Integrating Humanoid Robots in Stroke Rehabilitation: Practitioners' Expectations and Insights

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***Abstract*—Stroke is a leading cause of long-term disability worldwide. Rehabilitation, though effective, remains a highly resource-intensive process. Integrating assistive robots into current practices holds significant potential to enhance therapeutic outcomes by addressing workforce limitations and personalizing care. This stakeholder engagement study explored the perspectives and concerns of physiotherapists and occupational therapists on implementing humanoid robots in stroke rehabilitation. Drawing insights from this exploratory consultation with stroke rehabilitation experts in the United Kingdom, key directions for future robot development in stroke care were identified. Clinicians expressed enthusiasm about the potential for robots to mitigate workforce shortages, especially for upper limb rehabilitation, and highlighted the importance of robots' ability to analyze patients' motor dynamics, track progress over sessions, and operate autonomously with minimal supervision. Key concerns included the current biomechanical limitations of humanoid robots, doubts about their ability to rehabilitate patients with cognitive impairments, and operational challenges related to setup and use.**

***Index Terms*—Stroke Rehabilitation, Assistive Robots, Patient-Centered Care, Healthcare Robotics, Stakeholder Engagement Study**

I. Introduction

Stroke is a major cause of death and long-term disability worldwide, representing the second-highest disease burden in Europe [1]. It is expected that the cases of ischemic stroke will triple by 2060 [2]. Additionally, the anticipated increase in the number of stroke survivors will lead to greater demand for healthcare resources, further escalating costs, which currently account for 1.7% of total healthcare expenditure in Europe [3]. Furthermore, stroke significantly impacts survivors across physical, mental, and psychosocial domains, leading to diminished functional capacity and a significant decline in quality of life [4]. Survivors of stroke often experience one-sided paralysis [5].

However, ample evidence indicates that early stroke rehabilitation can greatly enhance a patient's ability to recover some of the lost motor function, provided that sufficient intensity and duration of rehabilitation are delivered during the early post-stroke period [6], [7]. Studies suggest that each stroke patient should receive a minimum of 15 hours of rehabilitation per week [8]. Action Observation Therapy, Mirror Box therapy, and Mental Imagery-based practices are commonly used methods for stroke rehabilitation [16]–[18]. Given the already overwhelmed healthcare system in both developed and developing countries and the critically low levels of clinical staff available [9], [10], the urgency for integrating assistive technologies into care delivery is evident.

Research in rehabilitation robotics has advanced rapidly over the past two decades, leading to a significant increase in the development and deployment of therapeutic robots. These systems are particularly well-suited for stroke rehabilitation, as they offer the capability to deliver high-dosage, high-intensity training, which is critical for promoting motor recovery and functional improvements in this population [11], [12]. Most of the currently implemented robotic technologies in stroke rehabilitation consist of end-effectors and exoskeletons and, are shown to be superior in some cases to conventional physiotherapy [11]. While effective, these robotic devices are limited in their capabilities compared to a general-purpose humanoid robot. Unlike single-use devices, a humanoid robot can deliver diverse rehabilitation techniques, be mobile, and engage with healthcare staff and patients in a versatile manner [13]–[15]. The clinician-informed and patient-centric aspirations to design such robots motivated researchers to conduct a stakeholder engagement study to gather clinicians' insights into future directions for robot developers to create sustainable and inclusive healthcare services targeting stroke rehabilitation.

II. Research Questions

In this exploratory discussion, we addressed the following research questions. Firstly, we asked what opportunities assistive robots could bring into stroke rehabilitation practice,

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what features and abilities the practitioners see as essentials in assistive robots, and eventually, what challenges the clinicians envision using such robots in their clinical routines.

III. Methods

A. Participants

Five clinical occupational therapists and physiotherapists from Rotherham Stroke Rehabilitation NHS Foundation Trust participated in the discussion. All participants were experts in the field of stroke rehabilitation with years of hands-on experience using a wide range of stroke rehabilitation techniques.

B. Study Design

This was a stakeholder engagement study aimed at gathering insights from clinicians about integrating humanoid robots into stroke rehabilitation practice. The aim was to investigate the potential factors influencing the sustainability, inclusiveness, and trustworthiness of such robots ensuring the development of robotic solutions that are practical, ethically responsible, and intuitive to use.

C. Procedure

The stakeholder engagement session was conducted remotely using the Microsoft Teams platform. The session lasted one hour and was facilitated by two researchers who guided the discussions and ensured active engagement from participants. The session began with a structured presentation by the researchers, introducing two humanoid robots, iCub and Kangaroo (shown in Figure 1) and their clinical objectives as potential assistant robots in stroke rehabilitation.The presentation was accompanied by a 2-minute video of the iCub robot reaching and grasping everyday objects, And a prototype of a prosthetic hand that could potentially be integrated into the Kangaroo robot(see table I). Participants were encouraged to share their experiences and thoughts. The discussion was recorded with explicit consent from all attendees to ensure accurate documentation and later analysis.

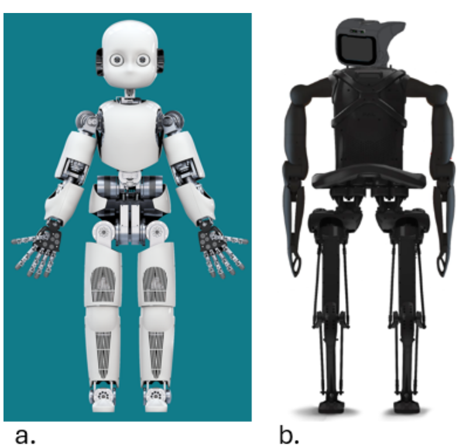


Fig. 1. Robots used in the demonstration. a. iCub robot by iit, and b. Kangaroo by PAL

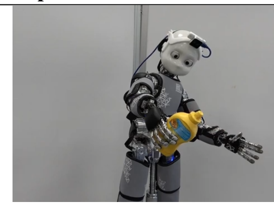
Video	Representative Picture	Link
iCub		iCub Video
Hannes		Hannes Video

TABLE I
The videos used in the demonstration, representative frames and the links

D. Questions

Table II shows the list of questions that were used to guide the discussion and elicit insights in a structured manner.

TABLE II
Interview Questions

No.	Question
1	Which rehabilitation approaches are currently used within your practice?
2	Please describe a typical day in your work with stroke rehabilitation patients.
3	What role does technology currently play in your practice?
4	Can you imagine a robot as part of your workforce?
5	What specific tasks or roles would you like the robot to do in the clinic for you?
6	How much autonomy should the robot have in making clinical decisions or recommendations?
7	How do you prefer to supervise the robot's activities during stroke rehabilitation sessions?
8	What methods of interaction do you prefer to use with the robot?
9	What are your concerns about using a humanoid robot in your practice?
10	How do you think those concerns could be mitigated?

E. Data Analysis

The recorded session was transcribed using Microsoft Teams' automated transcription feature, followed by manual corrections to ensure accuracy. The cleaned transcript was then imported into NVivo, a qualitative data analysis software, to facilitate systematic coding and thematic analysis. Deductive content analysis approach was used in this study as a priori thematic framework guided the analysis, with predefined themes aligned with the study's objectives and guiding questions. Table III presents the a priori themes identified for the study along with the corresponding frequency of coded items observed in the discussion transcript.

TABLE III
FREQUENCY OF A PRIORI THEMES IN THE INTERVIEW DATA

Theme	***Frequency***
Initial Impressions	19
Key Questions	18
Models of Practice	18
Service Delivery Constraints	5
Hopes and Expectations for Robotic Assistance	14

IV. RESULTS

The analysis of the discussion follows five key themes, which are presented in detail below. Each theme reflects a distinct aspect of the practitioners' perspectives on integrating robots into stroke rehabilitation. The frequency of occurrences for each theme is summarized in Table III and provides a quantitative overview of the discussion focus.

A. Initial Impressions

Practitioners expressed a mix of excitement, skepticism, and curiosity about the presented robot prototypes. In general, the practitioners showed enthusiasm and interest in the idea of using robots in stroke rehabilitation, with comments like *"Oh my God, it's magic!* [referring to the prosthetic hand's ability for fine grasping]", *"Crazy!"*, *"It is blowing my mind that the robots are this clever"* and *"This sort of idea* [implementing humanoid robots in stroke rehabilitation] *is very interesting!"* reflecting a strong initial intrigue and acknowledgment of the technology's potential in their practice.

On the negative side, concerns were categorized into three main areas. The first concern was the biomechanical limitations of the robot in imitating the natural grasping movements of healthy humans (see representative frame in table I. Physiotherapists emphasized that for robots to be effective in stroke rehabilitation, particularly when demonstrating motor actions to patients, they must closely replicate the movements of healthy individuals. Comments such as, *"We don't like its biomechanics around its wrist"* underscore this concern. The second concern focused on the robot's compatibility with patients who have cognitive or perceptual impairments. Many stroke patients experience conditions such as visual impairments, neglect, or disrupted body ownership, which could hinder rehabilitation. As one clinician remarked, *"One of the biggest issues is the number of patients who have visual, perceptual or cognitive impairments"*. Clinicians also raised concerns about the practical challenges of using the robot, noting that preparing both the robot and the patient could be time-consuming, labor-intensive, and require technical skills they might lack. Comments such as, *"There's quite a lot of getting the environment set up and getting the person in the right position for robot"* illustrate this issue

On the curiosity of the clinicians towards the robot, practitioners wondered if the robots could provide patient-specific and individualized feedback for each patient's needs, physical assistance to help with motor recovery in addition to Action Observation Therapy (AOT), and whether they could meaningfully interpret patients' behaviors in the session.

Furthermore, they were curious how the robot would do task allocation with the clinical staff. Some representative comments include *"How about hands on facilitation, which often accompanies the action demonstration?* [can the robot do that]", *"If you'd have to sit there with it* [the robot] *to get the interpretation of how the person is performing, what would be the point of that?"* and *"what will be the role of the robot?"*. These examples indicated that the designed robots should be able to be readily integrated into the workforce of the healthcare system with the demands and needs of patients and practitioners taken into account.

B. Key Questions

During the focus group, practitioners highlighted fundamental questions about robotic functionality that could affect the essential requirements for successful integration. These questions revolved around topics such as how much the robot will be able to fit in within the rehabilitation environment and adopt to diverse patient needs. This was important for practitioners as they adopt the range of techniques they use based on the needs and capabilities of each individual and hence, expected the robot to be able to do the same. Practitioners wondered whether such robots would be able to operate autonomously or if constant therapist supervision would be necessary, which could reduce its time-saving benefits and hinder operation within the rehab team.

It was important for the clinical team if the robot could monitor holistic body movements of the patient during the session and take their postural control, compensatory movements, limb misalignment, dysfunctional motor synergies, mental states, and level of effort into account. Some representative examples include *"How does the robot interact within a rehab environment?"*, *"Will the robot be portable?"*, *"So would the expectation be that we would program the robot for each individual and each task?"*, *"If, the robots focused on the upper limb specific function, does it have an awareness of what the rest of the patient's body's doing?"*, *"How much would the robot observe if the patient is losing the postural control or get tired"*.

C. Models of Practice

This part is focused on the current rehabilitation models and techniques implemented by practitioners. Practitioners emphasized that stroke rehabilitation is highly personalized, with each treatment plan adapted to the patient's unique abilities and impairments. Common practices currently being implemented include Action Observation Therapy, Mirror Box Therapy, Mental Imagery, and Functional Electrical Stimulation (FES), tailored to enhance motor recovery. Representative comments include *"There isn't a one size fits all kind of exercise or approach for any of our patients. We very much adapt for each patient"*, *"We are trying to implement a lot more kind of mirror therapy and mental imagery"*, *"we would do an action observation and perhaps a mental practice before* *we go into doing a task like a rehearsal"*, *"it's probably more of a demonstration* [AOT]. *This is what I'm wanting you to do and then you do it."*, *"Identifying a particular task that's meaningful to that individual and then sort of going through certain questions with them* [for mental imagery]."

D. Service delivery

This theme revolves around the constraints and challenges that clinicians currently face in their practice, and it also highlights situations where robots could be most applicable due to the limitations in the workforce and resources currently available. The practitioners mentioned that upper limb rehabilitation is often deprioritized due to time constraints and resource limitations, presenting a gap where robots could contribute significantly. With brief inpatient stays averaging around 20 days, the focus typically shifts to essential lower-body tasks that facilitate patient discharge, such as mobility and toileting. Due to their anatomical similarity to humans, humanoids' use for upper limb exercises, often overlooked in the acute phase, could be invaluable in filling this gap by providing extensive practice opportunities that adjust to the level of the patient at each stage.

Furthermore, practitioners emphasized that most of the acute training happens in the community and home setting and highlighted that these are the areas where robots could come handy the most. Some representative examples include *"Often, we prioritise transfers and getting people mobilised"*, *"The average inpatient stay would be somewhere around 20 days"*, *"Inpatient stay is short and minimised. So big priority is in helping people to be able to go to toilet and go home"*, *"We provide the therapy to progress them at home rather than in hospital"*, *"There's no money to support those changes without having more workforce to support it* [new guidelines for rehabilitation]".

E. Expectations for the robot

The practitioners' expectations for assistive robots in stroke rehabilitation could be summarized in four main domains. These domains include enhancing continuity of care, improving documentation of the session, supporting assessment and progress tracking, evaluating movement quality. Each area reflects the practitioners' hope that robots could bridge gaps in current practice and provide measurable benefits in terms of efficiency, accuracy, and patient outcomes. They hoped the robots could increase practice opportunities in the acute phase of stroke, allowing patients to engage more with rehabilitation exercises both before and after discharge from hospital. This would extend rehabilitation beyond hospital, which could reduce the burden on the healthcare system significantly. One clinician stated, *"Oh, my God, yeah!"* in response to if robots could take note in rehabilitation sessions. Some representative examples include *"That*[robot] *could bring more practise into that acute setting if it all span over into the Community."*, *"Patients get home and suddenly; they want their arm to work as well because their priority was getting to the toilet."*, *"If we could see again progress over days and weeks in terms of the amount of assistance, and range of movement"*, *"I think most clinicians would agree that that's a burden* [taking notes during session], *and if it* [robot] *is able to generate a report from a session which at least is 50% of your notes we like that"*, *"If it* [robot] *could measure range of movement, smoothness of the movement and the coordination of each limb, you know like are they getting better shoulder flexion, more elbow extension, what we would describe as normal movement patterns, that sort of comments."*, *"taking the notes and giving reports* [by robot] *would be a good help."*.

V. Discussion

The findings of this exploratory work provide critical insights into the nuances of the smooth and sustainable integration of robots into stroke rehabilitation practice. By analyzing the perspectives of clinicians within a pre-defined thematic framework, key insights were identified that underline the opportunities, challenges, and expectations associated with humanoid robots in stroke care. Practitioners stressed the need for adaptable systems capable of addressing diverse patient profiles, including varying levels of perceptual and cognitive impairments, with minimal supervision. Furthermore, a user-friendly interface that enables clinicians to easily customize exercises and settings was identified as crucial to reducing barriers to widespread adoption.

A major ambiguity raised by clinicians was around the nuances of task allocation between the robot and the practitioners. Precision in monitoring movement quality, detecting postural stability, and interpreting patient responses and progress over sessions were some of the other key features that clinicians wanted to see in stroke care robots. Reliable algorithms are essential for making the robots a practical assistance rather than a burden requiring constant oversight. This capability would enable clinicians to focus on broader aspects of patient care, effectively reducing their workload and optimizing resource utilization in clinical settings. And finally, given the shift in stroke rehabilitation from inpatient to community and home-based settings, the portability of stroke care robots was emphasized. Practitioners highlighted the need for lightweight, portable robots that are easy to set up in varied environments with minimal need for extensive setups, from hospitals to community centers. In a nutshell, the deployment of robots in stroke rehabilitation has the potential to address significant gaps in current practice. However, realizing this potential will require an iterative, co-designed approach with clinicians as well as stroke patients in the development of care robots—a direction this line of research is committed to pursuing. Future studies will aim to incorporate a bigger sample size from a wider background to improve the generalizability of the findings and ensure a comprehensive understanding of the potentials and challenges of robots in stroke rehabilitation.

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