Journal Club

# 遠端機器人是否可以提供較佳的上肢能力(upper limb capacity)訓練成效？

蔡翰霆 職能治療師
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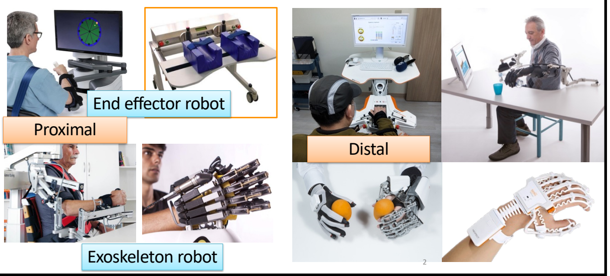
不可以 待驗證 可以

1

## Robotic Stroke Rehabilitation




2

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Journal of NeuroEngineering and Rehabilitation

REVIEW Open Access

Upper limb robotic rehabilitation following stroke: a systematic review and meta-analysis investigating efficacy and the influence of device features and program parameters

Kate Boardsworth[1], Usman Rashid[2], Sharon Olsen[1], Edgar Rodriguez-Ramirez[3], Will Browne[4], Gemma Alder[1] and Nada Signal[1*]

3

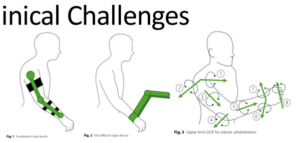
## Background

1. Stroke commonly leads to persistent **upper limb dysfunction**.
   – Stroke: 80% experience upper limb impairment; 65% persist after 6 months.
   Restore **functional capacity** and **ADL independence**.
2. Robotic rehabilitation aims to increase therapy intensity.
   – Robotic rehabilitation provides
   intensive, repetitive, task-specific training.
3. Evidence on its efficacy remains **mixed**.
   – Past reviews: Unclear at activity level.
   Improvements at body-function level | Dose-match: Robotic = Conventional
4. Understanding device and program variables is essential.

4

## Background: Clinical Challenges

1. Devices vary widely:
   – Exoskeleton vs. End-effector
   – Distal vs. Proximal focus
2. Program parameters differ
   – Dose, Duration, and Assistance type



Clinicians face difficulty **selecting appropriate robots** for patients.

3. Limited guidance for clinicians on device selection.
4. Evidence on effective robotic features is lacking.

5

## Research Purpose

To evaluate:

1️⃣ **The efficacy** of robotic rehabilitation versus dose-matched conventional rehabilitation on upper limb activity outcomes.

2️⃣ **The influence** of device and program features on rehabilitation outcomes.

6

## Search Strategy

1. Systematic review and meta-analysis following **PRISMA guidelines**.
2. Databases: Web of Science, OVID, CINAHL, Medline, Scopus, and PubMed Central
3. Final search: March 31, 2023.
4. Inclusion: RCTs, dose-matched comparisons.
5. Registered: PROSPERO CRD42022285794.

7

**Table 2** Eligibility criteria

| | Inclusion | Exclusion |
|---|---|---|
| Participants (>18y/o) | Adults over the age of 18 who had suffered a stroke resulting in loss of upper limb function | Adults who have suffered a cerebellar or brainstem stroke |
| Experimental intervention | Robotic exoskeleton or end-effector rehabilitation targeting the upper limb, for one or more sessions<br>Robotic and conventional rehabilitation were dose-matched in terms of total training time | Robotic rehabilitation combined with another exploratory intervention such as transcranial direct current stimulation (tDCS) or brain-computer interfaces (BCI) |
| Comparison intervention | Conventional occupational therapy or physiotherapy interventions to rehabilitate upper limb, such as task-specific training, strength training, repetitive practice, constraint-induced movement therapy (CIMT) | Comparison interventions that also use robotics unless the robotic component was very brief (< 10 min)<br>Comparison treatment combined with another exploratory intervention such as tDCS or BCI |
| Outcomes | Evaluation of 'activity' level outcomes including (a) upper limb capacity or (b) ADL as classified by the International Classification of Functioning Disability and Health model (ICF) | |
| Study design | Randomised control trials (RCTs) with a parallel-group trial design<br>Where there was more than one experimental group, provided that the study followed a parallel-group design and fit other criteria, data from both experimental groups was included | Randomised crossover trials or other study designs |
| Publication | Full-text peer-reviewed journal articles published in English | Conference abstracts |

8

## Data Extraction

1. Extracted data: participants, device type, parameters, outcomes.
2. Categorized outcomes:
   - **Upper limb capacity**: the Action Research Arm Test (ARAT), Wolf Motor Function Test (WMFT), and Box and Blocks Test (BBT), etc.
   - **ADL:** Functional Independence Measure (FIM) , the Barthel Index (BI), etc
3. Risk of bias assessed using **Cochrane RoB 2 tool**.

9

**Table 3** Device feature and programme parameter categories

| Subgroup analysis category | Category descriptor | Category levels |
|---|---|---|
| Device features | | |
| Device type (Type) | The type of device determined by how the device was applied to the upper limb<br>Where 'exoskeletons' (Fig. 1) were defined as having an external structural mechanism where the robot axes are aligned with the anatomical axes of the wearer; and 'end-effectors' (Fig. 2) were defined as devices which provide support and forces to the wearer's limb only at its most distal part which is attached to the wearer's extremity | Exoskeleton OR End-effector (Exoskeleton End-effort) |
| Degrees of freedom (DOF) (DOF) | The number of DOF or axes of motion of the participant's upper limb controlled or moved by the robot (Fig. 3). Main movements (degrees of freedom) of the upper extremity included:<br>1. Shoulder adduction/abduction<br>2. Shoulder flexion/extension<br>3. Shoulder internal(medial)/external(lateral) rotation<br>4. Elbow flexion/extension<br>5. Forearm pronation/supination<br>6. Wrist adduction (ulnar deviation)/abduction (radial deviation)<br>7. Wrist flexion/extension<br>8. Flexion/extension of all fingers = 1 DOF (not 4)<br>9. Flexion/extension of thumb = 1 DOF<br>(Flexion/extension of all fingers and thumb = 2 DOF (hand grasp/release))<br>10. Thumb adduction/abduction | Continuous moderator (Between 1–10) |
| Joints mobilised (Joint) | The joints of the upper limb that were moving as a result of the action of the robotic device (not the fixation points of the device on the upper limb)<br>Where 'proximal' encompassed devices which moved the upper limb from the shoulder to the elbow joint, 'distal' devices moved the upper limb anywhere past the elbow joint including the forearm, wrist, hand, or fingers, and 'whole arm' included devices which moved the upper limb at both proximal and distal components | Proximal OR Distal OR Whole arm (Proximal, Distal Whole arm) |
| Assistance | The amount of assistance provided by the device to the wearer to perform upper limb movements<br>Where 'full' assistance required no active movement from the wearer and device completed the entirety of the movement (the upper limb was moved passively). Devices were categorised as providing 'partial' assistance when the wearer actively contributed to the movement and the device supplemented the movement. Devices which provided both full and partial assistance were classified 'both'<br>No attempt was made to quantify the amount of assistance provided by the device in the 'partial' category due to a lack of consistency and clarity in the reporting of what constituted differing amount of assistance | Full OR partial OR both |
| Gravity | The planes of movement in space which the device moved the upper limb<br>Where 'against gravity' encompassed devices which moved the upper limb in the vertical plane, and 'planar' included devices which moved the upper limb in the horizontal plane. Some devices generated movements in both planes | Against gravity OR planar OR both |
| Portability | The portability of the device while it is in use by the wearer<br>Where 'portable' devices allowed the wearer to mobilise on foot while the device was in use, and 'stationary' devices required that the wearer stay fixed at the device (sitting, lying, or standing while in use | Portable OR stationary |
| Laterality | The attachment of the device to either one or both upper limb(s)<br>Where 'unilateral' devices were only worn on the affected upper limb, and 'bilateral' devices were attached to both the impaired and unimpaired upper limb. Some devices were able to be used both bilaterally and unilaterally in the intervention | Unilateral OR bilateral OR both |

**Table 3** (continued)

| Subgroup analysis category | Category descriptor | Category levels |
|---|---|---|
| Gamification | The inclusion of gamification or virtual reality paired with the device<br>Where 'gamification' included devices where a game component was present, and 'no gamification' included devices where there was no game component as part of the intervention delivery | Gamification OR No gamification |
| Feedback | The ability for the device to provide objective feedback on the wearer's performance or knowledge of results<br>Where 'feedback' included devices which provided feedback, and 'no feedback' included devices which did not provide feedback. Feedback provided from the device (not the clinician) included modalities such as a game score, a beep/noise, or a repetition count<br>No attempt was made to differentiate different types of feedback due to a lack of consistency and clarity in the reporting of feedback provided by the device | Feedback OR No feedback |
| Technology advancement | Exploring improvement of effectiveness of devices as the development of technology advances<br>Where the year of publication was taken to measure by proxy whether devices developed in more recent years were more effective than 'older' devices | Continuous moderator (Year of publication) |
| Programme features | | |
| Setting | The location where the device was implemented with the participant for the trial<br>Where 'inpatient' included interventions delivered to stroke patients in an inpatient hospital setting, 'outpatient' included settings where the participants travelled to attend sessions, such as outpatient hospital clinics, rehabilitation research centres, and medical centres, and 'home' included interventions delivered in the participants' home environment | Inpatient OR Outpatient OR Home |
| Participant age | The mean age of the participants in the experimental and conventional trial groups | Continuous moderator (Mean age) |
| Time since stroke | The mean amount of time in weeks post-stroke which the participants in the experimental and conventional groups commenced the trial protocol | Continuous moderator (Mean time in weeks) |
| Total training amount | The amount of intervention time participants spent training with the robotic device as the experimental treatment and the dose matched time with the conventional treatment<br>Additional 'usual care' intervention time for both groups was not included in the dose amount. The total hours spent training with the intervention was calculated by multiplying session duration (hours) x frequency of weekly trainings (sessions per week) x number of weeks in training (weeks of training)<br>Where a range value for time was given, the average time was taken. For example, 90–105 min, 97.5 was taken | Continuous moderator (Time spent training with intervention in hours) |
| Delivery mode | The number of participants receiving the treatment at the same time during the intervention<br>Where 'solo' interventions were delivered with one participant at a time, and 'group' interventions were delivered with two or more participants present during the session | Solo OR Group |
| Number of devices | The number of devices which were utilised as part of the experimental intervention protocol<br>Interventions were either delivered with a 'single' device, or utilised 'multiple' devices | Single OR multiple |
| Real-world (object) interaction | Whether the device enables interaction with real world objects (such as blocks, mugs, other objects used in ADLs or rehabilitation interventions) and if this was a part of how the intervention was delivered<br>Interventions were either delivered facilitating 'object interaction' or were delivered with 'no object interaction.' | Object interaction OR No object interaction |

10

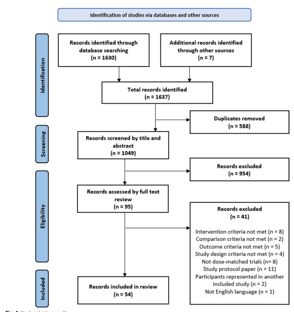



Fig. 4 Study selection results

11

## Methodological Quality

- Most studies: some concern or high risk.
- Overall evidence: low to moderate certainty.
- 54 RCTs, N=2744 participants.

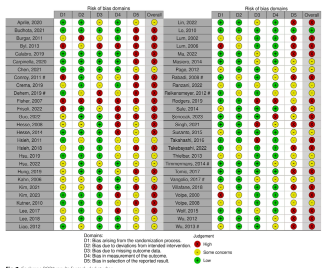



Fig. 7 Cochrane ROB2 results for included studies

12

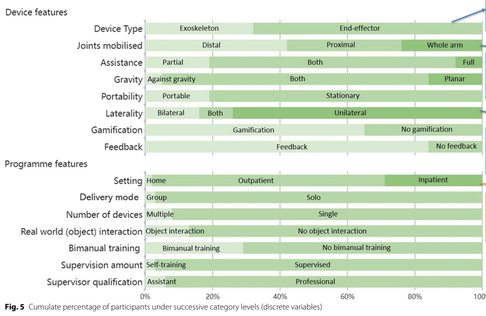


**Fig. 5** Cumulate percentage of participants under successive category levels (discrete variables)

- **Type:** >60% *end-effector* devices
- **Joints mobilized:** Distal joints dominate (>40%)
- **Laterality:** Unilateral training favored (~70%)

- Outpatient
- Solo

13

- **Degrees of Freedom (DOF):** Most devices have 3–4 DOF
- **Participant age:** Both robotic (RT) and control (CT) groups mainly aged 55–69 years.
- **Time since stroke:** Majority of participants within 0–99 weeks post-stroke. (<2 years)
- **Total training amount:** Most interventions provided 10–19 hours of total training. (1 hr/3 times, 3 times/week, 6 weeks)

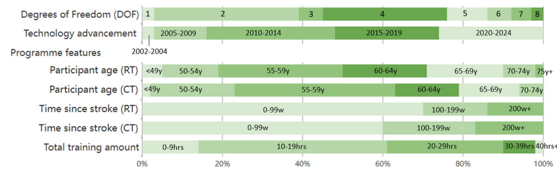


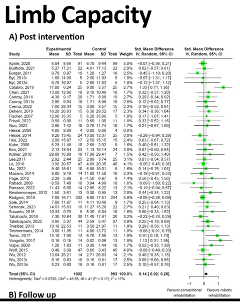
**Fig. 6** Cumulate percentage of participants under successive category levels (continuous variables) *RT* experimental intervention *CT* control intervention

14

## Quantitative Results
## Effect on Upper Limb Capacity

1. **Post-intervention:**
   - Robotic > conventional (SMD 0.14 [0.02, 0.26])
   - Small but significant.
2. **Follow-up:**
   - Effect not maintained (SMD 0.05 [−0.13, 0.24]

Suggests short-term improvement without sustained benefit.

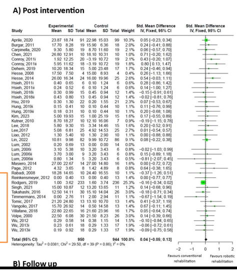



15

## Quantitative Results
## Effect on ADL Performance

1. **Post-intervention:**
   - No significant difference (SMD 0.04 [−0.05, 0.13]).
2. **Follow-up:**
   - No difference (SMD 0.00 [−0.13, 0.13]).

- No significant.
- Gains in capacity did not translate into ADL improvements.




16

## Subgroup Analysis

- Distal > Proximal > Whole-arm.
- SMD 0.30 (distal) vs 0.15 (proximal) vs -0.03 (whole-arm).

⬆️ Distal focus yields better improvement.

- Partial > Both > Full.
- SMD 0.37 (partial), 0.05 (both), 0.52 (full, ns).

⬆️ Active participation key.

- Unilateral > Bilateral.
- SMD 0.18 vs 0.17 (ns).

➡️ No major advantage for bilateral use.

**Table 5** Subgroup analysis results for discrete variables

| Subgroup category | Category options | Number of studies | Standardised mean difference [95% CI] for robotics versus conventional | Test for subgroup differences (trend observed) |
|---|---|---|---|---|
| Device features | | | | |
| Device type | Exoskeleton | 16 | **0.24 [0.07 to 0.41]** | p = 0.19 |
| | End-effector | 26 | 0.10 [− 0.06 to 0.26] | |
| Joints mobilised | Distal | 16 | **0.30 [0.07 to 0.53]** | **p = 0.0133*** |
| | Proximal | 13 | 0.15 [− 0.10 to 0.40] | |
| | Whole arm | 13 | − 0.03 [− 0.13 to 0.07] | |
| Assistance | Partial | 10 | **0.37 [0.19 to 0.55]** | **p = 0.0046*** |
| | Both | 29 | 0.05 [− 0.08 to 0.18] | |
| | Full | 3 | 0.52 [− 1.08 to 2.12] | |
| Gravity | Against gravity | 2 | 0.32 [− 0.69 to 1.34] | p = 0.14 |
| | Both | 33 | 0.12 [− 0.01 to 0.25] | |
| | Planar | 7 | 0.20 [− 0.21 to 0.61] | |
| Portability | Stationary | 32 | 0.10 [− 0.03 to 0.24] | p = 0.38 |
| | Portable | 10 | **0.28 [0.01 to 0.55]** | |
| Laterality | Bilateral | 4 | 0.17 [− 0.15 to 0.48] | **p = 0.0048*** |
| | Both | 3 | − 0.22 [− 0.69 to 0.25] | |
| | Unilateral | 35 | **0.18 [0.05 to 0.31]** | |
| Gamification | Gamification | 28 | 0.13 [− 0.01 to 0.27] | p = 0.71 |
| | No gamification | 14 | 0.18 [− 0.06 to 0.41] | |
| Feedback | Feedback | 34 | 0.10 [− 0.02 to 0.23] | p = 0.10 |
| | No feedback | 8 | **0.36 [0.02 to 0.70]** | |

17

## Subgroup Analysis — Degrees of Freedom

- Fewer DOF → better outcomes (p=0.012).

⬆️ Simpler design improves effectiveness.

**Table 6** Subgroup analysis results for continuous variables

| Subgroup category | Test for subgroup differences (trend observed) | Model coefficient |
|---|---|---|
| Device features | | |
| Degrees of freedom (DOF) | 0.012* | − 0.06, 95% CI [− 0.11, − 0.01] |
| Technology advancement | 0.5902 | 0.007, 95% CI [− 0.02, 0.03] |
| Programme features | | |
| Participant age | 0.2744 | − 0.01, 95% CI [− 0.03, 0.009] |
| Time since stroke | 0.6719 | − 0.06, 95% CI [− 0.34, 0.22] |
| Total training amount | 0.7511 | − 0.001, 95% CI [− 0.01, 0.007] |

*Statistically significant test for subgroup differences p < 0.05

18

## Discussion — Main Findings

1. **Scope:** 54 RCTs, 2,744 participants — first review defining both *device* and *programme* features in robotic rehabilitation.
2. **Upper limb capacity:**
   – Statistically significant but *small* benefit (SMD = 0.14 [0.02–0.26]).
   – Not maintained at follow-up (SMD = 0.05 [−0.13–0.24]).
   – Equivalent to ≈ +13 FIM motor or +8 ARAT — **not clinically meaningful**.
3. **ADL outcomes:**
   – No significant difference post-intervention or at follow-up.
4. **Overall:** Robotic rehab provides a **minor, short-term capacity gain**, without translation to daily-life function.

➡️ Limited clinical significance

19

## Discussion — **Tailoring Rehabilitation**

1. **Targeted delivery** improves efficacy — robotic rehab is more effective when focused on *specific* upper limb movements.
2. **Joint specificity:**
   – Distal-focused devices more effective than proximal or whole-arm.
3. **Degrees of freedom (DOF):**
   – Fewer DOF associated with greater improvement.
4. **Device number:**
   – Single-device interventions yield benefits; multiple-device do not.
5. **Key principle:** Training **specificity**—target limited, meaningful movement patterns.

•**Design implication:** Devices and programs should support *clinician-tailored*, *distal-focused*, and *specific-movement* training.🎯

20

## Discussion — **ADL Improvements**

1. **Main finding:** Gains in upper limb capacity **did not translate** into better ADL performance.
2. **Potential device factors:**
   – Features like portability, bimanual training, and object interaction were not statistically significant, though trends favored portable (SMD = 0.28) and object-interactive (SMD = 0.21) devices.
3. **Task specificity:**
   – Most devices trained simple movements (reaching, grasping), rarely complex ADLs (e.g., dressing, grooming).
4. **Conventional therapy** integrates **compensatory strategies**, while robotic rehab focuses mainly on *motor retraining*.

Current robotic gains ≠ improved ADL

Consider portability, real-world interaction. ➡️ Design robots for daily tasks.

22

## Conclusion

**1. Overall efficacy:**
   – Robotic rehabilitation provides small, short-term improvements in upper limb capacity.
   – No significant gains in ADL.

**2. Consistency with prior studies:**
   – Confirms prior findings that the clinical impact remains uncertain.

**3. Key determinants of efficacy:**
   – Level of assistance (partial > full).
   – Joints mobilized (distal > proximal/whole-arm).
   – Degrees of freedom (fewer better).
   – Number of devices (single > multiple).

**4. Clinical & design implications**

1. Tailor robotic interventions to specific impairments.
2. Implement devices in daily task contexts for better functional relevance.

24

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Thank you!!!

25