Can a shoulder continuous passive motion device be considered functionally safe after rotator cuff repair? An in-vivo study of evasive motion, muscle activation, and patient feedback

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Background: Early mobilization without muscle activation is important after arthroscopic rotator cuff repair (RCR). Motor-driven continuous passive motion (CPM) devices may support rehabilitation, but it is unclear whether motion remains passive or setup errors could push joint motion beyond ROM limits.

Purpose: To assess whether patients can relax shoulder musculature and avoid evasive movements during CPM, and to quantify how altered device setup affects joint motion and muscle activity.

Methods: Shoulder kinematics and bilateral surface EMG of four shoulder muscles were recorded during CPM-guided abduction/adduction and internal/external rotation using 3D motion capture. Patients completed 10 min in the “optimal” setup, followed by four suboptimal positioning conditions (2 min each). Patients then used the CPM device at home for 4 weeks and reported pain, comfort, compliance, and satisfaction.

Results: Thirteen patients (56.9±6.6 years) were assessed 12.9±2.8 days after arthroscopic RCR. Actual ROM differed from device-guided ROM ($p<0.001$), but discrepancies were similar between sides ($p>0.05$) and remained below approved limits (50-90° abduction and 0-30° external rotation). Suboptimal positioning showed a main effect on ROM ($p<0.015$); post-hoc differences occurred only for abduction ($p=0.002$) and remained within safe limits. Muscle activity stayed low and below activation thresholds; deltoid and upper trapezius activation remained within acceptable limits. Pain and discomfort were low (≤0.72±0.96 and ≤0.87±0.91; 0–10 scales), abduction ROM improved from 37±16° to 46±19°, and satisfaction was high (reuse willingness 9.1±1.58/10).

Conclusion: Early after RCR, the CPM device provides safe passive shoulder mobilization with very low muscle activation, limited sensitivity to setup errors, low pain/discomfort, and high acceptance.

What this study adds: CPM remains genuinely passive with very low muscle activation, while shoulder kinematics stay within approved ROM limits even with moderate setup errors; it is well tolerated by first-time users.

Implications for research, practice or policy: These findings support CPM as a safe, feasible adjunct to early rehabilitation and provide a biomechanical rationale for future clinical trials and guideline recommendations on CPM use after RCR.

Study Design: Experimental laboratory study

Level of evidence: IV

Keywords: postoperative rehabilitation, early postoperative mobilization, passive range-of-motion, glenohumeral kinematics, compensatory motion, surface electromyography, 3D motion tracking

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Introduction

Immobilization causes mechanical changes in joint tissues, including cartilage, the bone–ligament–bone complex, and bone itself [1][2]. After surgery, repair failures may occur due to inappropriate strains, overload, and/or inadequate biological healing at the repair site [3]. Rehabilitation therefore emphasizes early joint movement within safe boundaries for tissue healing [4]. CPM, introduced by Salter in the early 1980s, improved soft-tissue, bone, and cartilage healing and reduced swelling/hemarthrosis compared with prolonged immobilization in animal models [5][6]. In a rabbit arthritis model, Ferretti showed anti-inflammatory effects

with collagen reorganization, increased tendon vascularization, and higher tenocyte activity [7]. Human studies also suggest early postoperative movement (e.g., after knee arthroplasty) supports collagen healing, cartilage nutrition, and reduces stiffness/edema [8][9][10][11][12]. Several studies report greater early ROM gains and pain relief with CPM than with passive self-assisted exercise alone [13][14][15]. CPM devices guide joints along a preset axis and can deliver higher total motion volumes than physiotherapy sessions alone [16]. While many experts advocate CPM to improve early ROM and pain relief, others report minimal long-term benefit on function or tendon healing compared with standard rehabilitation. There is growing interest in evaluating both the true clinical effectiveness and the potential health-economic and system-wide benefits of CPM [14], particularly for arm and shoulder rehabilitation, where evidence remains limited [13][14][17][18].

Shoulder CPM systems typically use a chair with a motorized armrest rotating around a mechanical shoulder axis. Proper setup should approximate the physiological center of rotation, yet the impact of imperfect alignment on muscle activation, actual ROM, and patient experience is unclear - particularly during longer or unsupervised home use. Improper setup early after rotator cuff repair (RCR) could increase muscle tension or drive ROM beyond safe limits. One study reported inconsistent user instructions, partly attributed to inadequate familiarity with device settings, which may increase risk [19]. In addition, Kim [20] and Bible [21] showed discrepancies between CPM brace ROM and actual knee joint ROM, even when setup followed manufacturer recommendations, highlighting potential dangers arising from deviations between biological joint motion and device motion [20] and raising concerns about patient trust, unwanted muscle activation, and compensatory movements.

Given the risk of overloading the repaired rotator cuff tendon in the early postoperative phase, it is important to examine shoulder muscle activity and ROM during CPM in an optimal (neutral) position - where the joint center is aligned with the rotational center of the CPM motors - as well as under slightly suboptimal (misaligned) conditions, to ensure safe home use of the device.

This study addressed two primary research questions:

1. whether CPM-guided shoulder motion in the early postoperative phase after RCR remains predominantly passive and within surgeon-approved ROM limits, with minimal muscle activation and without clinically relevant evasive trunk or shoulder-girdle movements that would materially alter the effective glenohumeral excursion; and
2. whether moderate deviations from neutral device alignment adversely affect biological shoulder ROM or movement passivity.

We hypothesized that CPM motion would remain predominantly passive and within approved ROM limits, and that moderate setup deviations would not meaningfully alter ROM or muscle activation.

Materials and Methods

The study was performed at the biomechanical motion analysis laboratory Motum – Human Performance Institute (Rum, Austria). The study was approved by the ethics committee of the Medical University Innsbruck with the EK Nr: 1380/2023. All procedures performed involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments.

Participants

Inclusion criteria were age 40–65 years, height 150–195 cm, and unilateral RCR of the supraspinatus tendon and subpectoral biceps tenodesis performed at the Privatklinik Hochrum between November 2023 and March 2024. Included patients had no radiographically visible osteoarthritis, no neurological symptoms, and no significant joint stiffness. All were recruited by the medical project partner Gelenkpunkt (Innsbruck, Austria), without restrictions based on sex or socioeconomic background beyond the medically required eligibility criteria; participants received verbal and written information on study purpose, procedures, voluntary participation, and data confidentiality, and provided written informed consent. There was no case of retear or non-healing in the early rehabilitation phase of the study.

Study Design

At the first post-hospital clinical control 10–14 days after surgery (12.9±2.8 days), patients were evaluated and, if eligible, underwent biomechanics laboratory testing and their initial contact with the CPM device on the same day. Scheduling the first CPM measurement for postoperative days 10–14 ensured sufficient range of motion (ROM) for valid data collection, minimized the risk of complications, and avoided prior device exposure.

1. All surgeries were performed by the same surgeon using an arthroscopic double-row RCR technique. Postoperatively, the operated shoulder was protected in an abduction pillow for 6 weeks, and patients followed a standardized physiotherapy-

based rehabilitation protocol without CPM until the laboratory testing.

2. At the standard clinical post-surgery evaluation, stitches were removed and patients were assessed for safe participation in CPM testing. Patients cleared by the surgeon (adequate healing and shoulder range of motion of at least 45° in all directions safely achievable) were transferred to the CPM testing session on the same day, to minimize additional burden.

3. For biomechanical testing, participants were equipped with retro-reflective markers and surface EMG sensors. Using the 3D motion capture system, the CPM device was positioned in the manufacturer-recommended optimal alignment (position N0) by matching a marker on the motor's axis of rotation with markers indicating the glenohumeral axis. A 30-s resting trial was recorded. To assess first-time use, both the injured and contralateral healthy shoulders (healthy side as reference) were tested. For each side, 20 min of CPM were performed: 10 min of isolated ab-/adduction followed by 10 min of isolated external/internal rotation, each analyzed in 2.5-min intervals. On both sides, movement amplitudes were set to the maximum pain-free range within the surgeon-prescribed limits (maximum in abduction was 90° and in external rotation 30°). Subsequently, four suboptimal positions were tested on the injured side in randomized order, with each movement recorded for 2 min. These positions corresponded to vertical deviations of the adjustable rail by −4 cm (M4), −2 cm (M2), +2 cm (P2), and +4 cm (P4) from the optimal joint alignment. After each measurement, patients rated pain and discomfort during passive motion on a 0–10 scale (10=worst).

4. One day after CPM testing, patients received a CPM device for home use over four weeks in addition to physiotherapy and at no additional cost. While the operated shoulder was protected in an abduction pillow for 6 weeks, CPM was used as an adjunct within this regimen during dedicated sessions; the pillow was otherwise worn as prescribed. Recommended daily CPM use was approximately 3 h [18][35]. Home-care devices were adjusted to the individually determined optimal joint alignment by trained company representatives, based on the settings identified during the laboratory CPM session. After four weeks, patients completed a questionnaire: pain and discomfort during home use were again rated on a 0–10 scale, and additional items addressed perceived safety, ability to relax, handling, and overall experience.

EDI principles were addressed through consecutive recruitment, minimized burden during early recovery, and patient-reported outcomes capturing variability in pain, comfort, and tolerability.

Data collection

Kinematic data of the CPM device and patients were recorded using a 10-camera marker-based 3D motion capture system (100 Hz). A custom marker set with 12 retro-reflective markers on the CPM device and 29 markers on the upper body and both arms (healthy and injured; **Figure 1**) was used. Simultaneously, surface EMG (200 Hz) recorded muscle activity from the upper trapezius (pars descendens), middle trapezius (pars transversa), deltoideus (pars acromialis), and pectoralis major on both sides. Skin preparation and electrode placement followed SENIAM guidelines [22]. After each movement task, pain was rated on a Visual Analogue Scale (VAS). The CPM device used was the ARTROMOT-S3 (Enovis, ORMED GmbH, Freiburg, Germany).

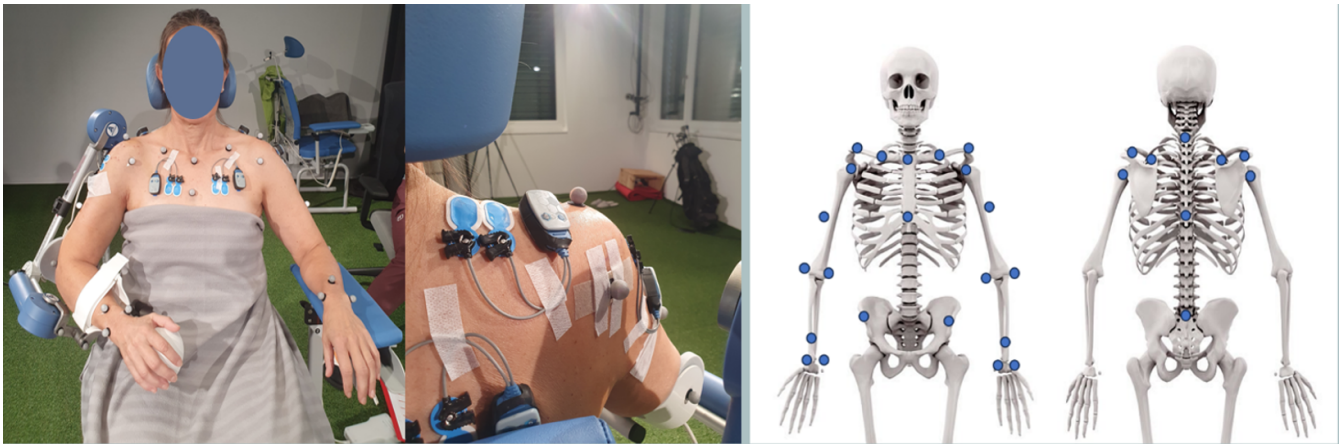

Figure 1. Marker-set created to represent upper extremity and thorax as well as EMG set-up on a patient.

Post Processing

Marker trajectories were labelled and gap-filled, and kinematic and EMG data were then exported to suppress ECG artefacts and motor-induced noise using ECG suppression, a 20–300 Hz band-pass filter, and notch filters at 50 and 150 Hz. Subsequently, data was imported into a biomechanical modelling software. Using the marker trajectories, segments for the CPM moving arm and chair and for the biological upper arm and thorax, were defined, and mechanical and biological 3D joint centers and angles were computed with the 6-degree-of-freedom model.

For each movement cycle - defined as abduction or external rotation from neutral to the individually prescribed maximum ROM and return (adduction or internal rotation) to neutral - the ROM of the CPM device and shoulder joint, lateral thorax tilt and shoulder joint displacement were calculated. For abduction, vertical joint displacement was evaluated; for internal/external rotation the anterior-posterior displacement was evaluated as an index of evasive joint motion. Displacements were expressed in centimeters as the difference between minimal and maximal joint position within a cycle, and lateral thorax tilt as deviation from the vertical axis (degrees).

For EMG data, Root mean square (RMS) envelopes were calculated (250 ms window). Because early postoperative patients could not safely perform maximal voluntary contractions, EMG amplitudes were normalized to resting activity. For each muscle, mean EMG during a quiet resting period in the test position served as the reference, so mobilization EMG is expressed as a multiple of resting activity. Muscle activity was operationally defined as EMG exceeding the mean resting level by five standard deviations, based on a 30-s resting measurement. This follows established non-MVC normalization strategies in patient populations that reference background or resting EMG rather than maximal effort [23][24]. The main variable evaluated was the mean muscle activation with respect to the resting activity.

Statistics

To evaluate the primary hypothesis, we compared injured versus healthy sides and the change over the 10-minute interval by contrasting the first and last 2.5-minute segments. For both hypotheses (sensitivity to suboptimal setup), the main variables were lateral thorax tilt, vertical and anterior–posterior shoulder displacement, mean muscle activation, and the ROM of the CPM device and the biological shoulder joint (defined as the angle range from lowest to highest value within one movement cycle). For each condition, mean values across all valid cycles were calculated separately for the injured and healthy sides in the optimal position and for each joint alignment setting. Time effects and differences between healthy and injured side were analyzed using paired sample t-tests (first vs. last 2.5 minutes). If normality was violated, Wilcoxon signed-rank tests were used. Position effects were assessed with repeated-measures ANOVA. When a significant main effect was found, post-hoc paired t-tests compared each misaligned position with the neutral condition, with p-values adjusted (p_adj) using the Bonferroni–Holm procedure [25]. Normality was assessed (Shapiro–Wilk), and α was set at 0.05. Effect sizes were reported as Cohen's d for t-tests (small <0.2, medium 0.2–0.5, large >0.8) [26] and partial η^2 for ANOVA (small <0.01, medium 0.01–0.06, large >0.14). Questionnaire data were summarized as mean scores (0–10) for pain and discomfort (VAS) and recommendation of the device. Perceived safety, ability to relax and handling were rated in four ordered categories (from high to low safety/relaxation and from very good to very difficult handling) and reported as percentages of patients per category.

Results

Thirteen patients met the inclusion criteria named above and took part in this investigation (56.9±6.6 years, 171.9±7.2 cm, 69.8±12.5 kg; 4 male, 9 female).

Comparison of Shoulder Joint ROM and CPM device ROM

When we compared the mismatch between the CPM device ROM and the corresponding shoulder joint ROM between the injured and healthy sides, no significant side-to-side differences were found for either abduction or rotation ($p>0.05$). However, within each side, the ROM of the shoulder joint differed significantly from the ROM set on the CPM device for both abduction and rotation (all $p<0.05$; **Figure 2**). Additionally, the ROM was compared between the neutral position (N0) and four suboptimal alignment position settings. Repeated measures ANOVA revealed a significant main effect for position for both the abduction ($F(4)=4.62$, $p=0.003$, $\eta p2=0.296$) and the rotation movement ($F(4)=3.48$, $p=0.015$, $\eta p2=0.240$). Post-Hoc analysis revealed a significant difference in abduction ROM between P4 (34.0°) and N0 (29.8°) ($t=-5.16$, $p\_adj=0.002$, $d=1.58$). This value, while being significantly higher than in the optimal setting, is still below the ROM of the CPM shoulder brace (34.7±15.1°). However, post-hoc analysis did not reveal any significant differences of a suboptimal position with respect to N0 for the rotation movement ($p\_adj>0.05$). For rotation the highest value of shoulder ROM was 34.4°±12.2° during the N0 position. ROM of the shoulder remained below the ROM covered by the CPM device (41.7°±15.9°) in every setting.

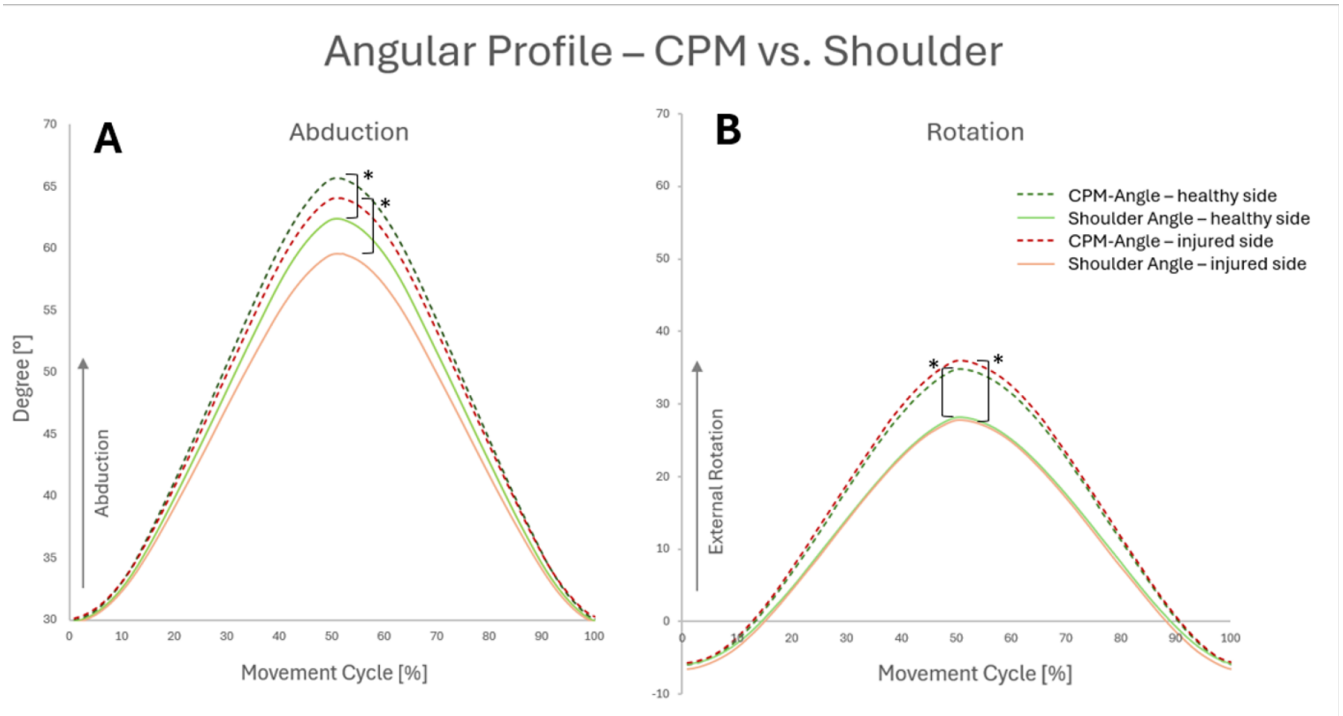

Figure 2. Comparison of the range of motion (ROM) of the passive motion shoulder brace and the shoulder joint itself in the abduction [A] and rotation [B] movement in degree [°] for the healthy (green) and injured side (red) respectively.

Shoulder Joint Evasive Motion

Figure 3A and 3B display the respective shoulder joint displacements for the healthy and injured side in neutral position as well as the four suboptimal settings while C and D demonstrate the change of displacement from the first to last interval in the optimal position.

While there were neither significant differences between the injured and healthy side nor between the optimal position and the different suboptimal settings during the rotation of the shoulder (**Figure 3D**), there was a significant difference between the healthy and the injured side during the shoulder abduction with a mean of 1.49±0.87 cm relative vertical displacement on the healthy side and 1.86±1.11 cm on the injured side with a medium effect size (t(12)=-2.48, p=0.029, d=-0.687) (**Figure 3C**). However, there was no significant effect for the position and no significant difference in vertical shoulder joint displacement between the optimal setting and the suboptimal settings during abduction and adduction.

In neither the abduction and adduction movement nor the rotation movement the displacement of the shoulder joint changed significantly over time for the healthy side. On the injured side, however, the displacement during the abduction movement decreased (2.05±1.19 cm to 1.82±1.08 cm) over the time period recorded (W=77, p=0.027, d=0.692) (see **Figure 3C**). For the shoulder internal and external rotation, no significant effects were found for the injured side (see **Figure 3D**).

Thorax Motion

During both the passive abduction (**Figure 4A**) and the rotation (**Figure 4B**) of the shoulder there was a significant difference between the healthy and the injured side regarding the lateral motion of the thorax. For the abduction the lateral motion increased from 1.14°±0.47° on the healthy side to 1.59°±0.69° on the injured side (t(12)=-3.11, p=0.009, d=-0.862). For the movement task of shoulder rotation, the deviation from the upright thorax position increased from 0.50°±0.21° on the healthy side to 0.86°±0.56° on the injured side (t(12)=-2.21, p=0.048, d=-0.612). No significant effect was found for suboptimal positioning during either movement plane (p>0.05).

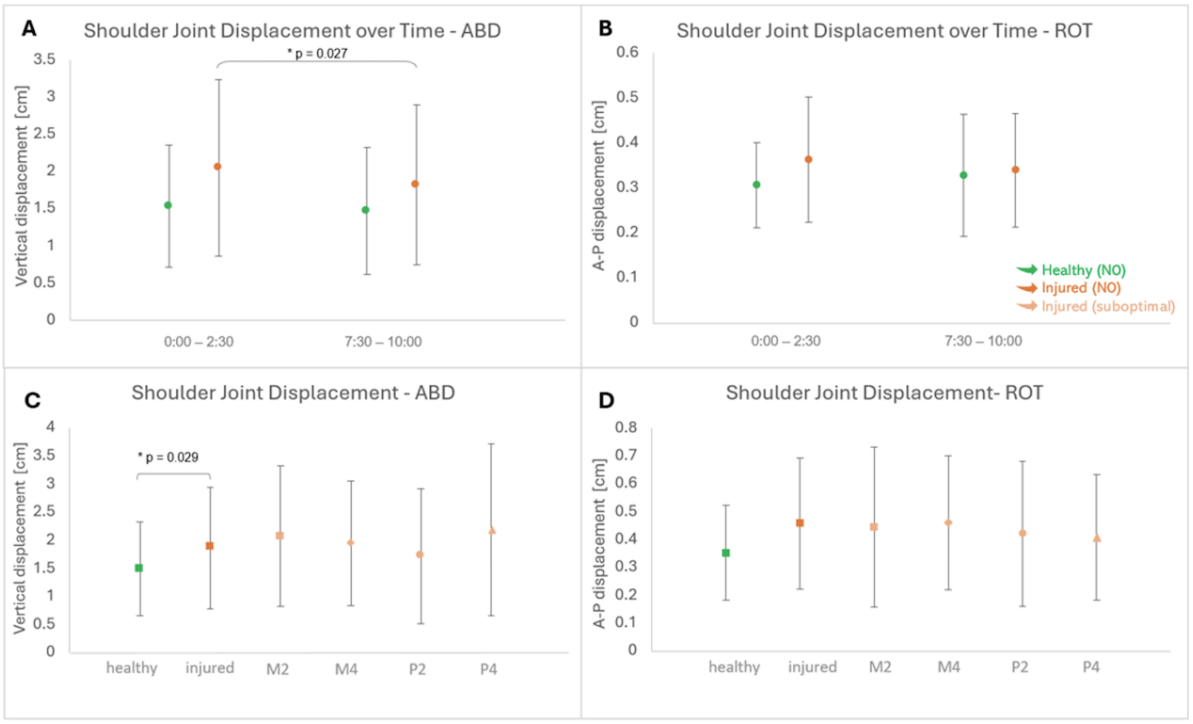

Figure 3. Evasive motion (vertical displacement in cm) of both the healthy (green) and injured (red) shoulder joint center during the abduction (ABD) [A] and rotation (ROT) [B] movement over ten minutes time of recording. Evasive motion (vertical displacement in cm) of both the healthy and injured shoulder joint center during the passive abduction movement [C] and rotation movement [D] as well as the extent of the evasive motion in the different positions (M2, M4, P2, P4).

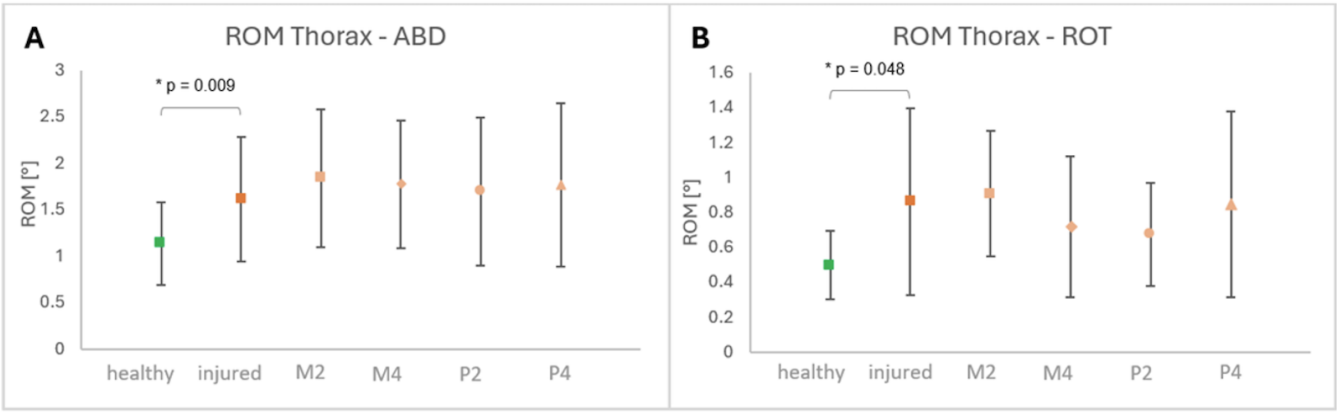

Figure 4. Evasive motion of the thorax in degree |°] during the abduction (ABD) [A] and rotation (ROT) [B] movement of both the healthy and injured shoulder joint center in cm during the passive rotation movement as well as the extent of the evasive motion in the different suboptimal positions (M2, M4, P2, P4).

EMG Activation

The mean EMG activation over the 10-minute recording period and the activation for the four suboptimal positions are shown in **Supplementary Figures S1 to S4.** Looking at the overall activation levels of the individual muscles, the pectoralis major muscle and the mid trapezius display an activity level below 100 % (resting activation level derived from the resting EMG-measurement). The mid trapezius shows an activation level of 57.3±26.3 % (61.2±41.7 % during rotation) on the healthy and 61.6±30.3 % (70.8±42.04 % during rotation) on the injured side, while the pectoralis major exhibits a mean activation during the abduction movement of 36.0 ± 32.0 % on the healthy side (36.7 ± 26.2 % during shoulder rotation) and 41.5±17.4 % on the injured one (38.7±18.6 % during shoulder rotation). The deltoid muscle does, however, display activity levels categorized as muscular activity during the abduction movement (233.7±186.7 % on the healthy side and 164.3±148.2 % on the injured side in the optimal setting). On the contrary, during the shoulder rotation the activation is below the threshold for activity (73.0± 41.9 % on the healthy side and 65.7±35.8 % on the injured).

Furthermore, the upper trapezius displays muscular activity during the abduction movement above the set threshold as well. For the healthy side the activation reached 121.8±65.1 % versus 208.0±155.8 % on the injured side. Mean EMG activation did not differ significantly between sides for any of the four muscles (paired t-tests, all p>0.05). The smallest p-value was observed for the upper trapezius during abduction ($t(11)=-2.13$, $p=0.057$, $dz=-0.61$), while the other muscles showed smaller effect sizes ($|dz|\leq0.30$; $p\geq0.316$). Furthermore, a significant increase was found over time on the healthy side for this muscle. The activation level, while being lower than on the injured side, increased from 99.6 ±45.1 % to 129.6±64.8 % during the 10 minutes time of recording ($t(11)=-2.21$, $p=0.049$, $d=-0.638$; **Figure S1**). Finally, the repeated measures ANOVA revealed a significant main effect ($F(4)=2.81$, $p=0.037$, $\eta p2=0.203$) for the comparison of deltoideus activation with suboptimal positioning. However, post-hoc analysis did not result in significant differences of any suboptimal position with respect to the neutral condition (N0) ($p\_adj>0.05$).

Questionnaires

The mean for the pain assessment during all measurements ranges between 0 and 0.71 out of 10 but does not exceed a value of 1. Similarly, the reported value for comfort ranges between 0.21 and 0.86 out of 10 on the VAS during the passive motion.

After the four-week interval of using the CPM device at home the set ROM for the abduction increased on average from 37° to 47°, but the ROM in the rotational motion barely increased from 37° to 38°. Furthermore, almost all patients stated that they adhered to the physician's recommendations regarding the application time, while one patient exceeded the indicated time. The level of pain, which was reported at 1.8±1.17 out of 10 in the beginning of the use at home, decreased to 0.2±0.4 on average. The handling of the CPM device was rated as very good by about 82 % of patients, 9 % rated it as good and 9 % as difficult. Thus the vast majority of patients reported to always have felt safe and been able to relax and nobody reported an insecure feeling while using the device. Lastly, the score for reapplication in case of a similar injury as well as the recommendation of the CPM brace was high with a mean of 9.1±1.58 out of 10.

Discussion

This study evaluated CPM effects on shoulder kinematics and muscle activation after RCR during first-time use, and patients' subjective experience after four weeks of home use. The biological shoulder ROM never exceeded the device's preset limits, even under suboptimal setup. Small side-to-side differences in shoulder/thorax motion did not affect shoulder ROM or device effectiveness, and muscle activation did not differ significantly between sides. Overall activation levels remained low, although some activity (e.g., deltoid and upper trapezius during abduction) was observed, consistent with predominantly passive mobilization.

Across movements, ROM did not differ between injured and healthy shoulders. Minor discrepancies occurred between device-set and actual ROM, but none approached medically approved limits. Abduction ROM increased at +4 cm vertical misalignment, yet remained below the set ROM. Thus, preset limits appear sufficient to ensure safe passive motion even with imperfect height adjustment. Minor thorax and shoulder motion differences on the injured side did not alter covered ROM, suggesting these evasive movements were clinically irrelevant; concerns about compensatory patterns due to stiffness were not supported by the small measured deviations, and vertical displacement of the shoulder joint already decreased significantly over the 10-minute interval. Because optimal alignment in the lab was camera-based and far more precise than typical clinical or home setup, we examined the "room for error" and found almost no significant effect on kinematics or evasive motion with misalignments up to ±4 cm, thereby confirming research question 2. Since CPM testing represented the very first device use for all patients, these findings indicate that minor upper-body adjustments at first contact do not compromise the ROM in which the joint is mobilized, ensuring reliable passive motion from initial use.

For muscle relaxation (research question 1), EMG during mobilization was expressed relative to resting measurements, providing an index of tension or active muscular support. Overall muscle activation remained low, supporting passive mobilization without relevant active engagement. Deltoid and upper trapezius showed slight activation during abduction, but clearly below typical voluntary contraction levels, indicating minimal tension; during rotation, none of the four muscles on either side exceeded 100 % of resting-normalized values, confirming full relaxation without unfavorable muscle loading. This is critical because early rehabilitation (weeks 2–6) aims to protect the repair and promote tendon-to-bone healing by avoiding active shoulder movement [28]. Suboptimal device settings had negligible influence on muscle activation.

Subjective feedback was favorable: pain improved, ease of use and perceived safety was high, and most patients met or exceeded the recommended daily use time. No patient reported feeling unsafe, and both willingness to reuse the device and recommend it to others were rated high. As this study was focused on immediate kinematic and EMG effects

of CPM at first contact after RCR, it does not provide data on long-term clinical outcomes.

Limitations

A limitation is that surface EMG captures only superficial muscles, thus, we cannot directly assess activation of the primary injured muscle (supraspinatus). However, previous work [29] has shown that basic shoulder movements are organized into six muscle synergies with contributions from most shoulder muscles examined, indicating that multiple muscles act in a coordinated pattern driven by a small number of control units. It is therefore unlikely that the supraspinatus would display isolated high activity while all other measured muscles remain minimally active. Therefore, surface EMG was considered a sufficiently precise, safe, and feasible approach for postoperative patients and a less burdensome alternative to kinetic/dynamic measurements e.g. by MacDermid [30] or Yen [31], or needle EMG.

A further limitation is the absence of EMG normalization to active maximal contractions, which is not feasible in this early postoperative cohort where muscle activity should be minimized. In line with current best practice, passive mobilization by a physiotherapist had already been initiated before testing; variation in home-based physiotherapy (different therapists) may have influenced relaxation, mobility, and perceived pain relief. In addition, varying postoperative pain medication requirements could have affected questionnaire-based comfort ratings, as passive mobilization after analgesic intake may be perceived as less painful. Finally, CPM dose may limit generalizability: although ~3h/day has been reported, contemporary pathways often prescribe shorter durations or alternative early-mobilization strategies, sometimes without strict sling protection [32]. Future studies should establish the optimal CPM dose under current rehabilitation standards.

Clinical Relevance

Postoperative rehabilitation protocols using the CPM device additionally to physiotherapy sessions show an earlier regain of ROM as well as onset of pain relief, although findings vary across studies and protocols. This is in line with the literature, e.g. [33], where patients in the CPM group reached the primary endpoint (90° of active abduction) on average 12 days earlier compared to the control group [34]. Similarly, potential economic implications of CPM in outpatient care have been discussed in the literature [35]; however, cost-effectiveness is strongly dependent on healthcare setting, rehabilitation pathways, and patient adherence, and was not subject of investigation in the present study.

Even though there is still no final agreement due to the lack of long-term studies, the data of this study suggests that the additional use of a CPM provides a safe mobilization of the shoulder joint. In the further rehabilitation phase this can improve the overall process, as the physiotherapist can use the time to address additional aspects that may need more individual supervision, whilst the vast majority of the mobilization task can be done by the CPM device. Nonetheless further investigations with larger cohorts can provide information about the long-term use, as well as the ideal application time duration per day as current recommendations range between 55min [35] and 3h [18]. This study underlines the safety of use of the device for continuous passive shoulder mobilization in early rehabilitation and supports the literature recommending the use during the early phase of postsurgical intervention [36].

Conclusions

In conclusion, this study demonstrates that the CPM device provides functionally safe and feasible passive motion for the shoulder joint in the early stages of rehabilitation following RCR. The minimal differences in kinematics and muscle activation, even with suboptimal device settings, suggest that the device can be reliably used at home, without adverse effects on the RCR. Future research could concentrate on optimizing the application of the brace as a rehabilitation tool to achieve the optimal outcome for the patients.

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Conflict of interest

S. Braun discloses a consultancy for Arthrex; however, this relationship is unrelated to the content of this manuscript. All other authors declare that they have no competing interests.

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Use of AI tools: ChatGPT (OpenAI) was used for linguistic and stylistic revision only. The authors reviewed and approved all edits and take full responsibility for the final content.

Data availability

The data sets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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