Support Protocol

The adaptive intervention would begin with a clinician-approved exercise program. Each activity would include instructions, demonstration media where appropriate, prescribed frequency, repetition or duration targets, safety advice, and acceptable symptom parameters. Adaptation would occur primarily at the support level, not through unsupervised clinical alteration of the therapeutic prescription.

If adherence remained stable, the application would provide low-intensity reinforcement and progress visualization. A missed session could trigger a neutral reminder and allow the patient to record a reason. Repeated missed sessions could initiate problem-solving prompts concerning time, confidence, symptoms, or practical barriers. Recurrent reports of excessive difficulty, worsening symptoms, or uncertainty regarding exercise technique would be escalated for therapist review. Exercise progression would occur only when permitted by a clinician-approved protocol or after professional reassessment.

The static mobile comparison would contain the same core exercise instructions and scheduled reminders but would not alter support based on individual adherence patterns. The usual-care condition would receive conventional home-rehabilitation instructions and routine scheduled clinical follow-up without continuous mobile adaptation.

Table 1: Proposed Adaptive Mobile Rehabilitation and Questionnaire Framework

Component / Code	Proposed assessment or function	Purpose	Response or system action
Adherence monitoring	Record prescribed and completed sessions	Detect adherence trajectory	Weekly completion percentage
Difficulty monitoring	Patient records perceived exercise difficulty	Identify possible mismatch between capacity and prescription	Therapist review when threshold repeatedly exceeded
Symptom monitoring	Patient records predefined rehabilitation-relevant symptoms	Support safety screening	Escalation according to clinician-approved rules
Adaptive reminders	Reminder frequency changes after missed sessions	Reduce disengagement without excessive notification	Low, moderate, or targeted reminder intensity
Progress feedback	Display adherence and rehabilitation milestones	Support self-monitoring and motivation	Personalized progress summary
Q1	“The mobile support helped me remember when rehabilitation activities were due.”	Reminder usefulness	1–5 Likert scale

Q2	"The rehabilitation instructions were clear enough for me to exercise confidently at home."	Instructional confidence	1–5 Likert scale
Q3	"The feedback I received reflected my actual rehabilitation progress."	Perceived personalization	1–5 Likert scale
Q4	"I knew when I should contact my rehabilitation professional instead of continuing independently."	Safety and escalation understanding	1–5 Likert scale
Q5	"I would be willing to use adaptive mobile support during a future home rehabilitation program."	Acceptability	1–5 Likert scale

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4.3 Outcome Measures and Statistical Analysis

The primary outcome is home-rehabilitation adherence, defined as the percentage of prescribed sessions completed during the study period. Secondary process outcomes include program completion, missed-session recovery, reported exercise confidence, successful therapist escalation, perceived usefulness of feedback, and patient acceptability. Clinical outcomes in a real study would need to be condition-specific and could include pain, mobility, strength, balance, walking capacity, activity performance, disability, or validated patient-reported functional measures.

A future randomized trial could compare mean adherence using analysis of covariance with adjustment for baseline adherence predictors. Repeated weekly adherence could be examined using mixed-effects regression with participant-level random effects. Time to disengagement could be investigated through survival methods where meaningful criteria for discontinuation are defined. Logistic regression could assess completion of the prescribed program, while interaction terms could evaluate whether adaptive support is particularly useful among participants with lower baseline self-efficacy, greater symptom variability, or lower previous adherence.

5. Analysis

5.1 Simulated Adherence and Program Completion

The simulated results demonstrate a graded pattern across the three support conditions. Mean eight-week adherence was approximately 77% in the adaptive mobile pathway, 65% with static mobile support, and 54% under usual home rehabilitation. These values were intentionally generated to demonstrate a plausible comparative analytical framework and do not represent measured effect sizes.

The distinction between adaptive and static mobile support is central. Both pathways use digital technology, but only the adaptive condition responds to emerging adherence patterns. The simulated difference therefore tests the proposition that responsiveness may be more important than digital delivery alone. This proposition is consistent with Lambert and colleagues' finding that an application accompanied by remote support improved adherence compared with paper instructions and with evidence that therapeutic relationships, individualized support, and monitoring influence rehabilitation behavior.

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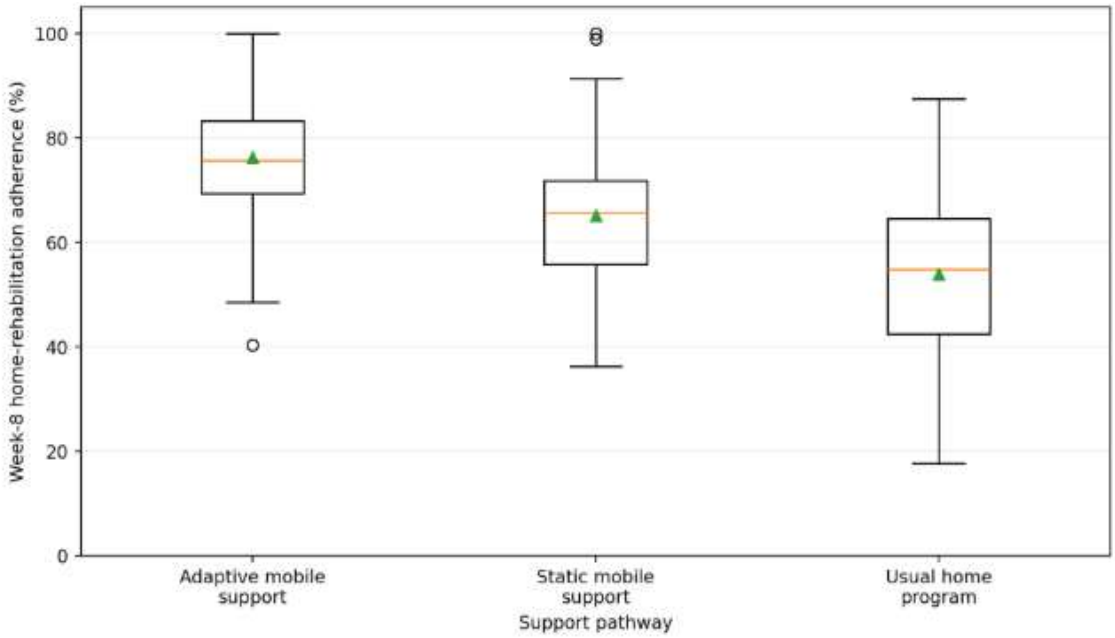
Table 2: Simulated Eight-Week Home-Rehabilitation Outcomes

Outcome indicator	Adaptive mobile support (n = 120)	Static mobile support (n = 120)	Usual home program (n = 120)
Mean week-8 adherence	77%	65%	54%
Completed ≥75% of prescribed sessions	68%	49%	34%
Completed full eight-week program	86%	74%	63%
Re-engaged after two consecutive missed sessions	72%	48%	31%
Reported high confidence performing exercises	81%	69%	56%
Understood when therapist contact was required	88%	76%	61%
Reported support as acceptable	85%	77%	66%

5.2 Distribution of Adherence Across Participants

Average adherence can conceal important variability. Two interventions may produce similar means while having very different proportions of patients with extremely low adherence or near-complete adherence. For this reason, the synthetic participant-level data were also examined using a box plot.

Graph 1: Simulated Distribution of Home-Rehabilitation Adherence at Week 8



The adaptive-support distribution is centered at a higher adherence level and demonstrates fewer participants within the very low-adherence range than the usual home-program condition. Static mobile

support occupies an intermediate position. The distributions nevertheless overlap, emphasizing that adaptive technology should not be expected to solve every adherence difficulty.

This overlap is clinically important because adherence depends on factors outside the application's control. Pain, fatigue, employment, caregiving responsibilities, mental health, transportation to periodic reassessment, digital literacy, fear of movement, and perceived lack of benefit may continue to influence participation. Reviews of home-based physical-therapy adherence have documented this multidimensional pattern. Adaptive technology can respond to some barriers but cannot eliminate the social and clinical context in which rehabilitation occurs.

5.3 Adaptive Support, Safety, and Therapist Escalation

The simulation models greater understanding of when professional contact is required in the adaptive pathway. This component is essential because improving adherence should never mean encouraging patients to continue an exercise program despite clinically important deterioration. The goal is adherence to an appropriate rehabilitation prescription, not maximum exercise completion regardless of circumstances.

The adaptive pathway therefore distinguishes ordinary barriers from potential safety concerns. A missed session caused by a busy schedule may justify a reminder or rescheduling prompt. Repeated reports of worsening pain, new neurological symptoms, abnormal shortness of breath, dizziness, falls, substantial swelling, or other diagnosis-specific warning signs require professional assessment according to the relevant clinical protocol rather than motivational messaging.

The model consequently preserves clinician authority over therapeutic progression. Automated algorithms may organize information and identify patterns, but clinically consequential decisions should remain within an appropriate professional framework. This safeguards against a common misconception that personalization necessarily requires autonomous algorithmic treatment.

6. Discussion

6.1 From Digital Exercise Instructions to Responsive Rehabilitation Support

The principal implication of the study is that digital rehabilitation should not be evaluated simply according to whether a mobile application is present. An application that reproduces paper exercises in electronic form may improve accessibility, but its behavioral and clinical contribution remains limited when every patient receives identical support regardless of adherence history or changing experience. Adaptive support attempts to use the longitudinal information generated during home rehabilitation more meaningfully.

This interpretation is consistent with the existing pre-2021 evidence. Lambert and colleagues demonstrated greater home-exercise adherence when an application was coupled with remote support, while Bennell and colleagues reported improved adherence and exercise confidence using web-supported exercise programming. Hosseiniravandi and colleagues also documented the broad range of monitoring, scheduling, education, and reporting functions already present across home telerehabilitation systems. The next logical step is not simply adding more functions but determining when and for whom each form of support should be delivered.

Adaptive support should consequently prioritize meaningful responsiveness rather than excessive notification. A patient who consistently completes exercises and reports manageable symptoms may require little intervention. Another patient who repeatedly misses sessions because of uncertainty may benefit from instructional clarification, while a patient experiencing worsening symptoms may require direct reassessment. Treating these situations identically would reduce the value of personalization.

6.2 Adherence as a Behavioral and Therapeutic Relationship Outcome

The simulated findings also reinforce the importance of understanding adherence as a behavioral process rather than a technical metric. Meade and colleagues' review of behavior-change techniques and Peek and colleagues' review of adherence-support interventions demonstrate that exercise behavior can be influenced through multiple mechanisms. Progress feedback, goal setting, self-monitoring, prompts, action planning, and professional support can potentially contribute, but their effectiveness is likely to depend on the patient's circumstances.

The therapeutic relationship remains relevant even in digitally mediated rehabilitation. Moore and colleagues found that therapeutic alliance was an important facilitator of longer-term exercise and physical-activity adherence among people with knee pain. This observation argues against designing mobile rehabilitation as a strategy for removing clinicians from the care pathway. Technology may instead help maintain continuity between less frequent direct encounters.

An adaptive mobile platform should therefore communicate the presence of professional oversight rather than create a sense that rehabilitation has been delegated entirely to software. Clinicians can use aggregated adherence and symptom information to focus limited consultation time on barriers that matter, while patients gain a structured method for recording difficulties rather than waiting until the next scheduled visit.

6.3 Equity, Sustainability, and Clinical Governance

Adaptive mobile rehabilitation also raises implementation questions concerning digital access and usability. Not all patients possess compatible smartphones, stable connectivity, high digital literacy, adequate vision, dexterity, cognitive capacity, or confidence with mobile health systems. Requiring application use as the only route to rehabilitation could therefore create a new access barrier for some populations.

An equitable model should preserve alternative modes of support and allow assisted use where appropriate. Technology-based exercise programs among older adults have demonstrated promising adherence, but systematic research has also emphasized the need for further investigation of feasibility, acceptability, and sustained use. Rehabilitation systems should therefore be evaluated across age, disability, socioeconomic circumstances, language, and digital-literacy groups rather than assuming uniform usability.

Clinical governance is equally important. Mobile platforms handling rehabilitation information require appropriate privacy, security, consent, documentation, escalation, and accountability procedures. Hospitals and rehabilitation providers should specify who reviews alerts, how quickly clinically meaningful reports are addressed, what happens during system failure, and which treatment changes can

or cannot occur automatically. Adaptive technology becomes clinically valuable only when these responsibilities are explicit.

7. Conclusion

Home-based rehabilitation can extend therapeutic activity into patients' everyday environments, but its potential depends on sustained and appropriate adherence. Conventional printed instructions and static digital programs can communicate exercises effectively yet offer limited ability to recognize when participation declines or when patients encounter new barriers. Adaptive mobile support offers a different model in which the intensity and type of support change according to adherence patterns, reported difficulty, progress, and clinician-defined escalation criteria.

The present simulation demonstrates how such a system could be evaluated. Under the synthetic assumptions used here, mean eight-week adherence was approximately 77% with adaptive mobile support, 65% with static mobile support, and 54% with usual home rehabilitation. The adaptive pathway also produced higher modeled rates of program completion, re-engagement after missed sessions, confidence in exercise performance, and understanding of when therapist contact was necessary. These figures are hypothetical and should not be interpreted as observed clinical effects.

The most important contribution of adaptive support may not be its ability to send more reminders but its capacity to differentiate among patients who require different forms of assistance. Stable adherers may benefit from minimal reinforcement, emerging non-adherers may require behavioral problem solving, patients uncertain about exercise technique may require clarification, and individuals reporting concerning symptoms may require prompt professional review. Such differentiation allows technology to support rehabilitation continuity without attempting to replace clinical judgment.

Future research should evaluate adaptive mobile rehabilitation through adequately powered randomized, pragmatic, or implementation studies using validated adherence measures and clinically relevant functional outcomes. Investigations should also examine cost, clinician workload, long-term engagement, usability, digital equity, safety, privacy, and the comparative contribution of automated versus therapist-delivered feedback. The strongest model of mobile rehabilitation is likely to be one in which digital adaptation reinforces rather than weakens the therapeutic relationship and helps patients remain connected to safe, individualized, and professionally governed rehabilitation care.

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