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Effectiveness of an AI-based home exercise app for rehabilitation of rotator cuff-related shoulder pain: A randomized controlled trial

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ABSTRACT

Background: Rotator cuff–related shoulder pain contributes to disability and healthcare use. Although therapeutic exercise is first-line treatment, limited supervision and adherence may reduce its effectiveness; digital rehabilitation with real-time feedback may address these limitations.
Objectives: To evaluate the effectiveness of adding a digital rehabilitation program to standard physiotherapy on pain, function, fear-avoidance beliefs, and healthcare utilization.
Design: Single-center, assessor-blinded, randomized controlled trial with two parallel groups.
Method: Forty-six adults (mean age 59 years) with rotator cuff–related shoulder pain were randomized to 12 weeks of conventional physiotherapy or physiotherapy plus an AI-based digital rehabilitation program using computer vision for real-time feedback and performance monitoring. Outcomes were assessed at baseline and at 2, 4, and 12 weeks. Pain intensity (NPRS) was primary outcome; secondary outcomes included upper limb function (QuickDASH), fear-avoidance beliefs (FABQ), and post-intervention healthcare utilization. Analyses followed an intention-to-treat approach.
Results: Pain reduction exceeded the MCID (1.3) at 4 and 12 weeks. Between-group differences favoured the intervention at Weeks 2 and 4 (MD −0.7; 95% CI −1.13 to −0.14 and MD −1.01; 95% CI −1.8 to −0.2, respectively). Upper limb function improved more at Week 4 (MD −7.3; 95% CI −12.3 to −2.2). FABQ scores decreased more at Week 12 (MD −7.6; 95% CI −14 to −0.5). Fewer participants in the experimental group required post-intervention healthcare (3 vs 10; $p = 0.02$).
Conclusion: Adding AI-based home exercise app to conventional treatment improve pain and may improve function and reduce healthcare utilization in rotator cuff–related shoulder pain.

1. Introduction

Shoulder pain is one of the most common musculoskeletal complaints in primary care and the third leading cause of musculoskeletal consultation, with rotator cuff-related shoulder pain (tendinopathy or partial tears) being the most frequently diagnosed subgroup (Lewis, 2016). This condition can impair upper limb function, limit daily activities, and increase the risk of chronicity if not adequately managed (Naunton et al., 2020). In Spain, musculoskeletal pain accounts for up to 36% of primary care consultations (Calsina-Berna et al., 2011; Seoane-Mato et al., 2020), placing considerable pressure on an under-resourced healthcare system, particularly in rural and ageing populations (García, 2022; Cano Montoro et al., 2002).

Clinical practice guidelines recommend structured therapeutic exercise as the cornerstone of conservative management for rotator cuff-related shoulder pain (Doiron-Cadrin et al., 2020a; de-Queiroz et al.,

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2022; Desmeules et al., 2025), and broader musculoskeletal guidelines also identify exercise as first-line care (Hayden et al., 2021; Blanpied et al., 2017; Fransen et al., 2015; Lin et al., 2020). However, in routine practice exercise is often prescribed through generic printed sheets, limiting individualization, progression, supervision, and monitoring (Jack et al., 2010). Adherence to home-based exercise programs remains suboptimal (Desmeules et al., 2025), with multiple patient and system-level barriers affecting the delivery and uptake of exercise-based care (Santello et al., 2023; Poulsen et al., 2025). These limitations highlight the need for scalable strategies that enhance supervision and personalization.

Digital health interventions, including telerehabilitation, have demonstrated clinical outcomes comparable to face-to-face physiotherapy across musculoskeletal conditions, with improvements in pain, function, and healthcare utilization (Seron et al., 2021; Baroni et al., 2023; Cottrell et al., 2017; Dias et al., 2021; Aily et al., 2023). Similar findings have been reported in non-operatively managed shoulder conditions (Lin et al., 2025). In upper limb rehabilitation, app and tablet-based interventions improve upper limb functional disability and reduce healthcare use (Suero-Pineda et al., 2025; Rodríguez Sánchez-Laulhé et al., 2022), while also positively influencing psychosocial factors such as maladaptive beliefs, including catastrophizing and fear of movement (Villar-Alises et al., 2024). Feedback-guided digital exercises may further enhance adherence and clinical outcomes compared with conventional approaches (Blanquero et al., 2020). Building on these developments, recent advances in artificial intelligence and computer vision enable real-time movement analysis, detection of compensatory patterns, and automated feedback without continuous clinician supervision (Moro et al., 2017; Oña et al., 2018), allowing objective monitoring and adaptive progression that may improve treatment fidelity, adherence, and personalization (Lau et al., 2020; Cottrell and Russell, 2020; Kairy et al., 2013; Liao et al., 2015; Chen et al., 2015). However, high-quality randomized controlled trials evaluating AI-supported rehabilitation in patients with shoulder pain remain limited.

In this context, This randomized controlled trial evaluates the clinical effectiveness of RehBody, an AI-based digital therapeutic application that uses the front-facing camera of smartphones or computers to guide, correct, and monitor exercises in real time. The primary aim is to determine whether combining RehBody with standard physiotherapy care improves pain intensity in patients with rotator cuff-related shoulder pain. Secondary outcomes include upper limb functional ability, fear-avoidance beliefs and healthcare utilization.

2. Method

2.1. Design

A randomized controlled, parallel group, single blind clinical trial was conducted in the rehabilitation and physiotherapy service of the Hospital Universitario Virgen Macarena. This clinical trial was registered in Open Science Framework (DOI https://doi.org/10.17605/OSF.IO/45DNQ). The hospitals' ethics committees approved this study. This study followed the Declaration of Helsinki (World Medical Association, 2024) and adhered to the CONSORT statement (Supplementary Table 1. Checklist CONSORT) (Hopewell et al., 2025).

2.2. Participants, therapists and centres

Adults over 18 years old with shoulder pain attributed to rotator cuff disorders (e.g., tendinopathy, tendinitis, or partial tears) were consecutively recruited at the Rehabilitation and Physiotherapy Service of Hospital Universitario Virgen Macarena (Seville, Spain), a tertiary public healthcare centre within the Andalusian health system. Although eligible for outpatient primary care physiotherapy, participants were treated at the hospital due to service organization.

To be eligible, participants were required to fulfill the following inclusion criteria: (i) were aged 18 years or older; (ii) had access to a smartphone or computer equipped with a front-facing camera and internet connectivity; and (iii) reported shoulder pain attributable to a rotator cuff disorder, such as tendinopathy, tendinitis, or partial thickness tears.

Exclusion criteria comprised: (i) shoulder pain secondary to neoplasm, infection, metastasis, osteoporosis, inflammatory arthropathy, or fracture; (ii) presence of psychiatric or systemic medical conditions that might have interfered with rehabilitation; (iii) pregnancy; (iv) fibromyalgia diagnosis; (v) involvement in medico legal or compensation claims related to work disability; and (vi) shoulder pain due to other shoulder pathologies such as calcific tendinopathy, adhesive capsulitis, glenohumeral joint stability, massive rotator cuff tears, or neurological disorders affecting shoulder function.

Initial clinical screening and participant selection were conducted by specialist physicians in Physical Medicine and Rehabilitation and physiotherapists from the Physical Medicine and Rehabilitation Service of Hospital Universitario Virgen Macarena, each with more than 10 years of experience. Diagnoses were confirmed through review of electronic medical records and imaging findings (ultrasound or MRI) available before enrollment, following the hospital's standard diagnostic protocol. Recruitment followed a two-stage process: first, administrative screening of referrals to the Rehabilitation Service based on diagnostic codes; second, a formal clinical assessment to confirm eligibility and determine final inclusion in the trial.

Eligible participants received study information and provided written informed consent. A designated researcher verified eligibility criteria and oversaw randomization using a pre-defined concealed allocation table specifically developed for this trial. The sequence was computer-generated with permuted blocks (1:1 ratio) and stored in a password-protected file accessible only to this researcher to ensure allocation concealment. The researcher explained the assigned intervention and provided technical support contact details. Participants were instructed not to disclose their group allocation during outcome assessments to maintain assessor blinding.

Baseline assessments were carried out by a blinded assessor in a separate room, and follow up measurements were obtained by blinded assessor via telephone at predefined time points.

2.3. Interventions

All participants received four sessions of an exercise prescription physiotherapy program in-person at the Virgen Macarena University Hospital, in accordance with the hospital's standard procedure for the management of musculoskeletal shoulder pain. During the four sessions (one per week), an experienced physiotherapist prescribed a home-based therapeutic exercise regimen. Although the four in-person sessions were completed by week 4, the home-based exercise program continued in both groups until the week-12 assessment. The in-person sessions were delivered by permanent staff physiotherapists from the Physical Medicine and Rehabilitation Service of Hospital Universitario Virgen Macarena, blinded to group allocation, whose routine practice includes supervising therapeutic exercise for musculoskeletal shoulder disorders. The experimental group additionally received a digital rehabilitation program. A detailed description of both interventions following the TIDieR checklist is provided in Supplementary Table 2, and a visual demonstration of the digital feedback system is available in Supplementary Video 1.

Supplementary video related to this article can be found at https://doi.org/10.1016/j.msksp.2026.103626

The in-person sessions were delivered by staff physiotherapists from the Physical Medicine and Rehabilitation Service at Virgen Macarena University Hospital, whose role was limited to providing routine in-person physiotherapy sessions. These professionals were unaware of group assignments throughout the trial and did not participate in

randomization, outcome assessment, or remote monitoring. Digital monitoring of the experimental group via the RehBody dashboard was conducted independently by a physiotherapist other than the hospital's physiotherapists, who reviewed performance data and made individualized adjustments as needed. Outcome assessor was completely unaware of group assignments throughout the trial.

2.4. Experimental group

Participants in the experimental group received conventional treatment plus a home-based exercise program using RehBody, an AI-based digital rehabilitation platform that delivers exercise treatment without external sensors. Patients received information through the RehBody app from their healthcare professionals and performed monitored and guided exercise programs using the front cameras of common devices (smartphones, PCs) thanks to computer vision algorithms. Physiotherapists monitored their patients' performance and progress through the RehBody dashboard, as well as developed individualized home treatment plans and exercises.

RehBody uses computer vision algorithms applied to data captured by the front camera of common devices (e.g., smartphones or computers) to guide, monitor, and control prescribed exercise programs. The system detects whether the patient is correctly positioned in front of the camera and performing the exercises properly, providing physiotherapists with objective information on performance, progress, and treatment adherence. Patients performed their exercises in front of their device camera, receiving continuous visual and auditory feedback. During the first three repetitions of each set, the system automatically calibrated the exercise to the patient's pain-free range of motion (ROM) to establish a safe movement threshold for that session. Subsequent repetitions were guided within this range using two auditory signals to distinguish correct execution from insufficient movement. The system also enabled real-time correction of compensatory movements and provided immediate objective performance data. The RehBody app included:

1. A system for prescribing and performing therapeutic exercises guided and monitored through the front camera of smartphones and computers, providing objective information on exercise execution. The home-based exercise program followed a synthesized "gold standard" protocol for rotator cuff–related shoulder pain derived from Kuhn (2009) and supported by clinical trials by Christiansen et al. (Christiansen and Hjort, 2021) and Granviken et al. (Granviken and Vasseljen, 2015)
2. The platform incorporated adherence-enhancing features, including patient graphs/diaries, behavioral change strategies, and personalized performance-based notifications to promote engagement and treatment completion. A monitoring system allowed clinicians to track patient performance and adherence in real time and automatically report achieved ranges of motion.

In Fig. 1, the patient performs an exercise while receiving real time visual feedback on screen, facilitated by the app's computer vision system. On the right, the recorded range of motion is graphically displayed, allowing clinicians to monitor objective progression over time through the RehBody platform.

Home-based exercise sessions were performed three times per week for approximately 20–30 min following a predefined protocol (Table 1), with progressive individualization according to each patient's clinical status, tolerance, and progression. Adjustments were made by the physiotherapist through weekly follow-ups and continuous remote monitoring via the RehBody platform throughout the 12-week intervention. At baseline, the physiotherapist provided a practical demonstration and instructions for app use, and participants received contact details for technical support during the intervention.

2.5. Control group

Participants in the control group received the hospital's standard home exercise program, consisting of a paper-based prescription of therapeutic exercises based on clinical guidelines for rotator cuff–related shoulder pain, including mobility, stretching, and strengthening



Fig. 1. Mobile application interface based on computer vision (left) and example of the graphical display of the recorded measurements (right).

Table 1
Exercise program delivered to the experimental group via the RehBody platform.

	Exercise	Series	Repeats	Session Sections
1	Bilateral Lateral Shoulder Raise – Without Weights	1	10	Warm-Up
2	Quadruped Lumbar Flexion	1	10	Warm-Up
3	Left Shoulder External Rotation – Lying, Without Weights	1	10	Exercise Program
4	Left Shoulder External Rotation – Lying, With Weight	1	10	Exercise Program
5	Right Shoulder External Rotation – Lying, Without Weights	1	10	Exercise Program
6	Right Shoulder External Rotation – Lying, With Weight	1	10	Exercise Program
7	Incline Push-Ups – Using Support	2	10	Exercise Program
8	Left Supported Dumbbell Row – With Weight	2	10	Exercise Program
9	Right Supported Dumbbell Row – With Weight	2	10	Exercise Program
10	Bilateral Lateral Shoulder Raise – Without Weights	1	10	Cool-Down
11	Quadruped Lumbar Flexion	1	10	Cool-Down

activities (Desmeules et al., 2025; Lowry et al., 2024; Dubé et al., 2020). The program was performed independently at home three times per week for 20–30 min per session. The full program is available in Supplementary Material 1.

Monitoring was conducted verbally during in-person rehabilitation sessions, where patients received clarification, reinforcement of exercises, and guidance on progression to be continued independently from week 4 until the week-12 assessment.

2.6. Outcome measures

Clinical outcomes were collected at baseline, 2 weeks, 4 weeks, and 12 weeks post-intervention. Baseline assessments were conducted prior to the first rehabilitation session. Clinical outcomes were measured by trained assessors who were blinded to group allocation, both in-person at baseline and via telephone follow ups (Meirte et al., 2020).

2.6.1. Primary outcome

The primary outcome was pain intensity, which was measured using the Numerical Pain Rating Scale (NPRS), a validated self reported scale ranging from 0 (no pain) to 10 (worst possible pain). Pain levels were assessed at all four time points: baseline, 2 weeks, 4 weeks, and 12 weeks.

2.6.2. Secondary outcomes – clinical

- Upper limb function was measured using the QuickDASH questionnaire, the abbreviated version of the Disabilities of the Arm, Shoulder and Hand (DASH) tool (Gummesson et al., 2006), which has demonstrated reliability, discriminative capacity, and cross-sectional validity comparable to the full DASH. The validated Spanish version (score range 0–100) was used, with higher scores indicating greater functional limitation (Jain et al., 2001; Rosales et al., 2009).
- Fear-avoidance beliefs were assessed using the Fear-Avoidance Beliefs Questionnaire (FABQ), a validated self-administered instrument measuring beliefs that physical activity or work may aggravate musculoskeletal conditions. It includes two subscales: physical activity (FABQ-PA; 0–24 points) and work (FABQ-W; 0–42 points), with a total score of 0–66, where higher scores indicate stronger fear-avoidance beliefs. The FABQ has demonstrated good psychometric properties, including internal consistency and test-retest reliability (Mintken et al., 2010a), and the Spanish version is validated for clinical use (Kovacs et al., 2006). Both subscales and the total score were analysed separately.

2.6.3. Secondary outcomes – healthcare usage

Healthcare usage was assessed as a secondary outcome to evaluate the intervention's impact on resource use within the public healthcare system. Data were collected after the 3-month follow-up through anonymized extraction from the hospital's electronic health records. Only cases in which patients requested a consultation and subsequently received treatment (infiltration or face-to-face physiotherapy) after evaluation by a rehabilitation physician were counted.

2.6.4. Data analysis

The primary outcome (pain intensity) was used to determine the sample size. The Minimal Clinically Important Difference (MCID) on the NPRS pain scale of 1.3 points out of 10 for within-group difference was applied, as established in previous studies in patients with musculoskeletal shoulder disorders (Tashjian et al., 2009; Yoo et al., 2024; Dabija and Jain, 2019). With a two-tailed significance level of 0.05, a statistical power of 80%, and a dropout rate of 10%, a sample of 44 subjects (22 per group) was required.

Analyses were performed on an intention-to-treat basis using SPSS (SPSS, IBM Corp.). For each outcome measure, mean scores and standard deviations, mean within-group differences, and between-group differences in change scores (95% CI) were reported. Categorical variables were expressed as frequencies and percentages, and between-group differences were analysed using the Chi-square or Fisher's exact test, as appropriate.

3. Results

3.1. Flow of participants

A total of 76 patients were recruited between March and May 2025. Of them, 46 patients met inclusion criteria and accepted to participate in this study. Patients were randomised to the experimental group (n = 23) or the control group (n = 23). The flow of participants through the remainder of the study is shown in Fig. 2. The study follow-up ended in September 2025, when all participants were assessed on primary and secondary outcomes. Sociodemographic characteristics and baseline clinical outcomes are reported in Table 2.

3.2. Effect of intervention on pain intensity (Primary outcome)

The experimental group showed a within-group difference greater than the MCID for shoulder pain (1.3) at Week 4 (MD -1.4) and Week 12 (MD -2) (Tashjian et al., 2009), whereas the control group did not reach the MCID at any measurement point. Between-group differences favoured the experimental group at Week 2 (MD -0.7, 95% CI -1.13 to −0.14) and Week 4 (MD -1.01, 95% CI -1.8 to −0.2). The confidence interval favoured the intervention but included effects below the pain MCID. Although the mean difference at Week 12 also favoured the experimental group (MD −0.9), the 95% CI (−1.81 to 0.1) did not support a statistically significant effect.

3.3. Effect of intervention on upper limb functional ability (Secondary outcome)

The experimental group showed greater within-group improvements in secondary outcomes than the control group. At Week 12, functional improvement reached −11.2 points (Mintken et al., 2009). Between-group differences favoured the experimental group at Week 4 (MD −7.3; 95% CI −12.3 to −2.2), indicating a clinically meaningful effect. Although the difference at Week 12 also favoured the experimental group (MD −6.6), the wide confidence interval (95% CI −14 to 1.1) indicates uncertainty regarding the precision of the estimate.

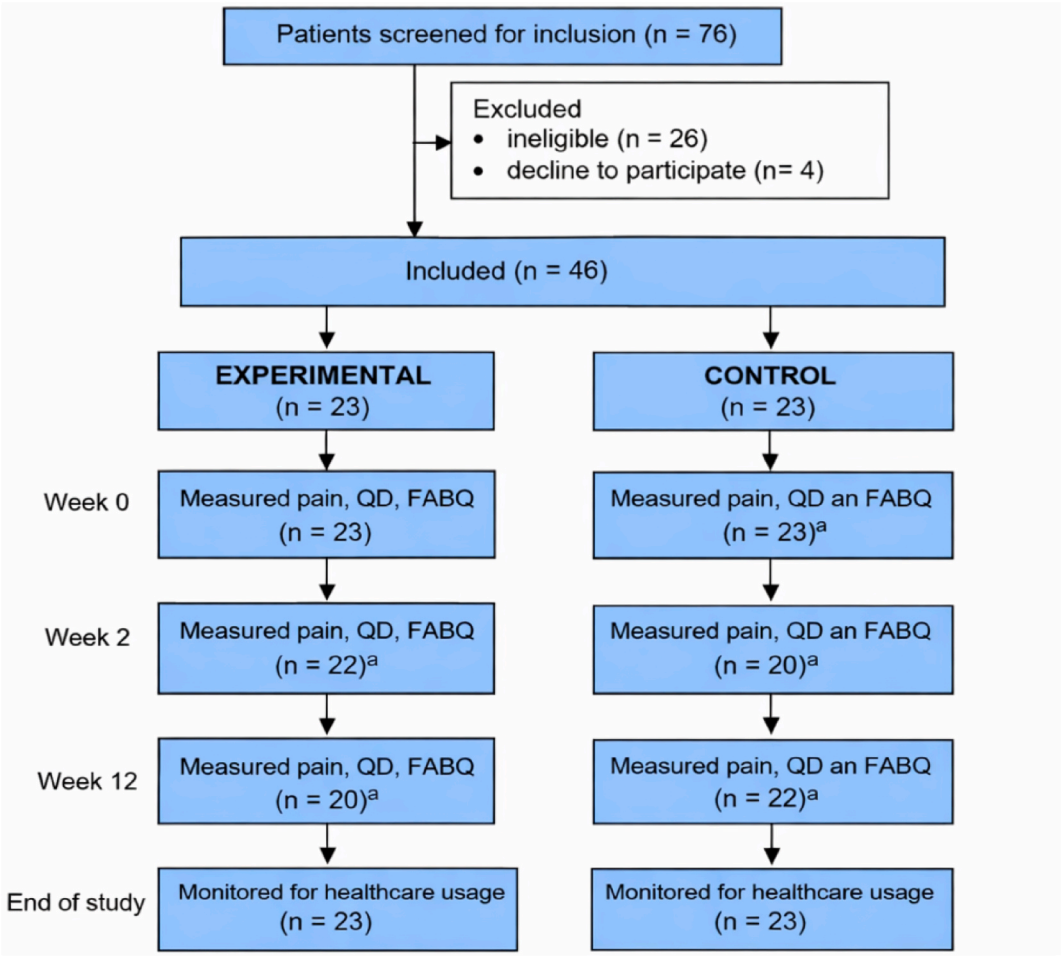

Fig. 2. Flow diagram through the trial.
QD: QuickDASH questionnaire.
FABQ: Fear Avoidance Beliefs Questionnaire.
a: Participants were unavailable or did not respond to phone calls for clinical measurements at certain assessment points.

Table 2
Demographic characteristics and mean (SD) of baseline clinical outcomes.

	Experimental	Control	*p* Value
Age	57 (9.3)	61 (6.9)	0.13
Gender, n(%)			
Female	14 (61%)	17 (74%)	0.5
Male	9 (39%)	6 (26%)	
Postal code			0.2
Profession, n(%)			
Non-professional job	11 (48%)	10 (43%)	0.9
House wife	4 (17%)	4 (17%)	
Medical profession	2 (9%)	1 (4%)	
Retiree	5 (22%)	7 (30%)	
On disability	1 (4%)	1 (4%)	
Transport, n(%)			
Public transport	17 (74%)	17 (74%)	0.3
Own vehicle	5 (22%)	4 (17%)	
Relative transportation	1 (4%)	0 (0%)	
Walking	0 (0%)	2 (9%)	
Pain Intensity *(0 to 10)*	6.9 (1.7)	6.7 (2.2)	0.1
Functional ability QuickDASH *(0 to 100)*	60 (17)	50 (21)	0.08
Fear-avoidance beliefs physical activity subscale FABQpa (0 to 24)	18.7 (5.1)	17 (6.1)	0.3
Fear-avoidance beliefs -work subscale FABQw (0 to 42)	25.4 (12.7)	19.5 (16.8)	0.2
Fear-avoidance beliefs total score FABQ (0 to 66)	44.1 (14.9)	35.6 (19.1)	0.1

3.4. Effect of intervention on fear-avoidance beliefs (Secondary outcome)

Fear-avoidance beliefs also decreased more in the experimental group. At Week 12, total FABQ scores decreased by −4.1 points in the experimental group and increased by 3.5 in controls, yielding a between-group difference of −7.6 (95% CI −14 to −0.5). As no MCID has been established for the FABQ in shoulder pain, the clinical relevance should be interpreted cautiously. However, studies in other musculoskeletal populations suggest that reductions of approximately 13 points in the physical activity subscale may be clinically meaningful (Mintken et al., 2010b). Similar patterns were observed in both FABQ subscales. For FABQ-PA, the experimental group improved by −2.5 points at Week 12 versus −1.3 in controls, with a between-group difference at Week 4 of −2.4 (95% CI −4.5 to −0.2).

These results are summarised in Table 3.

3.5. Effect of intervention on secondary outcomes – healthcare usage

Fewer participants in the intervention group required physiotherapy sessions or medical consultations after the intervention compared with controls. Only 3 participants (13%) required post-study care versus 10 (43%) in the control group (p = 0.02), representing an absolute reduction of 30.5%. Services included individualized physiotherapy sessions, medical follow-up consultations, shockwave therapy, or physician-delivered interventional procedures. These results are summarised in Table 4.

Table 3
Mean (SD) difference within groups and mean (95% CI) difference between groups for the clinical outcomes.

Outcome	Within-group difference						Between-group difference		
	Week 2 minus week 0		Week 4 minus week 0		Week 12 minus week 0		Week 2 minus week 0	Week 4 minus week 0	Week 12 minus week 0
	Exp Group (n = 22)	C Group (n = 17)	Exp Group (n = 22)	C Group (n = 20)	Exp Group (n = 20)	C Group (n = 22)	Exp minus C	Exp minus C	Exp minus C
Pain intensity (NPRS)	−0.6	−0	−1.4	−0.4	−2	−1.1	−0.7 (−1.13 to −0.14)	−1.01 (−1.8 to −0.2)	−0.9 (−1.81 to 0.1)
Upper limb function (QuickDASH)	3.2	1.5	−6	1.3	−11.2	−4.6	−4.5 (−9.7 to 0.7)	−7.3 (−12.3 to −2.2)	−6.6 (−14 to 1.1)
Fear-avoidance beliefs physical activity subscale (FABQpa)	0.1	0.5	−1.8	0.6	−2.5	−1.3	−0.4 (−1.4 to 0.6)	−2.4 (−4.5 to −0.2)	−1.2 (−3.9 to 1.5)
Fear-avoidance beliefs work subscale (FABQw)	0.5	−0.5	0	3.4	−0.16	−3.2	0.6 (−0.8 to 7.9)	−3.4 (−9 to 2.3)	−4.8 (−10.6 to 1)
Fear-avoidance beliefs total score FABQ	0.2	0.1	−1.8	3.5	−4.1	3.5	0.06 (−1.7 to 1.8)	−5.8 (−12.6 to 1)	−7.6 (−14 to −0.5)

Exp = experimental, C = control.

Table 4
Patients attending post-study care.

	Exp (n = 23)	Con (n = 23)	p-value
No post-study care	20 (87%)	13 (57%)	0.02
Patients attending post-study care	3 (13%)	10 (43%)	

Con = control group, Exp = experimental group.

4. Discussion

This randomized controlled trial suggests that the digital intervention may improve shoulder pain intensity and upper limb function in patients with musculoskeletal shoulder conditions. Pain reduction in the experimental group exceeded the minimal clinically important difference (MCID = 1.3) on the NPRS at 4 and 12 weeks, whereas the control group did not reach this threshold. Functional improvement in the experimental group reached −11.2 points on the QuickDASH at Week 12. No baseline differences were observed between groups in postal code–based socioeconomic indicators, suggesting that the effects were unlikely influenced by socioeconomic disparities, an important consideration when evaluating technology-based interventions (Graham, 2016).

These findings are consistent with previous studies on digitally supervised exercise for musculoskeletal conditions (Aily et al., 2023; Lin et al., 2025; Hamine et al., 2015). Pak et al. reported reductions in shoulder pain and functional improvement using a digital platform as an alternative to conventional care (Pak et al., 2023), while Shim et al. found that digital rehabilitation after rotator cuff repair accelerated recovery milestones by three weeks compared with standard protocols (Shim et al., 2023). Similarly, in our study the experimental group reached the Minimal Clinically Important Difference (MCID) for pain at Week 4, whereas the control group did not. Unlike studies evaluating telerehabilitation as a replacement for face-to-face care (Pak et al., 2023; Shim et al., 2023), this trial examined the added benefit of integrating RehBody into usual care. Pratama et al. also reported pain and quality-of-life improvements with digital interventions performed 2–3 times weekly for ≥6 weeks (Pratama et al., 2023), consistent with the clinically meaningful improvements observed by week 4 in our study. Meta-analyses also support digital rehabilitation in musculoskeletal and non-surgical shoulder conditions (Lin et al., 2025; Huang et al., 2024). Finally, the 30.5% reduction in healthcare use aligns with previous findings (Correia et al., 2022), achieved here through accessible computer-vision technology without external sensors. Unlike other systems that require additional hardware, RehBody works without external sensors or wearables, using only the camera of common devices to improve accessibility, thus facilitating early symptom management and greater equity in access to treatment.

In addition to clinical improvements, digital intervention appeared to reduce healthcare utilization. Only 3 participants (13%) in the experimental group required post-study physiotherapy or medical consultations compared with 10 (43%) in the control group (p = 0.02), an absolute reduction of 30.5%. Although quantitative evidence on healthcare utilization in digital rehabilitation remains limited, telerehabilitation has been associated with lower healthcare costs and reduced in-person service use compared with traditional models, likely due to improved access, adherence, and earlier symptom management (Molina-Garcia et al., 2024; Pereira et al., 2025; Domingues et al., 2025). Similar effects have been reported in hybrid and fully digital rehabilitation programs (Suero-Pineda et al., 2025; Blanquero et al., 2020), supporting the potential of remote rehabilitation to improve outcomes while reducing healthcare demands.

There are several aspects of the intervention and mechanisms that could explain experimental group results. One key component of the RehBody intervention was progressive resistance training plus supervision. Prolonged inactivity may hinder recovery by promoting muscle atrophy, stiffness, and maladaptations (Hayden et al., 2021; Fransen et al., 2015). Therapeutic loading is now considered a cornerstone in managing musculoskeletal shoulder conditions, improving strength, joint stability, and pain modulation (Fransen et al., 2015; Doiron-Cadrin et al., 2020b). Systematic reviews consistently show that exercise outperforms passive treatments, with load-based rehabilitation reducing pain and improving function across tendinopathies (Fransen et al., 2015; Lin et al., 2020; Sluijs et al., 1993). Physiotherapy supervision via RehBody objective and patient reported data (adherence, symptoms during concrete exercise performance, PROMS, etc.) facilitated progressive training when compared with conventional methods in which the professional do not have this information for supervision.

Another key aspect was the inclusion of dynamic calibration and differentiated auditory feedback, which likely contributed to the observed outcomes. By ensuring exercises were performed within a pain-free range of motion, the system minimized sensitization risk, supported tendon remodeling, and reduced movement-related fear. This approach aligns with clinical guidelines recommending strengthening within pain-free ranges to improve adherence and may partly explain the reductions in pain, disability, and fear-avoidance beliefs observed in the experimental group (Blanpied et al., 2017; Lin et al., 2020; Doiron-Cadrin et al., 2020b). Although the between-group FABQ difference (−7.6 points) did not reach the ~13-point change suggested as clinically meaningful in other musculoskeletal populations, fear-avoidance beliefs decreased in the experimental group and the

lower confidence interval bound (−14) approached this threshold. The system's ability to recalibrate in real time when pain limited movement also ensured safe, individualized performance, reinforcing motor learning and patient confidence (Aily et al., 2023; Mahmood et al., 2023), yet exercise with controlled pain can also be effective (Tran et al., 2025). In this study, the pain-free strategy was chosen to maximize adherence and safety in an unsupervised environment and has previously been associated with faster improvements in pain, function, and recovery time (Suero-Pineda et al., 2025; Blanquero et al., 2020).

The platform's visual feedback promoted an external focus of attention (EFA), associated with enhanced motor learning and movement efficiency (Zentgraf and Munzert, 2009; Zachry et al., 2005). The digital interface transformed them into goal-directed tasks through individualized calibration and success-based feedback. Systematic reviews support EFA benefits in musculoskeletal rehabilitation (Piccoli et al., 2018), potentially explaining the early improvements observed at 4 weeks. Although adherence was not directly measured, RehBody's interactive design, real-time feedback, and performance-based progression likely enhanced motivation and engagement (Lloréns et al., 2015; Proffitt and Lange, 2015; Cole et al., 2019; Lyngcoln et al., 2005; Peek et al., 2017; Mendez-Balbuena et al., 2012). Platforms with these features have been shown to improve adherence and outcomes (Suero-Pineda et al., 2025; Blanquero et al., 2020). Clinicians also accessed real-time performance data, enabling personalized adjustments and weekly follow-up supporting treatment continuity (Suero-Pineda et al., 2025; Leochico et al., 2025). Consequently, the observed clinical improvements should be interpreted as the result of a multicomponent strategy based on the synergy between the AI's technical precision (real-time feedback and dynamic calibration) and the clinical oversight provided by the hybrid care model, rather than the isolated effect of a specific mechanism alone.

This study has several limitations. First, the sample size was relatively small and from a single center, which may limit generalizability. Second, differences in exercise selection between groups represent a potential confounder, making it difficult to isolate the specific effect of AI feedback from loading parameters. As a pragmatic trial, the aim was to evaluate the impact of adding a digital program to standard physiotherapy. Third, adherence was not objectively monitored, limiting our ability to determine its contribution to clinical improvement. Given the pragmatic design and the absence of a reliable method to measure adherence in conventional clinical practice for the control group, objective monitoring was not implemented in either group. Fourth, excluding participants without internet-connected devices may have introduced selection bias. Finally, the inclusion of various musculoskeletal shoulder conditions limited condition-specific analyses.

4.1. Future research

Future studies should assess patients' experiences with RehBody using qualitative methods or validated questionnaires, incorporate objective adherence measures, evaluate larger multicenter samples, compare RehBody with other digital platforms, and explore how socioeconomic status influences engagement with digital interventions (Graham, 2016).

4.2. Clinical implications

The findings of this trial suggest that integrating an AI-based, feedback-guided digital exercise program into usual care may improve pain and upper limb function in patients with musculoskeletal shoulder conditions. As therapeutic exercise is already first-line treatment, the added value of this approach may lie in improving its delivery through technological monitoring and adaptation. Improvements in pain (exceeding the MCID at weeks 4 and 12) and function (reaching the MCID at week 12), together with reduced subsequent healthcare utilization, support digitally supervised home exercise as an effective complement to conventional physiotherapy.

4.3. Conclusions

In our study, conventional treatment plus an AI-based home exercise app improve pain intensity at 4 and 12 week. This intervention may also improve upper limb function at 12 weeks and reduce healthcare utilization in patients with musculoskeletal shoulder pain.

Ethics committee

The hospitals' ethics committees approved this study.

Provenance

Not invited. Peer reviewed.

Source of support

None.

CRediT authorship contribution statement

Olga Villar-Alises: Conceptualization, Data curation, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Celia Cónstenla Cortés:** Data curation, Investigation, Supervision. **Manuel Rodríguez-Piñero Durán:** Data curation, Investigation, Supervision. **Pablo Rodríguez Sánchez-Laulhé:** Data curation, Investigation, Methodology, Supervision. **Javier Martinez-Calderon:** Writing – review & editing. **Alejandro Suero-Pineda:** Data curation, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interests statement

Alejandro Suero-Pineda was one of the clinical initiators of the project and founded a spinoff. Both Alejandro Suero-Pineda and Olga Villar-Alises are employed by this company. The rest of the authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.msksp.2026.103626.

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