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Stroke survivors interaction with hand rehabilitation devices: An observational study

Wodu Chioma, Gillian Sweeney, Milena Slachetka, Andrew Kerr

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Stroke survivors interaction with hand rehabilitation devices: An observational study

Wodu Chioma[1, 2]; Gillian Sweeney[1]; Milena Slachetka[1]; Andrew Kerr[1]

[1]Department of Biomedical Engineering University of Strathclyde Glasgow GB
[2]Department of Biomedical Technology University of Port Harcourt Port Harcourt NG

Corresponding Author:
Wodu Chioma
Department of Biomedical Engineering
University of Strathclyde
106 Rottenrow
G4 0NW
Glasgow
GB

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Abstract

Background: The hand is crucial for carrying out activities of daily living as well as social interaction. The functional use of the hand is affected in 75% of stroke survivors. Rehabilitation can help restore function and several rehabilitation devices have been designed to improve hand function, however, access to these devices is compromised in people with more severe loss of function.

Objective: In this study, we aimed to observe stroke survivors with poor hand function interacting with a range of commonly used hand rehabilitation devices.

Methods: Participants were engaged in an eight-week rehabilitation intervention at a technology-enriched rehabilitation gym. The participants spent 50 to 60 minutes of the two-hour session in the upper limb section at least twice a week. Each participant communicated their rehabilitation goals and an action research arm test (ARAT) was used to measure and categorise hand function;poor (0 – 9), moderate (10 – 56), and good (57). Participants were observed during their interactions with three handbased rehabilitation devices that focussed on hand rehabilitation; Gripable™, Neuroball™, and Pegboard. Observations of device interactions were recorded for each session.

Results: Twenty-nine (n=29) participants were included in this study. Out of whom, 10/29 (34%) had poor hand function, 17/29 (59%) had moderate hand function, and 2/29 (7%) had good hand function. There was no difference in the age and years after stroke of participants with poor hand function and those with moderate (p = .06 and p=.09) and good (p=.37 and p=.99) hand function. On the ability of the 10 participants with poor hand function to interact with the three hand-based rehabilitation devices used, 2/10 (20%) with an ARAT score greater than 0 were able to interact while the other 8/10 (80%) who had a score of 0 on ARAT could not interact. The reason for their inability to interact with these devices was clinically examined to be a result of either the presence of muscle tone/stiffness or muscle weakness.

Conclusions: Not all stroke survivors with impairments in their hands can make use of currently available rehabilitation technologies. Those with an ARAT Score of zero (0) cannot actively interact with hand rehabilitation devices as they cannot carry out the hand movement necessary for such interaction. The design of devices for hand rehabilitation should consider the accessibility needs of those with poor hand function.

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Stroke survivors' interaction with hand rehabilitation devices: An observational cohort study

Wodu, C. O[1,2]., Sweeney G[1]., Slachetka M[1]., Kerr, A[1].

1. Department of Biomedical Engineering, University of Strathclyde
2. Department of Biomedical Technology, University of Port Harcourt

Corresponding Author:

Wodu, C.O
Department of Biomedical Engineering
University of Strathclyde
G1 0QX, United Kingdom
Phone: 44 7930584076
Email: chioma.wodu@strath.ac.uk

Abstract

Introduction

The human hand is crucial for carrying out activities of daily living as well as interacting with the environment. The functional use of the hand is affected in 75% of those who suffer a stroke as a result of lingering mobility impairment. Rehabilitation can help stroke survivors regain function and several rehabilitation devices target to improve the hand functions of stroke survivors. In this study, we aimed to observe how stroke survivors with poor hand function interacted with some of these hand rehabilitation devices.

Method

Participants included in this study engaged in an eight-week rehabilitation intervention at a technology-enriched rehabilitation gym. The participants spent 50 to 60 minutes of the two-hour session in the upper limb section at least twice a week. Each participant communicated their rehabilitation goals and an action research arm test (ARAT) with scores ranging from 0 to 57 was used to measure and categorize their levels of hand function as poor (0 – 9), moderate (10 – 56), and good (57). Participants with poor hand function were observed on their ability to interact with three rehabilitation devices that focus on hand rehabilitation; Gripable™, Neuroball™, and Pegboard. Observations of device interactions were recorded for each session.

Results

Twenty-nine (n=29) participants were included in this study. Out of whom, 10/29 (34%) had poor hand function, 17/29 (59%) had moderate hand function, and 2/29 (7%) had good hand function. There was no difference in the age and years after stroke of participants with poor hand function and those with moderate (p = .06 and p=.09) and good (p=.37 and p=.99) hand function. Of the 10 with poor hand function, 8/10 (80%) who had a score of 0 on ARAT could not interact with any of the hand-based technologies. The reason for their inability to interact with these devices was clinically examined to be a result of either the presence of muscle tone/stiffness or muscle weakness.

Conclusion

Not all stroke survivors with impairments in their hands can make use of the available hand rehabilitation technologies. Those with an ARAT Score of zero (0) cannot actively interact with hand rehabilitation devices as they cannot carry out the hand movement necessary for such interaction. The design of devices for hand rehabilitation should consider the accessibility needs of those with poor hand function due to muscle stiffness/tightness.

Keywords: Stroke, hand impairment, hand rehabilitation, rehabilitation technology, spasticity

Introduction

Stroke is a major cause of disability and among the most common cause of death in the world [1]. Globally, about 17 million people suffer from stroke each year [2]. In the United Kingdom, the prevalence of stroke is projected to rise from 950,200 to 2,119,400 between 2015 and 2035 [3]. This projected rise in the prevalence of stroke has among other reasons been associated with improvements in medical advances that have led to a decline in the number of deaths of acute stroke victims [4]. Nevertheless, stroke survivors are faced with considerable long-term periods of enduring physical impairments, the likelihood of reoccurrence of strokes, transient ischaemic attacks, or even death within one year of having a stroke [5]. Motor impairment (muscle weakness and loss of movement control) is the most common consequence of stroke, impacting several aspects of life and reducing the ability of stroke survivors to lead an independent life [6] and about 75% of those who survive a stroke experience motor impairment in the upper limb [7].
The upper limb/hand is important for carrying out activities of daily living such as eating, dressing, bathing, communicating, and cognitive activities [8]. Besides, the hand is a defining feature of human beings and is the primary structure for human daily interaction [9].
Due to the importance of the hand to human existence, impairments such as spasticity, and extension weakness which are the sequel of stroke and manifest in hyperflexion of the wrist and fingers, affect the usefulness of the hand as well as the overall quality of life [10].

Rehabilitation can have a positive impact on the recovery of functions in persons with stroke [11] as well as in enhancing their quality of life [12] and movement restoration is a key goal in the rehabilitation of persons with neurological disorders [13]. Re-learning of movement ability during rehabilitation is based on factors such as repetitiveness, intensity, and regularity of task-specific movements [14]. It has been suggested that the rehabilitation of hand mobility and strength be prioritized once the general physical situation of stroke survivors has been stabilized owing to the importance of the hand [15].

Several new rehabilitation technologies that target the upper limb to improve motor functions are currently in use; these include the use of robotic-assisted technologies, Virtual reality, and telerehabilitation [16], some others which were used in this study are gaming devices such as the Gripable and Neuroball. The Neuroball is an interactive device that connects wirelessly with a tablet app to carry out activities that can also be objectively measured. Its games are specifically designed to help stroke persons exercise their hand (and upper limb) [17]. The Gripable is a lightweight electronic handgrip [18] that also interacts wirelessly with a computer tablet thereby enabling users to interact with therapy games tailored to improve the upper limb and hand function in a way that can be objectively assessed [18, 19]. The ability of stroke survivors with poor hand function or serious hand impairment to access these devices is a major concern as according to a report, only mildly disabled hemiplegic stroke survivors are likely to access hand or arm training applications available on mobile devices [20].

This study aims to observe stroke survivor’s interaction with hand rehabilitation devices and to understand how the different categories of hand function (ARAT scores) influence the stroke survivors’ rehabilitation goals.

Methodology

Participants

Participants were from cohorts of stroke survivors recruited between September 2021 and April 2023 who were attending a university-based rehabilitation centre [21]. The inclusion criteria for this study were those who had experienced a stroke resulting in movement problems, had been discharged from the hospital's rehabilitation services, had lived up to 12 months after the stroke, were aged over 18, were well enough to engage in light to moderate exercise, had their Action Research Arm Test (ARAT) before the study and were able to attend 2-hour rehabilitation sessions at least twice a week, for 8 weeks more details on participants eligibility and timeline for recruitment and overview of the general rehabilitation intervention are available on a previously published report [21].

Out of a total of thirty-six (36) participants who agreed to take part in the intervention, seven persons were excluded from this study. Of the seven excluded persons, five (5) withdrew from the intervention (two (2) of whom were before the commencement and three (3) due to ill health/ unwillingness to continue), the other two were excluded as a result of incomplete data.

The upper limb rehabilitation intervention

The upper limb intervention involved measures to improve the upper limb functions of participants delivered completely through the use of technology and therapy devices that either stimulated or promoted repetitive and intensive movement training. The upper limb rehabilitation technologies available to the participants in this study are seen in Table 1. The participants spent at least 50 to 60 minutes of each of the sessions engaging with these devices

Table 1. Upper limb rehabilitation technologies used

Technology/ Device	Manufacturer	Function
Gripable	Gripable UK	Connect wirelessly with an app on a computer tablet [19] to interact with specifically designed therapy games [22] to train four different types of upper limb movements such as grip/release, pronation/ supination, wrist flexion/extension, and radius/ulnar deviations.
Neuroball	Neurofenix	Connects wirelessly with a tablet app and interacts with therapy games specifically designed to exercise the upper limb of stroke survivors. [17]. It trains upper limb movements such as finger grip, hand grip, right/left/upward, and downward tilt, and elbow and shoulder movements.
Mirror box	SAEBO USA	A form of mental practice that excites the primary motor cortex thereby evoking the movement of the affected limb as the participants move the unaffected side while looking into the mirror [23]
Sensory Tens	Medfit, Taiwan	A non-invasive nerve stimulator used to relieve pain [24], stimulates the muscles and also relieves muscle stiffness [25].
Pegboard	Rolyan, UK	A therapy tool, designed to improve upper limb strength, movement coordination, endurance, and range of motion. It aims to improve hand dexterity.
Armeo Spring	Hocoma, China	It provides arm weight support while encouraging users to carry out self-initiated arm movements in the shoulder, elbow, and wrist joints and trains different upper limb movements [26].
Vibrating/Hot compress massage ball	Dongguan Kooeej, China	Stimulate the hand using the vibrations delivered at different intensities.
VR headset	Occulus Quest,	Immerses the user into a virtual environment thereby

	USA with Incisiv software, UK	encouraging them to use their affected limb in interacting with functional tasks [27, 28].

a. b.

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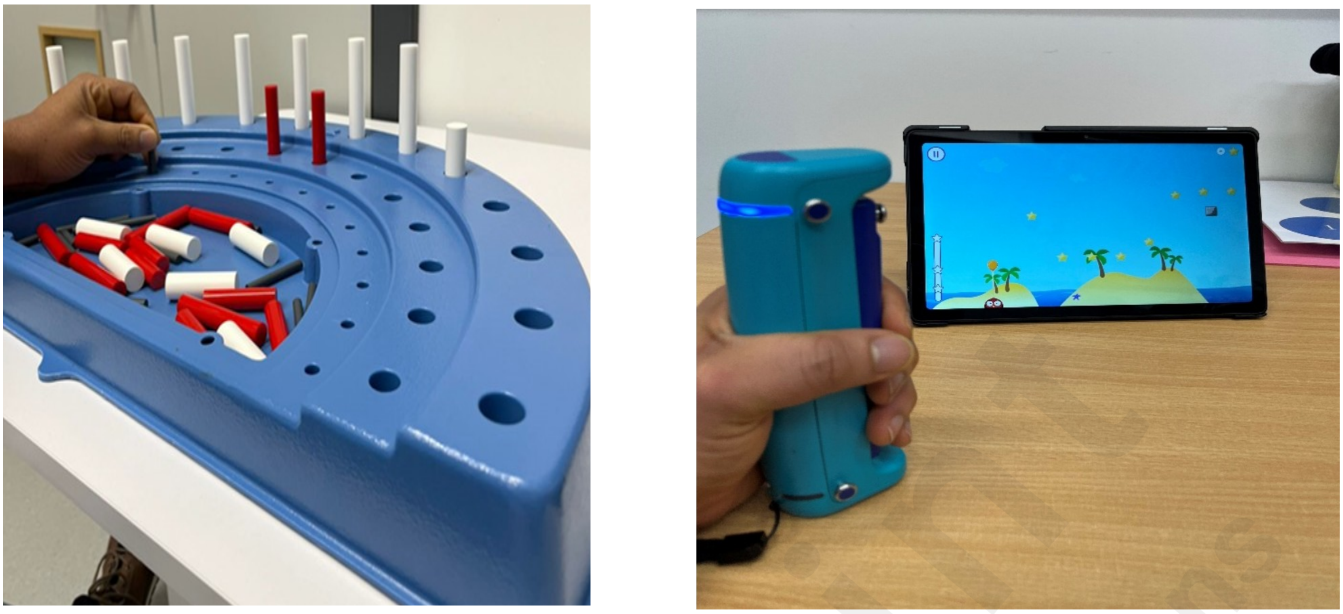

c. d.

Figure 1. Upper limb rehabilitation technologies and tools used a. mirror (mirror therapy) b. Neuroball device c. Semi-circular pegboard d. Gripable device

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Overview of upper limb rehabilitation program

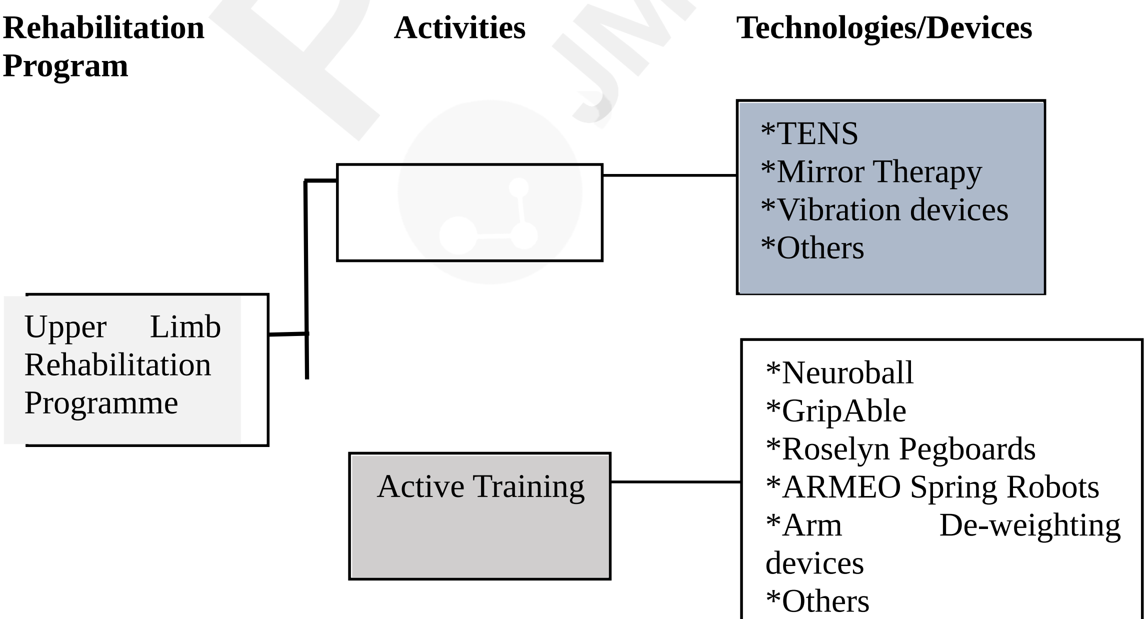

Figure 2: Upper limb (UL) and hand rehabilitation prog s

Figure 2 is a representation of the upper limb rehabilitation program template mostly encouraged at the rehabilitation gym. The activities were divided into two categories. The first part aimed at priming the brain. These priming activities mostly lasted within the first 10-15 minutes of each rehabilitation session. The second part i.e. the 'active training' aimed to engage the participants in various repetitive and intensity-driven motor activities such as grip, release, flexion, extension, pronation, supination, radial and ulnar deviations, reaching movements that will help them improve their range of motion, and activities to improve strength, coordination, endurance, and dexterity. The active training mostly lasted between 40 – and 45 minutes. The participants were not limited in terms of the number of devices they could use in each category or the number of devices they could use per session.

Categorising participants into different hand function groups

Participants were given a one-day initial appointment with a physiotherapist at the rehabilitation gym before the commencement of the eight-week rehabilitation intervention during which personal data (such as age) as well as data on stroke history were collected as well as baseline assessments. The ARAT was used to assess their hand function. The ARAT score obtained was used to categorize the participants into three different groups based on their hand function those whose ARAT scores fell between 0 – 9 were grouped as having poor hand function, 10 – 56 were grouped as having moderate hand function, and those who scored 57 were grouped as having good hand function [29].

Understanding the rehabilitation goals of the different categories of hand function

During the pre-intervention visit, participants were allowed to communicate their rehabilitation goals and interact with the upper limb devices to understand how they are set up and operated. The rehabilitation goals of the participants were summarized based on their different hand functions to help understand the needs of stroke survivors who fall under each of the different hand functions particularly the hand rehabilitation goals of those with poor hand function.

Observing the interaction of the poor hand functioning group with hand rehabilitation devices

Following the goal setting and initial interaction with the devices, a rehabilitation program was drawn up. The rehabilitation program was individually tailored by a physiotherapist using the rehabilitation goals of the participants. The program however only acted as a guide as participants had the freedom to interact with any of the devices. The ability of the participants to use each rehabilitation device was observed and recorded. At the end of the intervention, all the observations were gathered from participants with poor hand function and studied to see how they interacted with hand-based rehabilitation devices. Three of the upper limb devices the Gripable™, Neuroball™, and the semi-circular pegboard (see Figure 1) were selected for observation in this study. The reason for selecting these three is because these three devices were the only devices listed under the 'active training' category (see Figure 2) at the time of the study that were used to primarily train motor activities in the hand (involving the wrist and fingers) in addition to training other parts of the upper limb.

Data organization and analysis

The simple percentage method was used to estimate the percentage of stroke survivors who fall into each category of hand function. A one-way ANOVA Test was carried out using Minitab statistical software with the Dunnett multiple comparison method used to compare the age of the poor hand function group with the moderate and good hand function groups.

Ethics Approval

This study was approved by the University of Strathclyde ethics committee with approval number (UEC 20/08).

Results

Categorizing participants into different hand function groups

Table 2: Characteristics of stroke survivors and the three sub-groups

Groups	Number of Participants, n	Hand Function	Age in Years, Mean (SD)	Years after Stroke, Mean (SD)	Hemiplegic side, (L= Left, R=Right)	ARAT Score, Mean (SD)
1	10	Poor	64.70±8.83	2.10±1.45	L=5/R=5	2.00±3.74
2	17	Moderate	53.76±13.89	3.88±2.57	L=11/R=6	34.65±16.09
3	2	Good	76.50±0.707	2.00±1.42	L=1/R=1	57.00±.00
Average			59.10±13.62	3.14±2.31	L=17/L=12	26.63±21.51

Observations from twenty-nine (N=29) stroke survivors were included in this study. Their average age was 59.10±13.62 with an average of 3.140±2.31 years after stroke. 17/29 (59%) of the participants had their hemiplegic side on their left while the remaining 12/29 (41 %) were hemiplegic on the right side of their body.

10/29 (34%) of the participants scored between 0 -9 on ARAT and were grouped as having poor hand function, 17/29 (59%) scored between 10 -56 on ARAT and were grouped as having moderate hand function and 2/29 (7%) of the participants scored 57 on ARAT and were grouped as having a good hand function. A One-way ANOVA test carried out using the Dunnett multiple comparisons at 95% confidence involving the poor hand function group as control shows that there is no difference in the group age between the poor hand function group and both moderate hand function (p = .06) and the good hand function (p=.37) groups as they all fell under the same grouping (A). Similarly, there was equally no difference in the years after a stroke between the poor hand function group and both the moderate hand function *(p*=.09*)*, and the good hand function *(p*=.99*)* groups as they all also fell under the same grouping (A). There was also no observed difference in the hemiplegic side of those with poor hand function (L=5/R=5).

Understanding the rehabilitation goals of the different categories of hand function

Table 3a: Upper limb and hand rehabilitation goals of stroke survivors based on different hand functions

S/N	Hand Function	Rehabilitation goal
1	Poor	Gain the ability to hold objects e.g. paper, Gain some shoulder movement, Gain arm movement, Recovery of any movement, shoulder primarily, Improve grasp and release of objects, Improve active movements, [a] Grip Strength

2	Moderate	Improve; Dexterity, Grip, Range of upper limb movement, Upper limb strength, Supination/ Pronation range, grasp and release, release time, gain ability for small object manipulation, ability to move objects, purposeful movement of the upper limb
3	Good	Increase grip, improve wrist extension

[a] for those who record a score on ARAT

Table 3b: Upper limb rehabilitation goals of stroke survivors with poor hand function

S/N	ARAT Score	Rehabilitation goal
1	0	[a]NS
2	0	Improve active movements
3	0	Hold objects (e.g. paper) and gain some shoulder movement
4	0	Improve grasp and release of object
5	7	Grip strength, range of shoulder/elbow active movement
6	0	Gain arm movement
7	0	Gain some movement
8	0	Recovery of any movement, shoulder primarily
9	0	[a]NS
10	9	Grip strength

[a]NS= Not stated

Table 3a shows a summary of the rehabilitation goals of stroke survivors based on their different hand functions. Survivors with poor hand function stated goals that were more on gaining movements in different parts of their upper limb as well as improving the ability to carry out active movements which will enable them to grasp and release objects, however, stroke survivors with moderate and good hand function had goals that were focused on how to improving grip strength, fine motor movements, release time as well purposeful movement of the upper limb (see Table 3a). Table (3b) which looked at the rehabilitation goals of only those with poor hand function taking into consideration their ARAT scores shows that those with ARAT scores of 7 and 9 equally communicated the need to improve grip strength.

Interaction with hand rehabilitation technologies by the poor-functioning group

Table 4: Interaction of stroke survivors who had poor hand function with hand rehabilitation devices

	ARAT Score	Usage of Technologies for functional hand-training		
		GripAble™	Neuroball™	Pegboard
1	0	X	X	X
2	0	X	X	X
3	0	X	X	X
4	0	X	X	X
5	7	√	√	√
6	0	X	X	X
7	0	X	X	X
8	0	X	X	X
9	0	X	X	X
10	9	√	√	√

X= Unable, √ =Able

Table 4 shows that 8/10 (80%) could not interact with any of the three aforementioned devices to carry out active training this figure represents about 28% (8/29) of the total population in this study. However, only 2/10 (20%) of those with poor hand function were able to engage with these devices, the ARAT score shows that these two participants had an ARAT score of 7 and 9 as against the score of zero (0) recorded by the other 8 who were not able to engage with these devices.

Figure 2: Show participants with poor hand function taking part in the eight-week rehabilitation exercise.

Discussions

Principal finding

Stroke survivors with poor hand function leading to an ARAT score of 0 cannot actively interact with hand rehabilitation devices.

Comparison to prior work

About two-thirds of persons who suffer a stroke sustain upper limb (UL) impairments [27]. The extent of the impairments varies from person to person (see Table 2). In some, it results in poor hand function, while others present moderate or good hand function. The level of hand function present after stroke subsequently influences the upper limb rehabilitation goals of the stroke survivor (see Table 3a). Stroke survivors with moderate to good hand function who are likely to possess some range of motion in the hand can grip, grasp, or pinch [29, 30] hand rehabilitation devices and so have upper limb rehabilitation goals aimed at strengthening the existing motor ability these goals may be related to improving grip strength and endurance, the ability to release objects/ release time, improving existing range of upper limb movements, finger dexterity, and regaining the ability to manipulate small objects (see Table 3a). However, those with poor hand function especially with an ARAT score of 0 who cannot grasp, grip, or pinch objects irrespective of the sizes [30] have UL rehabilitation goals that focus on recovering some movement in the joints (shoulder, elbow, wrist, and/or fingers) (see Table 3a and 3b).

Muscle weakness and the appearance of muscle stiffness/tightness/tone (evident by the presence of a clenched hand) were clinically examined as responsible for the poor hand function of the participants in this study (see Figure 2). The appearance of clenched hands has been reported as a clinical feature of spasticity [31], besides, the presence of muscle stiffness/ tightness and tone have all been connected with spasticity [32, 33]. Previous studies have reported both spasticity and muscle weakness as two major motor impairments following a stroke [34, 35]. The severity of these impairments led to hand immobility in 80% of those with poor hand (with an ARAT score of 0) and according to an earlier report, spasticity and muscle weakness are capable of resulting in immobility [35].

Strength

The UK National Clinical Guideline for Stroke stipulates that stroke survivors should be considered to potentially gain from rehabilitation at any point post-stroke [36]. However, an earlier study that measured the accuracy of physical therapists' early prediction of upper limb function, reported that stroke survivors with ARAT scores more than 10 are those principally qualified to undergo rehabilitation exercise [37], this potentially excludes stroke survivors with poor hand function from taking part in hand rehabilitation. This study shows that not all stroke survivors with poor hand function should be considered ineligible to make use of hand rehabilitation devices as those with some range of motion in their hand as seen by participants with ARAT scores of 7 and 9 (see Table 4) can still benefit from hand rehabilitation devices and thus active hand rehabilitation.

Limitation

Only participants who exhibited poor hand function with a score of 0 on ARAT were not able to benefit from active hand rehabilitation using devices. Those in this category whose poor hand function was due to muscle weakness, were unable to carry out any intended active movement on the hand rehabilitation devices (see Table 4) even when supported to fit the devices, while those whose poor hand function was due to hand stiffness/tightness, in addition to their inability to carry out intended active movement, were also faced with the problem of accessibility which made it difficult for them to fit the device.

A limitation of this study was the inability to assess these conditions (muscle weakness and muscle tone/tightness) examined to be responsible for the poor hand function using the relevant outcome measures such as motricity index, grip strength/ pinch strength (for muscle weakness), or Modified Ashworth Scale (for spasticity) [38] to quantify their severity. However, the severity of the examined impairments was such that the hand was not useful in carrying out any of the ARAT tasks [30] as indicative by an ARAT score of 0.

Future direction

Improvement in technological advancement has led to the development of devices such as rehabilitation gloves (smart or robotic gloves) that can be useful in stretching the hands of stroke survivors with poor hand function without requiring their active participation [39, 40]. However, only stroke survivors with low spasticity (who possess some range of active motion in the hand [41]) may be able to make use of these rehabilitation gloves [39] This means those with considerable muscle stiffness resulting in difficulty in passive motion [41] are still unlikely to freely access these devices thus, future design of rehabilitation devices for hand rehabilitation should consider the problem of device accessibility in people with poor hand function due to considerable muscle stiffness/tightness.

Conclusions

It is therefore concluded that not all stroke survivors with impairments in their hands can interact with the available hand rehabilitation technologies as those with an ARAT Score of zero (0) cannot actively interact with any hand rehabilitation device. Thus, the selection of devices for hand rehabilitation should first consider the hand function of the affected stroke survivor. With muscle stiffness/tightness in the hand resulting in poor hand function capable of impeding access to hand rehabilitation devices, future design of devices for hand rehabilitation should consider the accessibility needs of those with poor hand function as a result of hand stiffness/tightness. A similar observation involving more stroke survivors will help ascertain the percentage of stroke survivors who fall into the category of having poor hand function and is therefore recommended.

Conflict of Interest: None declared

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Data Availability: The data sets generated during this study are available from the corresponding author upon reasonable request.

Author Contributions: All authors took part in the methodology, investigation, and administration of the study. Specifically, the first author (corresponding author) was involved with the conceptualization, original draft writing, formal analysis, and visualization of the work. The second and third authors were involved with editing and review of the draft and the last author was involved with the supervision of the project

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