COGNITIVE CHANGES IN STROKE PATIENTS FOLLOWING ROBOTIC REHABILITATION

WAN ADIBAH NADIAH ABD RAZAK

UNIVERSITI SAINS MALAYSIA

UNIVERSITI PENDIDIKAN SULTAN IDRIS

2022

COGNITIVE CHANGES IN STROKE PATIENTS FOLLOWING ROBOTIC REHABILITATION

DECLARATION

I, Wan Adibah Nadiah Abd Razak, hereby declare that the content presented in this Final Report Research Project are my own which was done at Universiti Sains Malaysia unless stated otherwise. I also declare that this Final Report Research Project has not been previously or concurrently submitted for any other degree at USM or any other institutions.

……..   ……...
(Student's Signature)   (Date)

ACKNOWLEDGMENT

This thesis becomes a reality with the endless support and help of many individuals. I would like to extend my sincere thanks to all of them. Foremost, I would like to express my deepest gratitude to my supervisor, Assoc. Prof. Dr. Muhammad Hafiz Hanafi, whose sincerity and encouragement has been endless throughout my research prosess. Also a big thank you to my co-supervisors, Dr Faizal Zulkifly and Assoc. Prof. Dr. Kamarul Imran Musa. It is an honor to learn from the best of the best such as the abovementioned.

Next, I would like to express my deepest gratitude to my parents, Dr Sharifah Khairol Musairah and Abd Razak, for always showering me with constant love and support. Deepest thanks to Wan Farah Adilah who has been my rock throughout this programme. I also could not have gone through this journey without my love, Qairul Amirul, for his unconditional love and support every single day. Finally, I would like to thank myself for enduring even though there were days where I felt like quitting; to quote Meredith Grey, "We're adults. When did that happen?".

ABSTRACT

Stroke continues to be a serious healthcare issue that has significant impact on the cognition. Different interventions are available for post-stroke patients to bounce back healthy again after obtaining a number of difficulties due to the stroke. Thus, the objective of this study is to investigate the effect of robotic rehabilitation and conventional rehabilitation on the cognition; specifically through the domains of general cognition, memory, and attention. A randomized trial design was used on a sample of post-stroke patients undergoing rehabilitation at Hospital Universiti Sains Malaysia and the participants were recruited through convenient sampling. The total number of participants that were obtained are ten, six from the robotic group and four from the conventional group. The participants were assessed twice using Wechsler Abbreviated Scale of Intelligence – 2nd Edition (WASI-II), Wechsler Memory Scale – 3rd Edition (WMS-III), and Comprehensive Trail Making Test (CTMT). The first assessment was done at the initial stage of the intervention and another assessment was done after a one month duration. The outcome of this study found that robotic rehabilitation has a higher improvement in terms of the cognitive domains of memory and attention, as opposed to conventional rehabilitation. The limitations of this study includes the sample size, accessibility of participants and time limitation. Despite the limitations found throughout the study, the findings have contributed to the understanding of the efficacy of robotic rehabilitation in the aspect of cognition because robotic rehabilitation is fairly new to Malaysia and the contributions of this findings act as a literary contribution to the field of rehabilitation medicine.

Keywords: stroke, robotic, rehabilitation, cognition, memory, attention, Malaysia

ABSTRAK

Strok adalah masalah kesihatan yang serius yang mempunyai kesan jangka panjang pada kognitif individu tersebut. Terdapat beberapa intervensi yang tersedia untuk pesakit strok untuk mereka kembali sihat semula selepas menghidapi kesan sampingan jangka panjang dari penyakit strok itu. Justeru, objektif kajian ini adalah untuk menyiasat kesan pemulihan robotik dan pemulihan konvensional terhadap kognisi; khususnya melalui aspek kognisi umum, ingatan, dan tumpuan. Kajian ini mengguna reka bentuk percubaan rawak ke atas sampel pesakit strok yang menjalani pemulihan di Hospital Universiti Sains Malaysia. Peserta kajian ini telah dipilih melalui persampelan mudah atau *convenience sampling* dan jumlah keseluruhan peserta yang diperolehi adalah sepuluh orang; enam orang daripada kumpulan robotik dan empat orang dari kumpulan konvensional. Para peserta dinilai dua kali menggunakan *Wechsler Abbreviated Scale of Intelligence – 2nd Edition (WASI-II), Wechsler Memory Scale – 3rd Edition (WMS-III),* dan *Comprehensive Trail Making Test (CTMT).* Penilaian pertama dilakukan pada peringkat awal pemulihan dan penilaian seterusnya dilakukan selepas tempoh sebulan. Hasil kajian ini mendapati bahawa pemulihan robotik mempunyai peningkatan yang lebih tinggi dari segi domain kognitif ingatan dan tumpuan, berbanding dengan pemulihan konvensional. Batasan kajian ini termasuk saiz sampel yang kecil, kebolehcapaian perserta, dan juga had masa. Walaupun terdapat beberapa batasan yang ditemui sepanjang kajian ini, hasil kajian ini menyumbang kepada pemahaman tentang keberkesanan pemulihan robotik dari aspek kognisi. Ini kerana pemulihan robotik dikira agak baru di Malaysia dan sumbangan penemuan ini bertindak sebagai sumbangan sastera kepada bidang perubatan pemulihan.

Kata kunci: strok, robotik, pemulihan, kognisi, ingatan, tumpuan, Malaysia

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADL Activity of Daily Living

CONSORT Consolidated Standards of Reporting Trials

COVID-19 Coronavirus disease 19

CTMT Comprehensive Trail-Making Test

CVA Cerebrovascular accident

CVDs Cardiovascular diseases

HAL Hybrid Assistive Limb

HREC Human Research Ethics Committee

HUSM Hospital Universiti Sains Malaysia

IQ Intelligence Quotient

JEPeM Jawatankuasa Etika Penyelidikan Manusia USM

KAP Knowledge, Attitude and Practice

MOH Ministry of Health, Malaysia

NCDs Non-communicable diseases

NEPSY-II Neuropsychological Assessment – Second Edition

NHS National Health Service

PIC Person-in-charge

RM Ringgit Malaysia

SOCSO Social Security Organisation

SOP Standard Operating Procedure

SRRR Stroke Recovery and Rehabilitation Roundtable

TBI Traumatic Brain Injury

TEA-Ch Test of Everyday Attention for Children

TMT Trail Making Test

TOL-Dx Tower of London DX-Second Edition

USM Universiti Sains Malaysia

WASI-II Wechsler Abbreviated Scale of Intelligence – Second Edition

WHO World Health Organization

WMS Wechsler Memory Scale

WMTB-C Working Memory Test Battery for Children

WPPSI-IV Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition

CHAPTER 1

INTRODUCTION

1.1   Introduction

Cardiovascular diseases (CVDs) is considered to be a global health issue as it remains to be the number one cause of death with about 17.9 million people died from CVDs in a year (WHO, 2017). CVDs is the general name given to the diseases which mainly affect the heart and blood vessels which includes arrhythmias, heart attacks and strokes among many others. As the human cognition relatively relates to every aspect of the human body, it is undeniable for CVDs to affect the patient's cognition in one way or another. With stroke being one of the top five leading causes of death and one of the top 10 causes for hospitalization in Malaysia, it is assumed to have had some impact on the patients' cognitive abilities.

The prevalence of stroke in Malaysia is rather significant which consequently demands for the awareness of stroke symptoms. Many clinicians also emphasise on the steps to be taken when confronted with someone who is displaying signs of stroke. Thus, the overall knowledge and stroke awareness is satisfactory in Malaysia (Ching et al., 2019).

Stroke is undeniably correlated to a higher risk of cognitive impairment which affects many post-stroke patients in terms of their day-to-day lives. It was found that the majority of post-stroke patients have trouble returning back to work after their first attack due to their limited cognitive ability which were not gained during rehabiltation (Pinter et al., 2018). Conclusively, the Stroke Recovery and Rehabilitation Roundtable (SRRR) agreed on the emphasis on cognitive evaluation and outcome following any stroke episode.

Many novel interventions have emerged to aid the rehabilitation of post-stroke patients, especially in terms of their cognitive abilities. The latest interventions include the integration of robotic devices in order to create life-like simulations for the patients, such as virtual reality and robotic limbs. In fact, it was recently found that the utilization of the robotic devices is beneficial for cognitive rehabilition on the stroke patients (Oliveira, 2020).

This study will utilize the use of a robotic device which is called the Robot Suit Hybrid Assistive Limb (HAL) in order to aid the rehabilitation of post-stroke patients.

The evaluation of the cognition will be done through a battery of neuropsychological assessments which includes Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II), Wechsler Memory Scale Abbreviated – Third Edition (WMS-III) and Comprehensive Trail Making Test (CTMT). Thus, the aim of this study is to evaluate the effectiveness of the integration of the robotic device with conventional therapy on post-stroke patients.

1.2   Problem Statement

Stroke is undeniably a serious and disabling health-care issue that has significant impact on the post-stroke patients to continue their daily lives. In fact, Mahon (2018) reported that stroke survivors may experience the ongoing severe impairments even years following the stroke. While the treatments available for stroke are primarily designed for the physical impairments that were produced due to stroke, cognitive impairments are typically reported yet overlooked. Thus, as robotic rehabilitation is fairly new in Malaysia, there is limited amount of study that utilizes the device in the community.

1.3   Study Rationale

The theoretical significance of this study would provide more evidence and insight into the cognitive profiles of stroke patients that have undergone robotic rehabilitation. Whereas the practical significance of this study would facilitate physicians to opt for robotic rehabilitation as opposed to the conventional rehabilitation. The findings of this study would also be useful to encourage the utilization of robotic therapy. Conclusively, this study would help to cognitively improve the rehabilitation process of post-stroke patients.

1.4   Research Questions

The research questions of this study are as follows:

1. Does robotic rehabilitation improve general cognitive functions, memory and attention in stroke patients?

2. Do stroke patients who undergo robotic rehabilitation differ in their general cognitive functions, memory and attention compared to those who undergo conventional rehabilitation?

1.5   Objectives

<u>**General Objective:**</u>

To investigate the effect of robotic rehabilitation and conventional rehabilitation on the cognition.

<u>**Specific Objectives:**</u>

1. To examine the general cognitive functions, memory and attention following robotic rehabilitation.

2. To compare the cognitive functions, memory and attention between patients who undergo robotic rehabilitation and patients who undergo conventional therapy.

1.6   Outcome Measures

To estimate the cognitive changes for patients with stroke who underwent robotic rehabilitation therapy and conventional stroke rehabilitation therapy from baseline to week four.

1.7   Operational definition

This study assesses the domains of cognition which are general cognition, memory and attention. Other operational definitions that will be described in this chapter are robotic and conventional therapy.

General Cognition

General cognition is referred to as the holistic cognitive aspect of an individual. In other words, it is an individual's mental capability which involves reasoning, problem solving, planning abstract thinking, and comprehension (Gottfredson, 1997). This study will measure the general cognition via the Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II).

Memory

Memory consists of the ability to encode, store and retrieve information. This study will measure the different dimensions of the human memory which includes auditory and visual memory, and immediate and delayed memory. To measure memory, the primary subtests from Wechsler Memory Scale-III will be used.

Attention

Attention is referred to as a cognitive process that enables one to select, focus and sustain the processing of a specific information (Cohen, 2011). Simply put, it is an individual's ability to concentrate on a specific stimulus. This study will measure the cognitive domain of attention via the Comprehensive Trail Making Test.

Conventional Rehabilitation

Conventional rehabilitation is referred to as the treatment of movement disorders which may have been caused by impairments of joints and muscles. This study will utilize the conventional rehabilitation which are due to hemiparesis from stroke. Thus, this study will execute conventional rehabilitation through gait training, physiotherapy and occupational therapy.

Robotic Rehabilitation

Robotic rehabilitation is referred to as the treatment of movement disorders by utilizing a technological device or robot. The rehabilitation robot is an automatically operated machine that was designed to aid the rehabilitation process in movements. The Hybrid Assistive Limb (HAL) will be used for this study as it is programmed to detect the

wearer's movement commands. Thus, the robotic rehabilitation of this study will include the robotic session of HAL, physiotherapy and occupational therapy.

1.8   Conceptual Framework
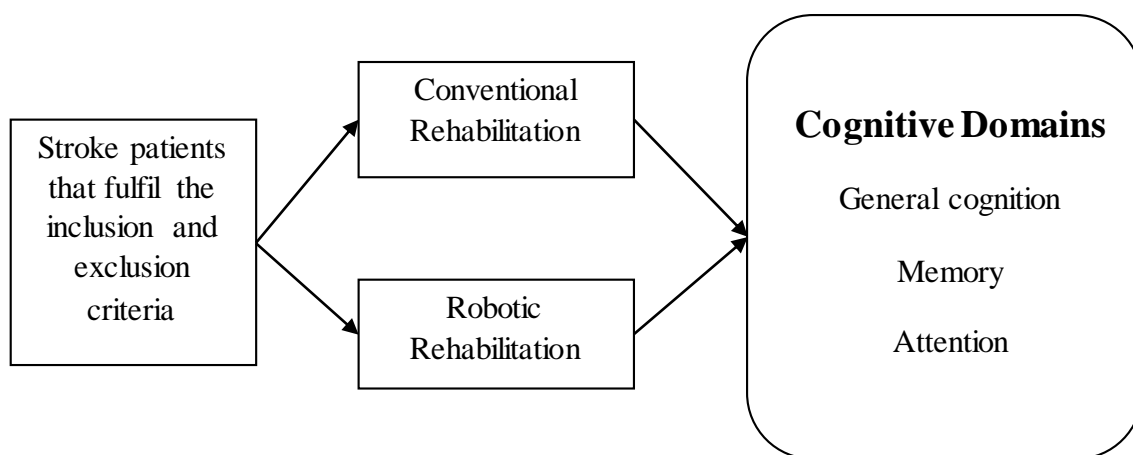
Figure 1: Conceptual Framework

The framework above is based on the ICF Model (International Classification of Functioning, Disability and Health) which is a framework for describing and organizing information on functioning and disability. In other words, the model acts as a standard language and concept for the definition and measurement of health and disability. Another model that is applicable for this study is the Cognitive Rehabilitation Model which was proposed by Abreu and Tonglia (1987) which is a framework that acts as a basis for understanding the function and dysfunction of cognition and perception. Furthermore, this model acts as a prerequisite when developing assessments and

treatments during rehabilitation. Thus, according to the two models mentioned, this study will measure cognitive changes following robotic rehabilitation through the general cognition, memory and attention.

1.9   Research Hypotheses

The hypotheses of this study are as follows:

1. First time stroke patients who undergo one month of robotic rehabilitation will score higher in general cognitive functions (WASI-II) compared to those who undergo conventional rehabilitation.

2. First time stroke patients who undergo one month of robotic rehabilitation will score higher in memory (WMS-III) compared to those who undergo conventional rehabilitation.

3. First time stroke patients who undergo one month of robotic rehabilitation will score higher in attention (CTMT) compared to those who undergo conventional rehabilitation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A brief literature review relating to stroke and rehabilitation are presented in this chapter. Past literature of stroke and the rehabilitation interventions are also reviewed in this chapter to provide a contextual understanding of the present research. This chapter is divided into ten sub-categories for easier understanding. The literature reviewed includes understandings of stroke in Malaysia, the impact it has on the human cognition, the interventions available, robotic rehabilitation for stroke, and the specific assessments to measure cognition.

2.1.1 Cardiovascular diseases (CVDs)

The latest aim for global healthy policy is for there to be a 25% decrease in premature mortality from noncommunicable diseases (NCDs) by the year 2025. Joseph et al. (2017) had conducted a two-part review on the latest epidemiological data on cardiovascuar diseases (CVDs), the risk factors, as well as the strategies of reducing the global burden of CVDs. It was found that the number of deaths are significantly increasing with the majority occuring in middle to low income countries while individual level risk factors also play a role. Consequently, in order to reach the 25% reduction, a better implementation of policies and strategies must be executed in order to improve CVD prevention and management. The second part of the review on the global burden of CVDs (Leong et al., 2017) discussed on the effective approaches in order to prevent and treat CVDs, specifically the management, care, surgical strategies, and approaches to the prevention of CVDs.

2.1.2 Cerebrovascular Accident (CVA)

Stroke is also part of the umbrella term cerebrovascular diseases; in fact, a stroke is also called cerebrovascular accident. Some may be questioning, is stroke part of cerebrovascular diseases or cardiovascular diseases? The answer is that it is both. Generally, the main cause of stroke is hypertension; this then damages the lining of the

arteries which makes the arteries more susceptible to the buildup of plaque which then narrows the artery walls leading to the heart and ultimately brain (Khaku & Tadi, 2021).

2.1.3 Stroke situation in Malaysia

Stroke prevalence is quite significant in Malaysia. In fact, a study had been conducted by Ching et al. (2019) to investigate the level of knowledge and recognition of stroke symptoms among the general public in Malaysia. This cross-sectional study utilized adult samples who have undergone early screening and self-administered questionnaire to measure the participants' knowledge on the actions to be considered during stroke. As it was a public screening programme, the findings suggests generalizability towards the whole population of Malaysia and the results indicate that the overall knowledge of stroke was good.

Another study was conducted by Sowtali et al. (2017) to investigate the knowledge, attitude and practice (KAP) that had been carried out among stroke patients and the general population. The researchers focused primarily on the public's perceptions towards stroke, knowledge on the risk factors, signs and symptoms of stroke and its assocication with the background of the participants. The findings produced by the KAP is beneficial in increasing awareness on stroke among the general public in Malaysia.

Ismail et al. (2020) had conducted a study to investigate the factors associated with the length of stay in the hospital for patients with stroke. The findings show that stroke patients remain in the hospital for a range of one to 17 days based on the severity. It is an essential step to describe the characteristics of stroke patients while determining the factors predicting the length of stay of the patients in the hospital.

Furthermore, Wijaya et al. (2019) had investigated the stroke management cost, mortality rate and disability rate in three countries which are Malaysia, Indonesia and Singapore. Stroke epidemiological data which includes the prevalence, incidence, mortality and disability was utilized over the last 12 years to calculate the overall cost. It was found that Malaysia has a mortality-prevalence ratio of 0.12 and disability-prevalence ratio of 2.11.

2.1.4   Stroke impact on cognition

Tang et al. (2017) had conducted a systematic review to explore the longitudinal effect of cognitive function in stroke survivors and to determine the factors that are associated with change as time passes. The review was conducted using three electronic databases namely Medline, Embase and PsycINFO in 2016 and retrieved a total of 5952 articles. All the samples of the studies were adults over the age of 50 years old with the inclusion criteria of being free from dementia. The review suggests that there were different themes in the cognitive test score deterioration among the stroke patients while some

cognitive stability and improvement were also acknowledged. A total of fourteen articles met the whole inclusion criteria with the acknowledgement of the variables that are associated with the cognitive impairment which includes age, ethnicity, premorbid cognitive performance, depression, location of the stroke, and history of any other previous stroke.

With stroke being correlated to a higher risk of cognitive impairment, it is vital to learn that the cognitive impairment is not the essential consequence of the stroke. Factors mentioned earlier could be utilized to design new models in order to predict any future risk of dementia after suffering from a stroke. These changes of cognitive impairment following stroke is important to investigate in order to form early intervention and preventative measures.

In addition, a study by Pinter et al. (2018) was conducted in order to investigate a consecutive sample of acute young ischemic stroke patients for any presence of neuropsychological deficits due to a limited amount of information on the prevalence and short-term changes of cognitive dysfunction among post-stroke young patients. The samples of this study were retrieved starting from February 2016 until April 2018 with patients ranging from ages 18 until 55 years old. The inclusion criteria of the study is the presence of an acute imaging-proven stroke and a total of 214 samples were invited, however only 150 patients were included in the study whereby 76% of them suffer from ischemic stroke while the rest were the common stroke.

Within the time period, extensive asssessments were conducted on the samples to examine their neurological and neuropsychological abilities as well as Magnetic Resonance Imaging (MRI). Conclusively, the samples had undergone a thorough clinical and cognitive assessment whereby their general cognitive functioning, processing speed, attention, executive functioning and word fluency were assessed. These measures were assessed following admission and also after 3 months as a follow up.

The study conducted by Pinter et al. (2018) found that cognitive deficits were particularly prevalent in processing speed, executive function, attention and general cognitive function (56.0%, 49.5%, 46.4%, and 42.1% consecutively). After a comparison with the 3 months follow up session, a significant improvement of cognitive performance was recorded among 87 of the samples. Nevertheless, the researchess found that there were some samples still suffering from cognitive deficits even after 3 months. Consequently, the follow up session revealed impairments in the executive function, processing speed and attention (44.0%, 35.0%, and 30.0% consecutively).

However, the limitations of this study includes the sensorimotor impairments that may have had an impact on the cognitive assessments such as the timed tests (Pinter et al., 2018). Another limitation includes the exclusion of a specific subtest for memory and the additional information on the impact of the presence and severity of other brain related deficits on the samples. Conclusively, cognitive deficits are extremely prevalent among young stroke patients in the acute and subacute stage.

Furthermore, McDonald et al. (2019) had elaborated on the effects of stroke rehabilitation and recovery on the human cognition. This is done while essentially elucidating that it is common for cognitive impairment to occur following a stroke episode which consequently relates to a disturbance with the motor and other types of recovery interventions; thus a decreased quality of life. The authors have proposed a few core recommendations that are consensus-based by the Stroke Recovery and Rehabilitation Roundtable.

The Stroke Recovery and Rehabilitation Roundtable (SRRR) is a convention gathering of a group of the world's top neuro-recovery researchers in order to hold a consensus on how to develop, conduct and report stroke research. The first Roundtable was conducted in 2016 and mainly emphasized on the motor recovery. Thus, the second Roundtable (SRRR-II) had produced a definition of post-stroke cognitive impairment which is a new cognitive deficit that appears in the first three months subsequent to stroke and thus remains there for a minimum of six months.

The authors have elaborated that there is insufficient evidence on the cognitive recovery following stroke because it is at an earlier stage of research as opposed to the work done on motor recovery following stroke. Nonetheless, it was agreed upon for all clinical stroke recovery researches to incorporate any forms of cognitive evaluation and outcome into their models. Another recommendation was to utilize the 'bedside to bench to bedside' approach in order to create a better alignment between researches.

2.1.5   Intervention to assess cognition in stroke

A more recent intervention has emerged which uses virtual reality which is a platform that involves real-time simulation of an activity or situation which allows interaction through multiple sensory modes. A study was conducted by Oliveira (2020) to evaluate a new approach in virtual reality with regards to cognitive rehabilitation following stroke. Previous evidence were found to utilize virtual reality activities to depict daily living which are deemed effective as an intervention for cognitive rehabilitation thus the study comprised of 30 sroke patients as samples and were assessed on their global cognition, executive functions, memory and attention. In order to make the intervention more comprehensiev, the virtual reality consists of multidomain cognitive training with various everyday life tasks such as preparing food, choosing clothes, and shopping. The findings suggest that the utilization of virtual reality is beneficial for cognitive rehabilitation in order to improve cognitive abilities following stroke.

A systematic review was conducted by Wiley et al. (2020) to investigate the effectiveness of exercise-based virtual reality therapy on cognition post-stroke. Searching in the database included terms related to stroke, virtual reality, exercise and cognition; the inclusion criteria for the articles being reviewed were randomized-controlled trials, virtual reality-based interventions, stroke patients as samples, and findings related to cognitive function. The findings of this meta-analysis suggest that virtual reality therapy is not superior to controlled interventions in improving cognition in stroke patients.

2.1.6 WASI-II (Wechsler Abbreviated Scale of Intelligence – Second Edition) and
general cognition

For this study, cognition will be assessed through three cognitive domains which are general cognition, memory and attention. The three domains will be assessed through three different instruments which are empirically sound to be used with regards to stroke recovery. Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II) is a tool to measure an individual's general cognition. The tool consists of four subtests and was reported to take around 30 minutes to complete all the subtests (Wechsler, 2011). The first index, Perceptual Reasoning Index (PRI) consists of two subtests; Block Design is used to measure an individual's ability to analyse visual stimuli while the Matrix Reasoning subtest was designed to assess an individual's fluid and visual intelligence. Whereas the Verbal Comprehension Index (VCI) comprises of the Vocabulary and Similarities subtests; the Vocabulary subtest was designed to assess one's knowledge on words while the Similarities subtests; the Vocabulary subtest was designed to assess one's knowledge on words while the Similarities subtest was designed to assess one's verbal concept formation and reasoning.

WASI-II was used by Bosenbark et al. (2017) to examine the clinical predictors of executive functioning in children folowing a stroke. A neuropsychological battery was used which consists of a few other scales including The Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (WPPSI-IV), Neuropsychological Assessment – Second Edition (NEPSY-II), Working Memory Test Battery for Children

(WMTB-C), The Test of Everyday Attention for Children (TEA-Ch), Tower of London DX – Second Edition (TOL-Dx), and Trail Making Test (TMT). The findings suggests that children with stroke are at risk for later deficits in terms of attention and executive functioning and the scale correctly measured what it was meant to measure.

In addition, Swamy et al. (2013) had employed WASI-II to measure the relationship between Intelligence Quotient (IQ) and environmental factors on cranial capacity. This study was conducted on a total of 419 children and adolescents in Malaysia. With the employment of WASI-II to investigate IQ among the samples, it was found that the IQ and cranial capacity may actually be enhanced by modifying the lifestyles and economic conditions of the families in these developing countries.

2.1.7   WMS-III (Wechsler Memory Scale – Third Edition) and memory

The Wechsler Memory Scale – Third Edition (WMS-III) is also found to be an empirical measure to assess another domain of cognition among stroke patients. WMS-III comprises of three primary indices which measure three different types of memory: immediate memory, general memory (delayed) and working memory. The immediate memory index measures an individual's ability to remember information after either an oral or visual presentation whereas the delayed index measures an individual's ability to recall an information that was presented to them after a 30-minute gap.

Ghaffari et al. (2021) conducted a study utilizing WMS-III to determine the predictors of instrumental activities of daily living performance in individuals with stroke. The researchers employed WMS-III to assess verbal memory in terms of forward and backward numbers with the total scores ranging from six to 15. Other scales were used in the study including Lawton IADL scale, Barthel Index, TMT, Motorcity index and Beck Depression Inventory-II. The findings suggest that stroke individuals with more dependency in basic activities of daily living and cognitive impairmenet are more prone to be dependent in instrumental activities of daily living, consequently less participation in home and community affairs. Thus, it is evident that the use of WMS-III is a beneficial tool to determine the performance of stroke patients.

To further investigate the use of WMS-III among the Malaysian population, Sayuthi et al. (2009) had used this scale among a battery of other assessments which includes Wechsler Adult Intelligence Scale (WAIS) and Quality of Life (QOLIE-31). The study was conducted among epilepsy surgery patients who were seeking treatment in HUSM; these tests were used to assess the efficacy of surgery on an individual's cognitive functions and quality of life. The tests were conducted pre-surgery and post-surgery on a total of seven individuals and it was found that neuropsychological tests are essentially useful in determining the laterality of seizure focus.

2.1.8   CTMT (Comprehensive Trail Making Test) and attention

The Comprehensive Trail Making Test (CTMT) was originally designed to detect brain defects while tracking the progression of rehabilitation (Reynolds, 2002). CTMT comprises of five sets of tasks that measures attention and concentration among others and the tool was designed to be administered on individuals aged 11 until 74 years. This test is fairly easy to administer and would take around 10 minutes to complete because the tasks only requre the examinee to connect a series of numbers and letters together which would result in a trail. These tasks are significant predictors of attention as it requires an individual's focus and concentration when executing the tasks.

Fruhwirth et al. (2020) had conducted a study utilizing CTMT to investigate the course of cognitive function in patients with recent small subcortical infarction and whether it has a correlation with white matter hyperintensities. Other than CTMT, the neuropsychological test battery employed by the researchers include the Montreal Cognitive Assessment and the Symbol Digital Modalities Test. The study used CTMT to evaluate attention and set-shifting which is a part of the broader cognitive flexbility concept that involves the ability to shift attention between two different tasks. The findings suggests that the assessments utilized by the researchers, especially CTMT, successfully measured the cognitive impairment among the patients thus deeming the tool to be a beneficial measurement of attention.

Also, CTMT was employed by Ros Azamin et al. (2019) in the Malaysian population to measure the correlation between perceptual ability and intelligence through the brain's attention regulatory mechanism. Throughout the said study, a total of 115 samples of resting EEG were collected from the left prefrontal cortex. Rox Azamin et al. (2019) assessed perception by employing CTMT and found that there is a correlation between IQ level prediction and cross-relational analysis with perceptual ability.

2.1.9   Robotic Stroke Rehabilitation

An extensive research was conducted by Stephenson and Stephens (2017) to explore physiotherapists experiences using robotic therapy among stroke patients. Robotic Therapy (RT) is considered as an effective addition to promote movement among post-stroke patients while controlling the impact of functional capabilities. As RT is comparatively a newer field of rehabilitation, there is a lack of research available on the experience of the utilization of the device, especially from the physiotherapists' perspective. Stephenson and Stephens (2017) had an objective of investigating the clinician's experiences of using RT on the upper limb of the stroke patients.

A total of six physiotherapists were interviewed about their experiences of using the machine and thematic analysis was utilized to further interpret the data. The findings suggest that five interdependent themes emerged which were individualized care,

influenced by evidence for practice, human relationships, skill mix, and resources and resource management. Despite researches showing evidence that utilization of RT adds as a supplement to conventional rehabilitation for stroke patients, the physiotherapists agreed that there are certain barriers that impedes the successful usage of the device.

However, the limitation of the study includes the lack of generalizability due to the samples being from the same area which is the north of England. This may create a possibility that their experience and understanding vary from other countries. Conclusively, the authors have proposed a framework which summarizes the correlation between participant's views and experiences in order to understand the impact of RT.

Another study was conducted by Cerasa et al. (2018) to explore the effect of cerebral lesion load on the response to a robotic-assisted rehabilitation. In other words, the authors have conducted a lesion mapping to explore the effect of the utilization of exoskeleton-robot therapy on stroke patients. As the previous study focused on upper limb rehabilitation, this study explores the use of exoskeleton robotic therapy in improving stroke recovery.

A total of fourteen patients were used as samples with the inclusion criteria of suffering from hemiparesis post-stroke (M=10, F=4). Initial assessments were conducted to measure the neuropsychological abilities of the patients which was measured again after the seven-week robotic rehabilitation merged with conventional

therapy. The assessments of Fugl-Meyer and Motricity Index were used to assess the primary outcomes which were the motor functions and strength whereby Functional Independence Measure and Barthel Index were utilized to assess the secondary outcomes which includes daily living activities. Meanwhile, in order to establish the degree of cerebral lesions that are associated with motor recovery, Voxel-based lesion symptom mapping was used.

The findings suggest that robotic rehabilitation was beneficial in improving stroke recovery even after the consideration of the primary and secondary outcomes. However, the major limitation of the study is the limited control group to really evaluate the efficacy of robotic therapy as opposed to conventional therapy. Nonetheless, the authors have emphasized that this study is consistent with the findings of previous research.

Another systematic review and meta-analysis was conducted by Bruni et al. (2017) to compare the effects of different robotic machines in improving post-stroke gait abnormalities; in other words, to determine what past research found about the benefits of robotic gait rehabilitation on stroke patients. The review was conducted using a computerized literature research through MEDLINE, PEDro and COCHRANE and 13 randomized controlled clinical trials were selected which were then segregated into subacute and chronic stroke patients. The selected trials included one of the five tests which are 10-Meter Walking Test, 6-Minute Walk Test, Timed-Up-and-Go, 5-Meter Walk Test, and Functional Ambulation Categories.