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A CASE STUDY TO DETERMINE THE EFFECT OF AN ACTIVITY-BASED NEUROMUSCULAR ELECTRICAL STIMULATION (NMES) PROGRAMME IN ACUTE STROKE SURVIVORS.

Alexis Badenhorst

A research report submitted to the Faculty of Health Science, School of Therapeutic Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Masters of Science in Occupational Therapy.

Johannesburg, 2020

DECLARATION

I, Alexis Badenhorst, declare that this research report is my own work. It is being submitted for the degree of Masters of Science in Occupational Therapy in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university/institution.



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PLAGIARISM DECLARATION

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ABSTRACT

Stroke survivors in South Africa are often discharged from inpatient care before they have reached functional independence. Due to the distance to healthcare facilities and the high costs associated with travelling, they are often unable to access outpatient rehabilitation. Neuromuscular electrical stimulation (NMES) is one of the adjunctive treatment modalities available to facilitate improvement in motor function and participation in activities of daily living post stroke in the acute inpatient phase of treatment. However, research has yielded contradictory results in relation to the use of NMES in stroke cases. This study investigated the change in motor function and participation in activities of daily living of an activity-based NMES programme in the short inpatient admission period for first incident stroke survivors. The effect of dominance, age and cognition on the improvement found after an activity-based NMES programme was described.

A case study research design was used with three stroke survivors who complied with the inclusion and exclusion criteria associated with the application of NMES after stroke. A NMES programme of two 30-minute sessions was administered in addition to a routine occupational therapy programme for a duration of five days.

The participants achieved a significant statistical improvement in overall motor function as assessed by the Fugl-Meyer assessment (FMA) ($p=0.002$). Scores on all subtests of the FMA improved significantly for two participants, except for the coordination subtest. Improvement in personal activities of daily living assessed on the Modified Barthel Index (MBI) also showed statistical improvement ($p=<0.001$). The greatest improvement was found for toilet transfer, personal hygiene and washing. Scores on the FMA and MBI indicated that initial deficits or severity of the stroke determine outcomes rather than age and or dominance. Participants with better cognitive function who had higher scores on the Mini Mental-State Examination (MMSE) had better outcomes after the intervention.

The use of an activity-based NMES programme during the short inpatient admission with selected stroke survivors in the South African context has a positive outcome in facilitating upper limb motor function and personal activities of daily living. The

significant improvement in these components found in this study reduced the participants' dependence on caregivers at discharge. Home programmes to facilitate further improvement were recommended for all participants.

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OPERATIONAL DEFINITIONS

Activity: “In the Occupational Functioning Model activities are considered small units of goal directed behaviour that makes up tasks. The Occupational Therapy Practice Framework defines activity as a class of human actions that are goal directed.” (Trombly Latham, 2008, p2)

Activity based neuromuscular electrical stimulation: “Use of neuromuscular electrical stimulation with a repetitive, task-specific practice using functional activities meaningful to the client.” (Page et al., 2009)

Hemiparesis: “Weakness or partial paralysis on one side of the body caused by brain damage.”(Woodson, 2008, p1002)

Neuromuscular electrical stimulation: “The external control of innervated, but paretic or paralytic, muscles by electrical stimulation of the corresponding intact peripheral nerves.” (Huckabee and Doeltgen, 2007,p2)

Outcome: “Determinants of success in reaching the desired end results of the occupational therapy process.” (American Occupational Therapy Association, 2014, p960)

Personal activities of daily living: “Activities or tasks that a person does every day to maintain personal care. Also referred to as basic activities of daily living.” (Fasoli, 2008, p22)

Stroke: “A variety of disorders characterized by the sudden onset of neurological deficits caused by vascular injury to the brain.” (Woodson, 2008, p1002)

LIST OF ABBREVIATIONS

ADL	Activities of daily living
AIDS	Acquired immunodeficiency syndrome
ARAT	Action research arm test
CID	Clinically important difference
CIMT	Constraint induced movement therapy
DTI	Diffusor tensor imaging
FES	Functional electrical stimulation
FMA	Fugl-Meyer assessment
fNIRS	Functional near infrared spectroscopy
GROC	Global rating of change scale
iADL	Instrumental activities of daily living
fMRI	Functional magnetic resonance imagery
HIV	Human Immunodeficiency virus
MBI	Modified Barthel index
MMSE	Mini Mental-State Examination
MOCA	Montreal Cognitive Assessment
MRI	Magnetic resonance imagery
NIHSS	National Institute of Health Stroke Scale
NMES	Neuromuscular electrical stimulation
pADL	Personal activities of daily living
PET	Positron emission tomography

RTP	Repetitive, task-specific practice
TES	Therapeutic electrical stimulation

CHAPTER 1: INTRODUCTION

1.1 Introduction to the study

Stroke is one of the leading causes of death and disability in the world today (Barreca et al., 1999). In South Africa, stroke is the third most common cause of death, with 25 000 deaths attributed to stroke in 2007 (Bertram et al., 2013). Furthermore, between 2000 and 2006, 6.1% of stroke survivors in South Africa were human immunodeficiency virus (HIV) positive, with the majority below the age of 46 (91%) (Tipping et al., 2007). Due to advances in medicine, the aging population and the HIV pandemic, there are more stroke survivors living with disabilities related to stroke. According to the South African Stroke Society, the reasons for the high disability level in South African strokes are unclear, but one of the contributing factors is the inadequate rehabilitation services (Bryer et al., 2010). Mamabolo et al. (2009) observed that South African patients, in both private and governmental settings, are discharged before receiving adequate rehabilitation or reaching full functional independence due to short hospital admissions. The average hospitalisation for stroke survivors in South Africa is between six and 10 days, where they receive between one and seven rehabilitation sessions from therapists (Mamabolo et al., 2009; Parekh and Rhoda, 2013).

It is essential that therapists providing rehabilitation after stroke are aware of and offer interventions that support best practice, to assist the stroke survivors in achieving the maximal return to independence during their short inpatient admission, thus reducing the burden of disability. In areas where outpatient rehabilitation services exist, stroke survivors, particularly those accessing the public sector, cannot access these services due to the costs associated with transport to and from hospitals (Bryer et al., 2010). Limited research has been reported on the effectiveness of therapy in the acute stroke patient population in the first two weeks after stroke, however, researchers have hypothesised that neuroplasticity during this early period post stroke can be augmented and prolonged by the introduction of therapy at this stage (Coleman et al., 2017).

Impaired upper limb function and an inability to perform personal activities of daily living (pADLs) are two of the main deficits with which stroke survivors present (Lai et al., 2002). While the outcomes for these may be predicted by factors such as the severity of the stroke, age, cognition, comorbidities and hand dominance (Feys et al., 2000; Harris and Eng, 2006; Kwakkel and Kollen, 2013; Miltner et al., 1999; Woodson, 2008), there are a variety of adjunctive treatment techniques that the occupational therapist can access to improve motor and functional ability (Pulman and Buckley, 2013). These adjunctive treatment techniques supplement the routine occupational therapy programme, which includes facilitation of upper limb movement, and improvement of pADLs. These techniques include, but are not limited to, mirror therapy, constrained induced movement therapy (CIMT), drugs and injections and neuromuscular electrical stimulation (NMES) (Pulman and Buckley, 2013).

Two major divisions of electric stimulation exist, namely functional electric stimulation (FES) and therapeutic electric stimulation (TES) (Hayward et al., 2010). Therapeutic electric stimulation, of which neuromuscular electric stimulation forms part, is used in occupational therapy during the acute, sub-acute or chronic phases to improve function and promote participation in meaningful activities (Chae et al., 2008). Activity-based NMES is used in upper motor neuron injuries to stimulate the intact lower motor neurons to cause a muscle contraction (Reed, 1997). Moreover, the use of activity-based a repetitive, task-specific practice (RTP) NMES supports motor relearning after stroke by facilitating stroke survivors with upper limb paresis to participate in goal-oriented tasks that are repetitive and functionally relevant using voluntarily controlled movement (Kleim and Jones, 2008; Page et al., 2009). The outcome achieved with this training supports the functional use of the hemiparetic upper limb when the activity-based NMES is removed (Page et al., 2009). There is however some controversy in terms of the outcomes of activity-based NMES with significant, non-significant and transient improvements in basic self-care tasks or upper limb function being reported in the populations under study, relative to controls (Francisco et al., 1998; Lin and Yan, 2011; Rosewilliams et al., 2012).

1.2 Statement of the problem

Rehabilitation services are not easily accessible to stroke survivors who rely on the public service in the Ehlanzeni district of Mpumalanga, where, in a province with a large rural population, all 11 hospitals in the province are based in the larger urban centres (National Department of Health, 2018). Consequently, many stroke survivors need to travel long distances to the hospital using public transport. The cost of transport in communities where poverty and unemployment rates are high, affects the stroke survivors' ability to attend rehabilitation therapy on a regular basis. This is a problem because rehabilitation is key in assisting stroke survivors regaining upper limb function and maximising their potential for the reduction of restrictions to occupational performance in their everyday activities. Inability to attend rehabilitation therapy can thus limit the potential for functional recovery.

In a situation where stroke survivors receive limited rehabilitation, it is important that the effectiveness of different techniques, which are available for use in occupational therapy in this context, be evaluated. Impairment of the hemiparetic upper limb is one of the greatest concerns in the rehabilitation of the stroke survivor. Notably, three months post stroke, only 20% of stroke survivors have regained their previous upper limb function (Hara, 2008). In recent years, the use of NMES as a motor relearning tool has been established, with research findings showing significant improvement in proximal and distal upper limb movement, in combination with repetitive, novel, active movement.

Although NMES is seen as an adjunctive technique, which assists motor relearning that results in improved function and participation in activities (Chae et al., 2008), the effect of an activity-based NMES programme, over a short admission, on both upper limb movement and function in personal ADLs in occupational therapy intervention, within a stroke rehabilitation programme in a regional hospital serving a rural community in South Africa, has not been established. It is not known whether this technique can be used in a context where rehabilitation time is limited, nor whether stroke survivors will respond to the treatment. In addition, the effect of NMES on functional recovery in relation to other

predictors of functional outcomes for stroke including age, cognition and dominance, are also unknown.

1.3 Purpose of the study

The purpose of the study is to determine the outcomes of an activity-based NMES treatment to routine occupational therapy offered in the short inpatient admission period for first incident stroke survivors within a rural regional hospital in South Africa.

1.4 Research question

What is the effect of NMES in an activity-based therapy programme on upper limb impairment and independence in personal ADLs of first incident stroke survivors treated during their short inpatient admission?

1.5 Aim of study

The aim of the study was to investigate the effect of an activity-based NMES programme on upper limb impairment and personal ADLs when added to routine occupational therapy for stroke survivors with acute first incident stroke during their short inpatient admission in a regional hospital in Mpumalanga.

1.6 Objectives of the study

1. To assess the change in upper limb motor function and personal ADLs in stroke survivors who received a RTP NMES activity-based programme.
2. To determine the association between the change in motor function and personal ADLs in stroke survivors who received a NMES activity-based programme.
3. To describe the change in upper limb impairment and personal ADLs in stroke survivors according to demographic and medical factors, which affect the outcome of stroke in a NMES activity-based programme.

1.7 Justification of the study

Occupational therapy practice must be based on evidence to ensure stroke survivors receive good care. This can only be achieved if research is aimed at assessing the available interventions and ensuring these interventions are effective in the persons' context. This study will contribute to the body of knowledge on the range of treatment techniques available to occupational therapists, even those who serve in rural under-resourced areas, where treatment and rehabilitation access is not ideal. It will therefore provide occupational therapists with evidence on the use of another adjunctive technique to facilitate better outcomes for stroke survivors who have inadequate access to rehabilitation. Although NMES is a high technology modality, it is a relatively inexpensive tool that is easily accessible to therapists' in an under-resourced area.

Practitioners in under-resourced areas often have difficulty accessing information on best practice for stroke survivors due to barriers in information access, finances and continuous professional development. The results of the research report will be made available to Occupational therapy practitioners in Mpumalanga province through the provincial forums.

1.8 Layout of Research Report

Chapter 1 - Introduction

The focus of the Introduction of this research report was to make the reader aware of the extent of stroke in South Africa, the challenges faced by stroke survivors accessing rehabilitation services and the impairments stroke survivor's experience. The purpose of the study was to determine whether adding a NMES activity-based programme to standard occupational therapy practice has any benefit for stroke survivors in an acute phase of treatment in a regional South African hospital serving a rural community. The study investigated improvements to the stroke survivors' upper limb function and pADLs, and if there was a correlation between them. The influence of medical and demographic factors was also investigated.

Chapter 2 - Literature review

The literature review focused on the definition and prognosis of a stroke, as well as the factors contributing to a good or poor prognosis. Factors such as dominance, cognition and age were discussed in depth. Stroke within the South African context was discussed, as well as the unique challenges South African stroke survivors face.

The different treatment techniques were discussed with the focus on the adjunct technique of NMES. Neuromuscular electrical stimulation was discussed in depth, including the physiology, benefits and the barriers therapists' experience. Furthermore, the neuroscience and neuroplasticity underlying NMES was discussed.

Chapter 3 - Methodology

The benefits of a case study design within Occupational Therapy were highlighted and discussed in depth. The methodology described the research site, population sample with inclusion and exclusion criteria, the data collection instruments, as well as the research procedure, which included the pilot study, data collection, intervention, data analysis and ethical considerations.

Chapter 4 - Results

The results of this research report were presented in seven main parts. The demographic information of the participants was presented including any relevant medical and demographic information. The FMA was used to determine each participant's motor ability. The overall motor function as well as each subtest of this assessment was presented. Thirdly, the change in the group and each individual participant's personal ADLs are presented with an additional focus on the subtests of the MBI. The correlation of the participant's motor ability and the personal ADLs were highlighted. The influence of the participants' hand dominance, cognition and age on the FMA and MBI are presented.

Chapter 5 - Discussion

The discussion of this research report focuses on each participant, and if NMES could have had a significant impact on their motor ability and participation in personal ADLs. The discussion also focuses on prognostic factors, such as dominance, age, cognition, as well as other demographic factors, such as HIV on stroke outcomes. The limitations of this study are presented at the end of the discussion.

Chapter 6 - Conclusion

The main findings of the study and clinical and research recommendations are summarised**.**

CHAPTER 2: REVIEW OF LITERATURE

2.1 Introduction to the review of literature

The literature review presents the definition of and the prognosis of stroke. A brief explanation of stroke rehabilitation within the South African context and the controversies related to dominance, age and cognition are included, as well as treatment approaches. The best practice, with a focus on NMES for upper limb rehabilitation, is reviewed. The literature for this review was sourced from databases such as EBSCO Host, Science Direct, PubMed, ClinicalKey and the Cochrane Library.

2.2 Stroke: Definition and outcomes

2.2.1 Definition and outcomes

Stroke can be defined as "a variety of disorders characterised by the sudden onset of neurological deficits caused by vascular injury to the brain" (Woodson, 2008, p1002). The two main causes of a stroke are arteriosclerosis or hypertension with the anterior circulation of the brain most commonly affected (Mtui et al., 2015). In like manner, hemiparesis or hemiplegia are the most common sign/symptoms associated with stroke (Woodson, 2008). Additionally, modifiable and non-modifiable risk factors such as smoking, hypertension and a sedentary lifestyle have been associated with stroke and these risk factors are on the increase in South Africa (Bertram et al., 2013).

A dynamical systems theory can be utilised to explain the interaction of different systems on stroke outcome. A dynamical system theory is a "multidisciplinary approach to characterize how constantly changing interdependent systems evolve over time" (Guccione, Neville & George, 2019, p4). The person, task and environment all place constraint upon each other, and movement is achieved when the different systems self-organize within these constraints (Guccione et al., 2019). The emphasis of this theory is not necessarily to achieve optimal performance, but the best performance a person can achieve within the different constraints (Guccione et al., 2019). A variety of factors can

have an influence on recovery and will be discussed further.

Stroke survivors with co-morbidities such as diabetes, heart disease, arthritis and dementia have a poorer outcome (Woodson, 2008). Other factors that contribute to a poor outcome are bowel and urinary incontinence, severe visuospatial deficits and poor social support. Conversely, factors influencing a good functional outcome include good family support and access to services after initial hospitalisation (Woodson, 2008).

Research on stroke outcomes has attempted to identify characteristics that can predict survival rate and the degree of disability, but it appears that a number of factors need to be considered. While it is hypothesised that the type, size and lesion site influences recovery to some extent (Woodson, 2008), other factors should also be considered. Dominance and cognitive ability are factors that influence recovery and will be discussed later in the review.

2.2.1 Physical upper limb deficits

Risk of secondary complications, such as contractures, pain and spasticity, can cause a delay in the recovery of the upper limb and hamper the rehabilitation progress (Bryer et al., 2010; Hara, 2008). Research shows that up to 77% of stroke survivors have weakness of the upper limb and between 55-75% have a poor prognosis for recovery and will not regain their previous function and have difficulty returning to their previous occupational function (Nakayama et al., 1994; Woodson, 2008). Current literature suggests that signs and symptoms of a stroke can be categorised in positive, negative and secondary features. Positive features include new signs and symptoms such as, spasticity and hyperreflexia, both previously thought to be the main activity limitation. Negative features are abilities that are lost due to a stroke; these include a loss of strength and power, dexterity, endurance as well as functional movements. Secondary features are due to functional and physiological changes that occur due to disuse. Contractures, myofascial tension, neural tension and joint stiffness are examples of secondary features (Trombly Latham, 2002). The influence of NMES on the positive, negative and secondary impairments will be discussed later in the literature review.

2.2.2 Cognitive deficits

Stroke location is predictive of poor cognitive function and can increase the risk of cognitive disorders following the incident. The relation of stroke location and cognitive function was found in 428 stroke survivors assessed with magnetic resonance imaging (MRI) in comparison to their Montreal Cognitive Assessment (MOCA) scores in a study by Munsch et al. (2016). Their study confirmed the findings of Kwakkel and Kollen (2013) who found that cognition and initial assessment scores on standardised tests of ADL function (including the National Institutes of Health Stroke Scale (NIHSS) and Barthel Index) associated with the severity of volume of the stroke, were the strongest predictor of outcomes for stroke after three months. Thus it appears that the risk of dementia after stroke increases substantially depending on the size of the lesion (Pendlebury and Rothwell, 2019).

The effects of cognition on stroke outcome have been widely researched, with the influence of pre-morbid cognitive ability showing mixed results. However, it is hypothesised that pre-stroke cognitive reserves can play a role in post-stroke cognitive impairment, just as it can account for differences in the outcome of normal ageing and degenerative disorders (Umarova, 2017). Cognitive reserves refer to the lifetime intellectual activities as well as other environmental factors, such as occupation and leisure activities. Cognitive reserve is assessed using education in years, level of education and vocabulary. Although the influence of cognitive reserve on all stroke impairments has not been well researched, it has been found to influence the outcome of anosognosia or the ability to be aware of a disability (Umarova, 2017).

The influence of cognitive reserves on stroke outcomes in the South African context is not known because good formal education is not always possible. Societal factors, infrastructure and resources (both human and non-human) have a negative influence on access to good formal education in South Africa. Therefore, in the absence of formal schooling, cognitive reserves could be impacted yet remain unconfirmed, necessitating the need for research and assessment tools that are sensitive to the South African context. A study by Meijer et al. (2005) demonstrated this when it could not be

determined if pre-morbid cognitive impairment has an influence on stroke outcomes due to limited significant statistical power.

Cognitive function is also known to deteriorate post stroke, with common conditions such as dementia and post stroke cognitive impairment (Sachdev et al., 2017). Typical cognitive impairments that occur following stroke include deficits in language, perception, attention, memory, reasoning and other higher executive functions (Prigatano and Wong, 1999). These impairments can have an influence on the stroke survivors' response to intervention (Prigatano and Wong, 1999) and ultimately overall outcomes.

Correspondingly, the ability to re-learn a movement following stroke depends on the stroke survivors' cognitive ability (Barreca et al., 1999). While few studies have researched the influence of cognition on upper limb function, cognitive system studies hypothesise that motor paralysis is due to a loss of learning (Krishnan, 2006). A study by Barreca et al. (1999) found that stroke survivors who made less mistakes on the Halstead Cognitive test had better gains in hand and upper limb function, with 81% of the variance attributed to cognitive functioning. Similarly, a study by Goh et al. (2017) found that higher scores on cognitive assessments had an influence on maximum walking speed, due to stroke survivors, in the chronic phase of treatment, prioritising task accuracy and completion over maintaining a consistent walking speed. Likewise, a case study by Paolucci et al. (2019) found that hand grip and recovery of the hemiparetic hand improved with the use of cognitive exercises using the cognitive tool UOVO, which correlates to other studies that use cognitive tools to assist in the recovery of hand grip after stroke.

Cognitive impairments are known to be a barrier on achieving full functional independence. To demonstrate this point, Jaywant et al. (2019) found that mild to moderately impaired stroke survivors who had higher MOCA scores on admission had better functional outcomes on the FIM assessment, although it is not clear which cognitive ability affects ADL. For example, orientation to time, place and person is a basic measure of general intellectual function; however, it has shown mixed results. Literature has shown that orientation has no association with ADL function and quality of life

(Pedersen et al., 1996) but more recent studies have shown that orientation at six months post stroke has a strong association with ADL function and quality of life (De Haan et al., 1993; Hofgren et al., 2007; Pedersen et al., 1996). Apart from the researched factors that influence the prognosis of a survivor following a stroke, other demographic factors are associated with stroke outcomes, which will be elaborated.

Motivation of the patients to be involved in rehabilitation also needs to be considered and occupational therapists have reported they consider patient motivation as a factor affecting the outcome of rehabilitation. There is little research on motivation of patients with stroke receiving rehabilitation literature relying on unsupported models. A study by Maclean et al., (2000) found patients with stroke who have close alignment with the goals of and methods used during occupational therapy have high motivation for rehabilitation. Having comprehensible information about their rehabilitation, see improvement compared to other stroke patients, and the desire to go home determined motivation in their participants. Motivation was decreased by overprotection, lack of information, therapists providing mixed messages about rehabilitation and when a lack of progress compared to other patients was perceived.

2.2.3 Demographic factors related to stroke outcomes

2.2.3.1 Age

Age of stroke survivors has been the subject of many studies. Research has shown that stroke aetiology, prognosis and outcome differ between young and aged stroke survivors. The incidence and risk of stroke is higher in the aged population, with the risk doubling for every decade after the age of 55 years and exacerbated due to other conditions associated with ageing (Boehme et al., 2017; Michael and Shaughnessy, 2006). It is clear that knowledge of stroke in each age group is important to address unique challenges that stroke survivors face.

Risk factors for stroke are more common in certain age brackets. In the elderly, stroke is commonly associated with atherosclerosis (O'Neill et al., 2004) and elevated cholesterol levels (Michael and Shaughnessy, 2006). Hypertension, which can affect both young and

older persons, is recognised as changing vascular function on a physiological level (Michael and Shaughnessy, 2006). Other risk factors include diabetes and smoking in both older and younger persons. The prevalence of type 2 diabetes increases with age and peaks at 75-84 years (Michael and Shaughnessy, 2006). Smoking however is more common in younger persons' than in their older counterparts (Griffiths and Sturm, 2011). In addition, it appears that the type of stroke is more common in certain ages.

Age can influence the type of stroke that people have. Population based studies have found that younger stroke survivors are more likely to suffer a haemorrhagic stroke than older adults (33% and 20% respectively) (O'Neill et al., 2004). Although atherosclerosis remains a risk factor in 15–25% of young adults under 45 years who present with stroke, other causes account for stroke in this population (Griffiths and Sturm, 2011). These can include factors such as migraine, drug use, oral contraceptives, HIV and rheumatic valvular heart disease (Griffiths and Sturm, 2011; Shehatah, 2010). However, it is important to note that the cause of stroke in the younger population is mostly undetermined (20%) (O'Neill et al., 2004). It is clear that age is a well-known risk factor for stroke, and influences recovery.

The age of the stroke survivor can have an impact on their recovery. Older stroke survivors have a higher mortality rate than young stroke survivors (Feigin and Donnan, 2013). Research has shown that mortality due to stroke can be as high as 25% within the first month, 33% within the first year and 50% within the first two years, with an average mortality rate of 5% within the first 10 years. The most common cause for mortality within the first month after stroke are the effects of the brain lesion followed by recurrent stroke (Feigin and Donnan, 2013).

Moreover, numerous studies have found that age is an important prognostic factor for recovery after stroke (Karaahmet et al., 2018). Kwakkel and Kollen (2013) found that age is a valid predictor of functional recovery during rehabilitation and this is corroborated by a prospective study, which found that age is a highly significant inverse predictor of functional outcome after ischemic stroke independent of severity and other complications (Knoflach et al., 2012). Functional recovery is slower in older stroke

survivors and improvement less than that reported in younger stroke survivors (Kugler et al., 2003). Age has an influence on recovery, but the reason for this is still unclear.

Many possible reasons have been hypothesised as to why age has an impact on stroke outcome. Age related decline in cognitive function (Levine et al., 2018), strength (Fong et al., 2001) and other body structures (Scherbakov et al., 2013) could be possible explanations for the differences in young and older stroke survivors. Bettger et al. (2013) found that stroke survivors older than 75 years had a poorer prognosis for upper limb motor ability than stroke survivors between the ages of 66-74 years and 40-65 due to a loss of age-related muscle strength. A study by Sawaki et al. (2003) found that the ability of the motor cortex to reorganise itself in response to training decreases with age and therefore age could have a negative influence in re-learning a motor movement after stroke.

2.2.3.2 Dominance

Function of the dominant hand and bilateral hand function is essential for independence in daily activities. Due to the delicate interaction of hand function, sensation and the demands of the activity, a stroke affecting the dominant limb would be more limiting for the stroke survivor since certain skills such as fine motor speed and accuracy are more developed in the dominant limb, allowing for independence in participation (Harris and Eng, 2006). Evidence on the effect of dominance on the functional outcome of stroke is limited and contradictory. To this effect, Miltner et al. (1999) found that the treatment effects for participants with both dominant and non-dominant upper limb dysfunction was the same during constraint induced moment therapy. Conversely, Harris and Eng (2006) found that a person whose dominant upper limb was affected post stroke had fewer impairments and no deficits in function. For the most part, the hypothesis is that the dominant hand has superior strength and dexterity compared to the non-dominant hand and that this could have a protective effect after stroke (Harris and Eng, 2006).

2.3 Stroke in South Africa

Stroke is one of the leading causes of death and disability in the world today (Barreca et al., 1999). In South Africa stroke is the third most common cause of death, with 25 000 deaths attributed to stroke in 2007 (Bertram et al., 2013). Furthermore, between 2000-2006, 6.1% of stroke survivors in South Africa were HIV positive, with the majority below the age of 46 (91%) (Tipping et al., 2007). Coupled with the change of status of HIV to a chronic illness, the aging population and advances in medicine, there has been an increase in the incidence of stroke survivors who are living longer with the effects of stroke. Equally important are the financial implications, as it is estimated that the cost associated with cardiovascular disease (and stroke) is between 13 and 16 billion Rands annually (Bertram et al., 2013).

Not only does stroke contribute to the mortality rate in South Africa, but also the morbidity. According to the South African Stroke Society, there is a high disability level in South African stroke survivors (Bryer et al., 2010). While the reason for this is unclear, notably one of the contributing factors is inadequate and inaccessible rehabilitation services (Woodson, 2008). Despite the awareness with regards to stroke prevention being identified as a priority, lack of support from government and its employees has resulted in poor implementation of preventative measures (Fritz, 2006). Part of the reasons for this is the government's focus on the HIV/AIDS epidemic. Moreover, only 10-20% of the South African population have access to acute stroke units and rehabilitation services (Fritz, 2006).

Early stroke recognition and knowledge of the available rehabilitation services for stroke survivors amongst those offering first line medical care, is poor. This is of concern, as the current South African Guidelines recommend that patients who have moderate to severe stroke with limited bed-mobility should be treated on an in-patient basis (Bryer et al., 2010). Likewise, stroke survivors in rural areas or those unable to access hospital services should either be offered out-patient rehabilitation, admitted to step-down facilities or have access to community-based rehabilitation services (Bryer et al., 2010).

South African stroke survivors, in both private and governmental settings, are discharged before receiving adequate rehabilitation and reaching full functional independence due to short hospital admissions (Mamabolo et al., 2009). While stroke survivors accessing private care in South Africa are discharged after 30-34 days of hospitalisation, stroke survivors accessing public care are discharged between 6-12 days post incident (Parekh and Rhoda, 2013). Therefore, stroke survivors in the public sector are discharged during the time when spontaneous recovery is still occurring, often with no follow up treatment.

Consequently, these stroke survivors are not returning to their previous roles and activities due to neurological deficits, sedentary lifestyles and the overprotection by family members and carers. It has however been found that stroke survivors who live alone often return to their roles and activities more quickly due to having no one to rely on (Stineman et al., 1997). Nonetheless, in most circumstances, difficulties in accessing healthcare services results in over-dependence after hospitalisation as stroke survivors may be dependent on their family for much needed support and care. As a result, there are decreased opportunities for neuroplasticity to occur.

It is therefore essential that occupational therapists providing after stroke rehabilitation in South Africa are not only aware of the challenges faced in the rehabilitation of stroke survivors in the South African context, but are able to offer intervention that supports best practice. This will assist the stroke survivors in achieving the maximal return to independence, thus reducing the burden of disability as far as possible.

2.4 Treatment modalities in stroke rehabilitation

Various treatment modalities are available for occupational therapists to use to decrease impairment and improve function in stroke survivors. These treatment modalities can be broadly categorised as those that are traditionally used after being described in the mid-20th century, and newer rehabilitation therapies as a result of the neuroplasticity theories (DeJong et al., 2005). The more traditional approaches often have a sensory-motor approach, which hypothesises that a sensory input can produce a typical motor output. Therefore, the traditional approaches are based on the facilitation and inhibition of sensory and motor functions. Examples of these therapies include the work done by

Bobath (1990), Brunnstrom (1966) and Rood (1956), who have also focused on spasticity as the main activity limitation in stroke.

However, recent literature contradicts the traditional approaches as not all of them have current substantial evidence to support their effectiveness (Metcalfe and Lawes, 1998; Naghdi et al., 2010). Although many occupational therapists use the neurodevelopment (NDT) approach, developed by Bobath, in the treatment of the neurologically impaired upper limb, this approach was not found to be superior to other approaches. The NDT approach is said to increase the length of hospitalisation (Langhammer and Stanghelle, 2000) and occupational therapists are advised to use it with care.

Conversely, research into the newer therapies in stroke recovery is supported by the theories of neuroscience and neuroplasticity. This includes the motor relearning approach, which was introduced in the 1980s by Carr and Shepherd (Carr and Sheperd, 1987). The motor relearning approach can be defined as "the re-acquisition of motor skills following central nervous system injury" (Knutson, Jayme, Fu, MJ, Sheffler, LR, Chae, 2015, p3). In short, this approach uses the active practice of context-specific motor tasks and feedback to regain the lost motor functions. Motor relearning is based on the assumption that motor control rehabilitation requires anticipatory actions and meaningful motor tasks practiced within a specific context. The few studies on this approach have indicated that stroke survivors tend to have a shorter hospital stay, better motor function and functional independence when treated using a motor relearning programme (Langhammer and Stanghelle, 2000).

Other techniques, such as robotics-assisted therapy, constrained-induced movement and NMES, are also supported by theories of neuroplasticity; these are used as adjunctive techniques to therapy and may be based on any of the approaches described above (Pulman and Buckley, 2013). There have been positive reports for the effectiveness of both robotics-assisted therapy and constrained-induced movement therapy, although the use of these modalities may be limited to select patients who are suitable (Kwakkel et al., 2008; Taub et al., 2003). Additionally, activity-based neuromuscular electrical stimulation has been found to be effective, and may be used as a motor relearning tool to improve

upper limb function. Ultimately, this enables stroke survivors to participate in repetitive goal-oriented therapy (Lin and Yan, 2011).

2.5 Neuromuscular electrical stimulation (NMES)

There are two major divisions of electric stimulation, namely functional electric stimulation (FES) and therapeutic electric stimulation (TES) (Hayward, Barker and Bauer, 2010). Studies use these terms inter-changeably making it difficult to compare different articles and draw conclusions on the efficacy, patient characteristics or benefits of electrical stimulation. Functional electric stimulation refers to the use of an orthotic that provides an electrical impulse, resulting in movement during activity and this is commonly used in the chronic phase of treatment, where the individual has reached their maximal potential and requires an assistive device to participate in activities (Hayward et al., 2010). Therapeutic electric stimulation, conversely, is used in occupational therapy to improve motor function using tasks that are repetitive, functional and motivating to the stroke survivor (Hayward et al., 2010).

Neuromuscular electrical stimulation and transcutaneous electrical nerve stimulation (TENS) used primarily for pain relief, are examples of TES. Both techniques can be used in the acute, sub-acute or chronic phases of treatment to improve function and promote participation in meaningful activities (Hayward et al., 2010).

Although TES has been around for many years, a few questions remain unanswered. The optimal dose, duration of intervention, device parameters and type of NMES must still be concluded. As of yet there is no evidence that one method of TES is superior over the other (Knutson et al., 2015) since many of the publications are based on non-randomised trials and case studies with many limitations in their study design. The high dropout rate, not using an intention to treat analysis and the experimental group receiving a higher intensity training than the control group all have an impact on the findings of these studies (De Kroon and Van der Lee, 2002). Furthermore, the effects of TES last for up to 1 hour after intervention and could influence results if final measurements are done to soon (Knutson et al., 2015). Therefore, knowledge of the physiology associated with electrical stimulation is important.

2.5.1 Physiology of neuromuscular electrical stimulation

Neuromuscular electrical stimulation causes involuntary contractions of skeletal muscles by applying an electrical current to the skin over the muscles. For this reason, an intact motor nerve is a prerequisite. The speed of these signals, or action potentials, depends on the diameter of the nerve as well as whether the nerve is myelinated (Shapiro, 2009). During electrical stimulation, large nerve fibres are recruited first and contractions are usually rapid and jerky (Shapiro, 2009). Action potentials are generated to a maximum frequency as defined by the nerves refractory period (recovery time). Skeletal muscles have a characteristic motor point, where they are activated easily by the applied electrical current. The motor point is usually located near the proximal part of the muscle belly where the motor nerve enters the muscle (Reed, 1997). There is no perfect placement of the electrodes since it varies from person to person, however two electrodes are required for each NMES circuit. This being said, an electrical impulse from a device remains different from a normal physiological one.

There are various electrical wave forms for use in electrical stimulation. A pulsed wave form works well for the upper limb due to the small muscles found in the hand (Knutson et al., 2015; Reed, 1997). For motor re-education, the rationale for the use of NMES is to supplement the person's volitional contraction while stimulating the targeted muscles; the person would then use the visual and kinaesthetic feedback to relearn a movement. The therapist would usually trigger the stimulation in conjunction with the person's efforts and electrodes would be placed on the agonist muscle. To avoid muscle fatigue, an on/off cycle of 4:12 seconds can be applied (Shapiro, 2009).

Since the person is using both mental and physical effort, sessions should be kept short with a high frequency, for example 10-30 minute session, 1-2 times a day 3-5 times a week (Shapiro, 2009). The recommended parameter settings for muscle re-education are a pulse frequency of 34-50 pulse per second, pulse duration of 150-200 micro seconds for small muscles and 200-350 for large muscles, amplitude sufficient for functional activity, on/off cycle of 4:12 seconds, ramp up time of at least 2 seconds and treatment time will depend on the functional activity (Reed, 1997; Shapiro, 2009). No studies have compared

the different frequencies or duration and the above specifications should be used with care.

2.5.2 Types of neuromuscular electrical stimulation

The characteristics of the electrical stimulation device, stimulation and how the device triggers muscle contraction are specific in each of the different types of NMES that can be used in the treatment of stroke survivors (De Kroon and IJzerman, 2008; Hayward et al., 2010). Universally, the device used during electrical stimulation has the following components: electrodes, stimulator (generates pulse) and controller (regulates timing and intensity) (Knutson et al., 2015).

As technology has advanced, and our understanding of stroke has evolved, electrical stimulation devices have developed. Initially, the electrical stimulation devices were based on the understanding of neurophysiology, such as the cyclic or EMG-triggered NMES device, but these have developed to incorporate elements of the task used, such as switch triggered or positional feedback. No superior device currently exists and a review of the devices will follow.

Cyclic NMES uses a one- or two-channel stimulator to activate muscles in a repetitive way according to a cycle determined by the therapist. In this instance, the stroke survivor does not have to use any voluntary movement, making this a passive form of NMES (Hayward et al., 2010). Conversely, electromyographic (EMG) triggered NMES use the stroke survivor's own muscle contraction to coincide with the stimulation to the muscles. A pre-set stimulation intensity is set and when the EMG signal from the muscle contraction is greater than the pre-set threshold, electrical stimulation to the muscle occurs. After several seconds, the stimulation turns off. The stroke survivor is then encouraged to repeat the movement obtained with the NMES input using visual input, which triggers the EMG NMES cycle again as enough muscle contraction occurs (Francisco et al., 1998).

In both the cyclic NMES and EMG triggered NMES, the intensity and time of stimulation is not controlled by the stroke survivor (Fields, 1987). The passive nature of this type of

NMES means that it is not typically used with activity-based programmes. Consequently, research indicates that these types of NMES have been found to improve motor function in stroke survivors with residual movement (Rosewilliams et al., 2012), however this did not reflect in improvements in personal ADLs (Hendriks et al., 2001).

In contrast, switch-triggered NMES is a technique that supports motor relearning in an activity-based programme by facilitating functional task practice. Although the intensity of stimulation is also pre-set, the switches allow the control of the initiation and termination of the stimulation sequence by either the therapist or the stroke survivor (Rosewilliams et al., 2012). Furthermore, the stimulation of movement is selected to match the task requirements. Significant therapeutic effects have been reported for spasticity, upper limb movement and hand function (Ring and Rosenthal, 2005).

Positional feedback NMES combines feedback of limb position with cyclic NMES by expecting the stroke survivor to achieve a set range of movement before a cycle of NMES starts. This requires greater involvement from the stroke survivor than passive cyclical NMES, facilitating motor learning. Although effective in improving range of motion, the effect on personal ADLs is unknown (Bowman et al., 1979).

Contra-laterally controlled NMES is sensor-controlled stimulation where movement from the unimpaired side controls the timing and intensity of stimulation to the hemiplegic upper limb giving the stroke survivor control of the stimulation. This type of NMES requires no residual movement in the hemiplegic upper limb. Studies indicate improvements in upper limb movement and ADLs (Knutson et al., 2012).

Outcome-triggered NMES is aimed at achieving a set outcome in an activity with the stimulation occurring when the stroke survivor reaches a movement to a pre-set distance in the direction of the activity-based goal. The distance to trigger stimulation increases if the movement is repeatedly successful and reduces if not. Only movements in the direction of the goal achieve stimulation input, retraining more normal patterns of movement (Cruse et al., 1993).

Iterative Learning Control-Mediated NMES also requires reaching but provides feedback on the accuracy and force exerted to alter the amount of stimulation delivered using a

robotic device. This ensures the stroke survivor is working at the upper limit of their ability. This method has shown improved motor function but not improved personal ADL function (Hughes et al., 2009).

2.5.2 Use of neuromuscular electrical stimulation in upper limb after stroke

Neuromuscular electrical stimulation may reduce impairment of the upper limb in stroke by increasing active movement in the limb and has been found to improve joint range of motion (Hayward et al., 2010), muscle strength (Hayward et al., 2010), decrease spasticity (Rosewilliams et al., 2012), improve function (Noma et al., 2014), improve motor control (Bracciano, 2008), reduce pain (Hayward et al., 2010) and improve cortical activation (Gharid et al., 2015). Moreover, studies have shown that stroke survivors with less severe impairments benefit most from NMES. However, despite more and more people surviving strokes and/or having multiple strokes in their lifetime, the impact of TES on more severe hemiparesis/hemiplegia and on recurrent stroke has not been established. Most studies have focused on the chronic phase of treatment, with limited research on the acute phase of treatment (Hayward et al., 2010).

A systematic review by Nascimento et al. (2014) found that electrical stimulation has a mild to moderate effect on activity and these improvements were sustained months after treatment ended. It is not known whether these changes were due to an improvement in strength or due to neuroplastic changes. A limitation of NMES studies that have been completed thus far is that researchers tend to focus on one joint/movement at a time, whereas activities are generally the sum of multiple movements in a wide variety sequence. If an improvement in activity is expected, it needs to be practiced in therapy.

2.5.3 Benefits of neuromuscular electrical stimulation in stroke rehabilitation

2.5.3.1 Muscle strength

Muscle strength can be defined as “a degree of muscle power when movement is resisted as with objects or gravity” (Bass-Haugen, Mathiowetz & Flinn, 2002, p125), or “an ability to generate high levels of torque” (Canning et al., 2004, p98). Clinically, manual muscle testing is used to measure muscle strength. Concentric (shortening of the muscle, causing

the limb to move towards the muscle pull), eccentric (muscle lengthens to ensure a smooth controlled movement) and isometric (length of muscle remains the same) muscle contraction are all muscle contractions that can occur in a muscle.

In addition, preventing a loss of motor units is just as important as increasing muscle strength and electrical stimulation can be used in this regard (Canning et al., 2004). The strength of a muscle will depend on its size as well as neural control. Therefore, a larger muscle will have more filaments available with a resultant increase in strength. Furthermore, an increase in motor units will increase the synchronisation of activation or firing of the motor unit and increasing muscle tension. This is due to the all-or-none principle during neural activation. A study by Canning et al. (2004) found that a 50% decrease in the amount of motor units occurs in the first 6 months after a stroke, thus corroborating the need to explore the effects of NMES in stroke survivors.

Muscle wasting is common with stroke survivors, and could be due to immobilisation, malnutrition or decreased innervation of muscles (Nozoe et al., 2017). Due to habituation, low frequency electrical stimulation might be preferable over high intensity if the goal is to maintain torque production. Currently, there is no consensus on whether or not NMES increases muscle strength and decreases atrophy since studies have shown mixed results, especially in the chronic phase of treatment (Gorgey et al., 2013).

It is important to note that the activation of motor units during NMES differs from normal muscle contraction. During normal muscle contraction, motor units are not recruited simultaneously like what occurs during NMES muscle contraction (Shapiro, 2009).

A recent systematic review by Nascimento et al. (2014) found that electrical stimulation increases strength, however it is not clear whether NMES is superior over other muscle strengthening modalities and the optimal dose of NMES was not established. A recent meta-analysis found that progressive resistance training was superior over NMES (Wist et al., 2016).

2.5.3.2 Spasticity

Post stroke spasticity is common after stroke, affecting between 30 and 80% of stroke survivors (Kuo and Hu, 2018). Spasticity can be a painful condition, which has an impact on the person's ability to participate in meaningful occupations and influences therapy.

Spasticity is only treated if the spasticity interferes with participation in daily tasks or causes complications, such as contractures. Different modalities can be used to treat spasticity, including pharmacological and non-pharmacological interventions. Neuromuscular electrical stimulation is a non-pharmacological intervention that can be used to treat spasticity if necessary. Studies have shown that when NMES is applied to the antagonist muscle, spasticity in the agonist muscle decreases. The hypothesis is that NMES inhibits the interneurons and decreases pain sensation (Kuo and Hu, 2018). However, the recent review of post-stroke spasticity by Kuo and Hu (2018) shows that NMES must only be used as an adjunct to therapy.

Many healthcare facilities in South Africa do not have the means to provide pharmacological intervention to treat spasticity, and NMES could be an affordable, available intervention to assist stroke survivors in a resourced constraint setting.

2.5.3.3 Range of motion and contractures

Stroke survivors who have not regained function in their upper limb are at risk of developing complications, such as contractures, as early as six weeks post stroke (Fletcher-Smith et al., 2016). Usual therapy includes positioning and education to prevent contractures from occurring (Bracciano, 2008). However, some stroke survivors could have difficulty with positioning due to severe spasticity (Bracciano, 2008). For stroke survivors with contractures, a longer ramp-up time could be recommended to not influence the stretch reflex, as well as a longer working time to maintain end-range (Bracciano, 2008). Limited studies are available to justify using NMES to treat the above goals.

2.5.3.4 Sensory function

Limited studies exist of the benefits of NMES in improving sensory function. The hypothesis why motor function improves is due to the sensory-neural feedback that the person receives from the electrical stimulation of a certain movement (Dos Santos et al., 2016). Therefore, it is a logical step to assume that electrical stimulation could improve a person's sensory function. Smith et al. (2009) found an increase in sensory discrimination of the fingers in chronic stroke survivors after repetitive electrical stimulation was applied. Bustamante et al. (2016) found an improvement in proprioception in the wrist but not the shoulder or elbow joint following 10 sessions of NMES of a chronic stroke survivor. It is important to note that this was a single case study and no other studies regarding sensory function and NMES were found.

2.5.3.5 Functional movements

Electrical stimulation can influence the recovery of functional movements in two ways. Firstly, a contraction of the muscle can prevent atrophy and secondly, a sensory component can stimulate neuroplasticity and decrease pain.

The goal of activity-based NMES when facilitating functional movement is to incorporate voluntary muscle contraction and sensory feedback with functional movement. The mechanism floods the central nervous system with sensory information, especially kinaesthetic, that is coupled to an anticipated motor response (Bracciano, 2008). Current stroke guidelines not only recommend that re-education of movements should take place (Fletcher-smith et al., 2016), but also that a variety of functional activities should be used when practicing the desired movement to allow for adequate carryover (Bracciano, 2008). However, some movement needs to be present for re-education to occur. Cyclic NMES could be a possible alternative for stroke survivors who currently have no voluntary movements (Fletcher-smith et al., 2016).

Neuromuscular electrical stimulation can be used to improve paresis early using (RTP). The task must be repetitive, meaningful, volition driven, novel and functionally relevant to the person (Chae et al., 2008).

Studies in activity-based NMES have shown mixed results in improving paresis. Some studies have shown an increase in Fugl-Myer scores that persisted 2-6 months after intervention, while others have shown no change (Knutson et al., 2015; Rosewilliams et al., 2012). Some studies showed improvements in impairments but were not translated to ADL and other activities. Subjects who have some motor movement at baseline have shown better results than those with none (Knutson et al., 2015).

A systematic review by de Kroon et al. (2002) found that NMES has a positive effect on motor control. However, a limitation of the studies was the experimental group would often receive a higher dose of treatment, for example typical treatment with electrical stimulation versus typical treatment alone in the control group. Another barrier to activity-based NMES research is that no true placebo exists. Even with sensory feedback as a placebo, it could have a possible positive effect on motor relearning and is not viewed as a true placebo (De Kroon and Van der Lee, 2002).

2.5.4 Barriers to using neuromuscular electrical stimulation

Therapists have reported some barriers in applying activity-based NMES. A study by Austaetter et al. (2016) in Canada, found that although NMES is part of the clinical guidelines in Canada, most therapists never or rarely use it despite their awareness of its potential benefits Barriers in using NMES included therapists' preference, lack of resources (for example short treatment sessions, short length of hospitalisation, large caseload and time required to set up machines and change parameters), knowledge and training, therapists' perceptions and limited access to devices. Additionally, more than half of the study population of Austaetter et al. (2016) reported they would like to start using activity-based NMES in their practice and that therapists would like hands on training. Notably, there are contra-indications for the use of NMES in certain stroke survivors, which must also be taken into consideration, such as pregnancy and certain cardiac conditions (Brooks et al., 2010).

2.5.5 Facilitators to using neuromuscular electrical stimulation

Facilitators to using activity-based NMES include access to resources, comfort and confidence levels of therapists, high quality evidence for the efficacy of NMES, client characteristics and increased likelihood of adherence and transition to home environment and identifying therapeutic goals (Auchstaetter et al., 2016). Current best practice guidelines in the United States of America and Canada recommend using NMES for upper limb and gait retraining as this has resulted in improvement. However it has not been shown to be superior over other treatment modalities (Auchstaetter et al., 2016).

2.6 Effect of neuromuscular electrical stimulation in relation to neuroplasticity and neuroscience

The field of neurorehabilitation has progressed due to the advances in neuroscience, especially neuro-imaging techniques. Neuroplasticity can be defined as "an adaptive response within the central nervous system" (Kleim and Jones, 2008, pS225), and studies on brain damaged individuals strongly support the use of training in rehabilitation to improve brain reorganisation and functional outcomes. How this can be optimised needs further study, particularly in terms of the window of opportunity within which this can be optimally and safely achieved (Kleim and Jones, 2008).

Numerous studies have determined structural and functional changes in the brain after training in rehabilitation, including after the application of NMES. Research indicates that NMES facilitates the control of movement in the central nervous system by promoting motor relearning (Rushton, 2003). In this regard, it is hypothesised that the residual upper motor neurons are activated in an artificial way and presynaptic and postsynaptic activity is synchronised (Hebbian plasticity), especially if simultaneous voluntary effort occurs in conjunction with the electrical stimulation (Rushton, 2003). Moreover, cortical excitability has been shown to increase more when NMES is paired with voluntary muscle contraction than with NMES alone (Rushton, 2003). This supports the use of ECG triggered NMES and other NMES where the stroke survivor's muscle contraction activates the stimulation.

It has been suggested that as a result of proprioceptive and cutaneous afferent feedback occurring with the attempted movements, the long-term potentials induced in sensorimotor cortex may produce functional cortical reorganization (Fields, 1987; Francisco et al., 1998). This is supported by Hara et al. (2013), who found an increase in activation of the sensorimotor cortex when using NMES and imaging has shown a decrease in short-term cortical activation in the primary sensory area of stroke patients who received 5 minutes of NMES to the fingers and wrist. An increase in cortical activation of the sensory-motor cortex area is indicative of an increase in motor learning in the cortex (Hara et al., 2013). Other studies that have a longer therapeutic period have similar findings (Jang et al., 2014). In chronic stroke survivors, an increase in corticospinal activity in the affected hemisphere compared to the control group was reported (Tarkka et al., 2011).

Structural and functional changes have been found with imaging techniques such as functional magnetic resonance imaging (fMRI), positron emission tomography (PET) and diffusion tensor imaging (DTI), which has contributed to the evidence base of neurorehabilitation (Chen et al., 2010). Limited studies exist on NMES that use imaging techniques due to the interaction between electrical stimulation and the imaging machine. A new imaging technique, functional near infrared spectroscopy (fNIRS), shows promise due to its lower price, portability and decreased sensitivity to electrical stimulation (Chen et al., 2010).

Kleim and Jones (2008) describe 10 principles of neuroplasticity based on research in neuroscience (Kleim and Jones, 2008). These principles include: Use it or lose it; use it and improve it, salience matters, time matters, age matters, repetition matters, intensity matters, salience matters, transference and interference (Kleim and Jones, 2008). Activity -based NMES using RTP as a therapeutic technique allows the person to engage in activity even if their abilities are not yet sufficient (use it or lose it); offers a high intensity (intensity matters); high repetition (repetition matters) and if used in activity that is meaningful to the person (salience matters) will apply multiple neuroplasticity principles.

2.7 Summary

Strokes are a debilitating disease, and the effects are going to increase in the future. Stroke survivors, especially in rural areas, have difficulty accessing healthcare and steps have been taken to minimise this through outpatient services, step-down facilities and community-based rehabilitation. However repetitive, meaningful, volition driven, novel and functionally relevant activities cannot be adequately applied in these settings. It is recommended that stroke survivors in South Africa, who are unable to mobilise in and out of bed and have a moderate to severe stroke should be admitted to in-patient hospital services. However, research has shown that stroke survivors are discharged too soon before rehabilitation can be completed.

Electrical stimulation is a tool that can be used to treat a multitude of impairments including strength, motor relearning, sensation, pain, range of motion and spasticity, and has a mild-to-moderate effect on activities, but NMES is not without controversy. Few studies have researched optimal dosages of NMES with little comparison between different types of devices/stimulation. Furthermore, these studies were not without limitations with higher intensity of training in the experimental group, small sample sizes and a lack of control being reported as limitations. Translated into clinical practice, few therapists use NMES due to time constraints, knowledge and a lack of supervision or mentorship.

CHAPTER 3: METHODOLOGY

3.1 Research Design

A case study design with multiple participants over a short-duration intervention was adopted to complete a quantitative description of the effect of a NMES activity-based programme in patients with first time stroke, during their short inpatient admission in a regional rural hospital in Mpumalanga (Stake, 2000; Yin, 2014). The case study considered the effect this intervention had in terms of motor function of the upper limb as well as participation in personal ADLs, thus addressing more than one source of data. Replication logic used in a multiple case study means the findings of this study may to be relevant to other cases (Ridder, 2017; Yin, 2014). Cases were selected based on the criteria indicated in previous research which make stroke survivors receptive to NMES. The cases were similar in terms of acute first stroke and inpatient treatment and the recovery of some voluntary movement in the affected upper limb.

A case study was chosen to focus on a process of intervention that was not easy to explore in an experimental study in the given context due to the limited number of participants available over the research period who met the inclusion criteria for a NMES therapy programme. Therefore, from a practical point of view, a case study research method was a relevant approach for this occupational therapy programme as it is a research method where single or multiple cases can be investigated within a specific context (Yin, 2014).

Colborn (1995) and Salminen et al. (2006) report that case study research in occupational therapy, offers a clinically relevant research approach for exploring practice outcomes and can assist in validating existing or new methods of intervention, such as the utilisation of NMES. The use of quantitative methods in a case study allows for an evaluation of the impact of intervention, which has not been extensively researched within a defined sample and environment.

The case study research used in this study also made use of multiple research methods, including more than one participant and assessment method (Yin, 2014). In order to fulfil the rigour required for scientific research, a systematic process of data collection was undertaken based on the theoretical proposition of neuroplasticity, which underlies the use of NMES (Salminen et al., 2006).

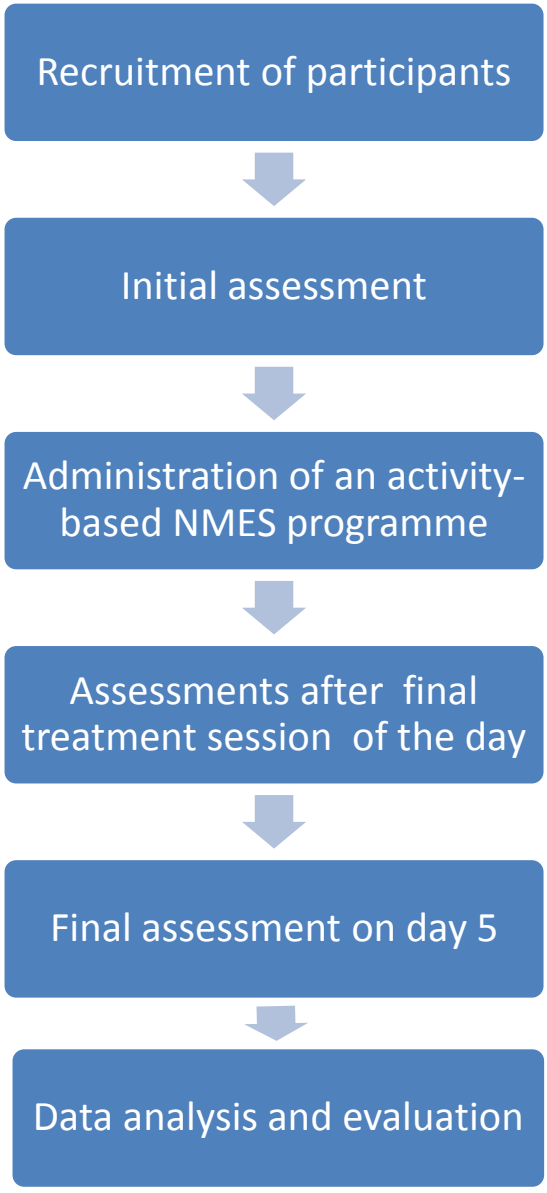


Figure 3.1 Outline of study

As illustrated by Figure 3.1, first incident stroke survivors admitted to Themba Hospital were recruited to determine if they met the inclusion criteria. After informed consent was obtained, the initial assessment of upper limb function and participation in activities of daily living were assessed. Five days of an activity-based NMES programme of 30 minutes twice daily (total daily treatment time of 1 hour) were administered. At the end of each day, upper limb function and activities of daily living were assessed. A final assessment was performed at the end of the five-day period. Data was analysed after all the participants completed the activity-based NMES programme.

3.2 Research Site

The study was conducted at Themba Hospital, one of the two regional hospitals in the Ehlanzeni district of Mpumalanga, which borders Mozambique in the east and Swaziland in the south. Themba Hospital has 14 wards, an ICU and 385 available beds. At Themba Hospital, stroke survivors are admitted to the medical ward and are discharged once medically stable. Approximately three to five stroke survivors are admitted to the ward on a monthly basis and the average length of stay is six days. Stroke survivors are then required to attend as outpatients at Themba Hospital occupational therapy department, one of the community health centres or clinics for further care.

3.3 Population and sample

Replication logic was used to sample acute stroke cases who according to literature would be receptive to NMES. The cases were sampled from stroke survivors who were referred for occupational therapy, both female and male participants between the ages of 18 and 70 years. Cases were limited to first stroke episodes in the acute phase. Purposive sampling was used to select stroke survivors who remained in hospital for at least five consecutive week days after they were medically stable. These stroke survivors fell into the participant selection described in case study research, as they met the inclusion criteria listed below (Table 3.1), which meant a NMES programme could be used with them.

Table 3.1 Inclusion and exclusion criteria

Inclusion	Exclusion
· 1-10 days after stroke and medically stable · No contractures · Participants must score 7 and above on the Mini Mental-State Exam · Paresis of the affected upper limb · Some voluntary movement of the affected upper limb reflected as more than 0 on the Fugl-Meyer assessment (FMA)	· Significant language impairment or aphasia · No contraindication for NMES: o Unstable cardiac conditions o Implanted pacemaker o Acute danger of haemorrhage o Acute danger of thromboembolism o Pregnancy o No diseased skin o Impaired sensation o Prosthetic joint motion restriction o History of epilepsy

3.3.1 Sample size

Over the six-month period of data collection, only three stroke survivors met the criteria for the NMES programme in terms of response to electrical stimulation as well as voluntary movement of the affected upper limb and cognitive function in addition to the other inclusion criteria. The suggested number of participants for multiple case studies should fall between two and four participants (Yin, 2014).

3.4 Data collection instruments

3.4.1 Demographic information sheets

The demographic information sheet (Appendix A) was used to capture the participants' details, such as age, gender, dominant arm, date of incident, date of admission, date of

initiation of therapy, co-morbid features and type of stroke (haemorrhagic vs. ischemic). Due to the lack of resources at the hospital, an in-depth medical assessment of the lesion size and area was not possible.

3.4.2 Fugl-Meyer Assessment (FMA)

The Fugl-Meyer assessment (Appendix B), which evaluates motor recovery post stroke in participants, is the most comprehensive quantitative measure of motor impairment post-stroke (Gladstone et al., 2002). The upper limb assessment consists of 68 points for the motor domain where participants are given a score from 0-2. A score of (0) indicates no movement noted, (1) indicates that the movement is poor and (2) indicates a full range of movement has been achieved (Gladstone et al., 2002). The time needed to administer the test is between 5-30 minutes. A change in the score of 4.25 to 7.25 is seen as a clinically important difference (CID) (Page et al., 2012). A Global Rating Scale of Change (GROC) for the FMA indicates a change of > 50% is excellent, a change of 30% -50% is marked, 30% -10% is moderate and < 10% is slight (Page et al., 2012).

The FMA is reported to be a valid and reliable instrument and shows excellent inter rater (r = 0.79-0.99) and intra rater reliability (r = 0.89-0.99) (Toluee Achacheluee et al., 2016; Trombly Latham, 2002). The FMA for upper limb had good test-retest reliability and convergent validity to the Action Research Arm Test (ARAT) and the Box and Block Test (r=0.92) (Platz et al., 2005). Rabadi & Rabadi (2006) found the upper limb FMA showed sensitivity to change in upper limb motor function during acute phase of inpatient rehabilitation with a responsively to change score of 74 (p<0,001). The FMA therefore has been recommended for use in research due to its sensitivity for evaluating changes in motor impairment following stroke (Velozo and Woodbury, 2011).

3.4.3 Modified Barthel Index (MBI)

The Modified Barthel Index (Appendix C) is a self-report or direct observation assessment with a five-point scoring system, which replaced the original two-, three- or four-point rating system of the original Barthel Index. This addressed the floor and ceiling effects in the original Barthel Index and its lack of ability to classify correctly those who only

needed some form of assistance. The MBI is more sensitive to small improvements in functional independence (Shah et al., 1989). This assessment evaluates the level of performance and the degree of independence in 10 basic personal ADL activities such as feeding, bathing, grooming, toileting as well as bowel and bladder control, transfers, walking, and climbing stairs. The MBI five-point scoring system shows the level of ability in self-care and their clinical status. Items are scored from 0-15, 0-10 and 0-5, with a score of 99 indicating slight dependence, a score below 90 indicating moderate dependence, a score below 60 indicating severe dependence and a score below 20 indicating total dependence. The MBI takes 5-10 minutes if the person self-reports or 20-60 minutes for direct observation (Shah et al., 1989).

The MBI scored 0.7 on the Spearman Rho test for validity and had excellent reliability (inter-rater reliability r = 0.99, test-retest reliability Kappa = 0.98) (Fasoli, 2008), and a Cronbach's coefficient alpha of internal consistency of $\alpha = 0.90$ (Shah et al., 1989).

A change in score of more than 1.85 is deemed as important and beyond measurement error for acute stroke (Hsieh et al., 2007). The assessment has been widely used internationally with stroke survivors and has been translated into 38 languages, and the Chinese version MBI-C suggests cross-cultural stability for stroke survivors (Leung et al., 2007).

3.4.4 Mini Mental State Exam (MMSE)

The Mini Mental State Examination (MMSE) (Appendix D) is widely used as a screening test for cognitive impairment and is used for exclusion of participants in clinical trials. The test covers a number of cognitive abilities, including orientation, short and long term memory, registration, recall, constructional ability, language and the ability to understand and follow commands (Folstein et al., 1975; Trzepacz et al., 2015) .

The MMSE was used to determine whether the participants were able to provide informed consent, ensure the participants were able to follow instructions as well as provide feedback whether the NMES was painful. The MMSE is widely used in clinical and research settings. The tool is a 30-point questionnaire that takes between 5-10 minutes to administer. A score of 21-25 indicates mild cognitive impairment, a score of 10-20

indicates moderate cognitive impairment and a score of below 10 indicates severe cognitive impairment.

The MMSE shows good test-retest reliability (0.80-0.95) (Baek et al., 2016). The MMSE correlates well with other cognitive screeners and shows good transfer validity to the Montreal Cognitive assessment (MOCA) (Trzepacz et al., 2015).

3.5 Research Procedure

Once ethical clearance and permission to do the study had been received, a pilot study was conducted on two stroke survivors to identify problematic questions in the demographic information sheet, assessments and instructions to participants. The tasks chosen and NMES settings were also assessed on a stroke survivor with acute stroke. Following the pilot study, suitable participants were recruited into the study once medically stable and referred by the medical team. Once recruited, an initial assessment session was scheduled in which each participant was required to sign informed consent for participation in the study. Where required, a research assistant, who was an occupational therapy technician, fluent in English and SiSwati, was available to assist in obtaining informed consent when the stroke survivors identified as suitable for the study were recruited. The researcher was present during informed consent. The researcher discussed each paragraph of the information document which the research assistant translated from English to SiSwati. After the paragraph was explained and translated the participant's needed to verbally indicate their understanding.

The primary researcher was responsible for the completion of the data collection instruments as well as the intervention. Blinding of the researcher was not possible but due to the interrater reliability of the instruments, this was not regarded as a barrier.

3.5.1 Data Collection

Once a participant had been recruited into the study, a pre-intervention assessment was completed after the participant signed informed consent. Participants were treated using the participant's performance on the assessment tools. Participants received activity-based NMES adjunct intervention twice a day for 30 minutes, each totalling one hour. The

first 30-minute session focused on retraining movements of the shoulder and elbow and the second 30-minute session of the day focused on retraining movements of the wrist and hand. The researcher was responsible for the intervention, which was done in the ward due to a lack of support staff (porters) and resources. Participants were assessed after the final 30-minute session of the day by the researcher. Intervention was repeated for five consecutive working days, as per the activity bank and assessment tools. Routine occupational therapy was carried out for a 45-minute session daily, which included stroke education, the facilitation of movement and mobility as well as independence in ADLs (Bryer et al., 2010), according to each participant's needs and limitations.

Data measurements were done at baseline (before intervention) and at the final treatment session of the day. After every session (baseline and treatment), the researcher collected and recorded results manually as per standardised instructions of the Fugl-Myer assessment (FMA) and Modified Barthel Index assessment (MBI). Participants were informed of their progress on the FMA and MBI after each session.

3.5.2 Neuromuscular electric stimulation Intervention

3.5.2.1 The instrument and parameters used

The instrument that was used during NMES intervention was the NeuroTrac®, which is a dual channel nerve stimulator. The NeuroTrac® provides cyclic NMES to the muscles. The device was chosen due to availability to the researcher. The instrument has 17 pre-set programmes and 3 custom programmes. The electrode size differed depending on which muscle was stimulated, but included 50x100mm, 40x40mm and 30 diameter electrodes. The electrodes used were self-adhesive electrodes that were discarded if there was significant wear and tear. Participant's interventions were designed according to their performance on the FMA.

The parameters of the NMES device used during the treatment programme are described in Table 3.2.

Table 3.2: Parameters of NMES device

Parameter	**Unit**
Frequency	80Hz
Pulse width	200
Duration	250us
Ramp up time	1 second
Ramp down time	1 second
Duty cycle	6 seconds on/6 seconds off

3.5.2.2 Placement of electrodes

- For Scapular retraction, 40x40 mm electrodes were used. The negative electrode was placed below the scapula. The positive electrode was placed on the lower portion of the serratus anterior muscle.
- For shoulder flexion the large 50x100mm were used. For shoulder flexion, the negative electrode was placed on the anterior deltoid and the positive electrode placed over the middle deltoid.
- For shoulder abduction, the large 50x100mm electrodes were used; the negative electrode placed on the middle deltoid and the positive electrode on the anterior deltoid.
- For elbow flexion, the 40x40 mm electrodes were used. The negative electrode was placed over the muscle belly of the biceps brachii muscle and the positive electrode was placed close to the crease of the elbow on the anterior surface of the upper arm.
- For elbow extension, 40x40mm electrodes were used. The negative electrode was placed on the middle of the triceps brachii muscle and the positive electrode more distal to the elbow joint.

- For supination, a 30mm diameter electrode was used for the negative electrode and the 40x40mm electrode was used as the positive. The negative electrode was placed proximal to the lateral epicondyle of the forearm and the positive electrode was placed over the flexor surface of the forearm.
- For pronation, a 30mm diameter electrode was used for the negative electrode and the 40x40mm electrode was used as the positive. The negative electrode was placed between the middle and the medial epicondyle proximally on the forearm and the positive electrode on the radial border.
- For wrist extension, 40x40mm and 30mm diameter electrodes were used. The negative electrode (30mm diameter) was placed distally to the lateral condyle and the positive electrode (40x40) was placed on the tendinous part of the forearm. Exact placement differed in each participant to ensure good radio-ulnar balance.
- For finger extension, medium 40x40mm and 30mm diameter electrodes were used. The negative electrode (30mm diameter) was placed similarly to wrist extension but brought down closer to the arm distally to the lateral condyle, and the positive electrode (40x40mm) was placed on the same position over the extensor tendons of the forearm as with the wrist extension.
- For wrist flexion, 40x40mm and 30mm diameter electrodes were used. The negative electrode (30mm diameter) was placed close to the medial condyle and the positive electrode (40x40mm) was placed over the anterior surface of the arm where the flexor tendons of the wrist and hand are located.
- For finger flexion, 40x40mm electrodes were used. The negative electrode was placed distally on the forearm compared to the wrist flexion, where the finger flexors exit under the wrist flexors and the positive electrode was placed on the flexor tendinous surface of the forearm.
- For thumb extension, a 30 mm diameter electrode was used as the negative electrode and the 40x40mm electrode were used as the positive electrode. The negative electrode was placed two thirds down the forearm on the extensor surface and the positive electrode was placed over the extensor tendons.

- For thumb opposition a 30mm diameter electrode was used for the negative electrode and the 40x40mm electrode was used as the positive. The negative electrode was placed on the lateral border of the metacarpal bone of the thumb and the positive electrode was placed over the extensor surface of the forearm.
- For thumb abduction, a 30mm diameter electrode was used for the negative electrode and the 40x40mm electrode for the positive. The negative electrode was placed on the proximal thenar eminence and the positive electrode was placed over the extensor surface of the forearm.

3.5.2.3 Programme for Participant 001

If the activities did not provide an adequate amount of repetition necessary for neuroplasticity to take place, the movement was practiced first but always ended with activity that was important to the participant. Participant 001 was retired and not expected to perform any home management activities so, activities during the programme focused on personal activities of daily living (Table 3.3).

Table 3.3: Programme for Participant 001

Muscles targeted	**FMA Score (Initial - final)**	**Amplitude**	**Activities used**
Scapular retraction	0-2	11.0mA	Forward wiping of counter tops; reaching for various objects, e.g. cup for drinking, soap for washing
Shoulder flexion	0-2	10.5mA	Putting on a shirt, towelling off upper limb
Shoulder	0-2	14.0mA	Horizontal wiping of

abduction			countertops
Elbow flexion	1.1	8.0mA	Eating, drinking, putting cream on unaffected upper limb
Elbow extension	1.1	7.5mA	Dressing of upper limb, cleaning bedside table
Wrist extension	0-1	11.0mA	Transfers (lying to sitting, sitting to standing), stabilising, various grasp activities using a grasp board
Finger extension	0-2	12.5mA	Release during various activities, e.g. grasp board, releasing cup or spoon during eating, drinking activities
Wrist flexion	1-2	8.0mA	Dressing and undressing of upper body
Fingerflexion	0-2	10.5mA	Grasps in various activities, e.g. using a grasp board, fasteners, holding cup or spoon during eating and drinking activities
Thumb extension	N/A	10.5mA	Lifting finger when typing on cell phone
Thumb opposition	0-2	8.0mA	Various grasps using grasp board, grooming tasks (e.g. holding tweezers)
Thumb abduction	N/A	7.0mA	Holding a cup

Supination	0-0	10.0mA	Turning a key
Pronation	0-0	8.0mA	Turning a key, pouring water

3.5.2.4 Programme for Participant 002

Where the activities did not provide an adequate amount of repetition necessary for neuroplasticity to occur, the movement was practiced first but always ended with activity that was important for the participant. Participant 002 was a stay at home mother and activities included in her programme focused on pADLs and home management. The amplitude and activities used to treat each muscle is described in Table 3.4.

Table 3.4: Programme for Participant 002

Muscles targeted	**FMA Score (Initial - final)**	**Amplitude**	**Activities used**
Scapular retraction	1-2	11.0mA	Forward wiping of counter tops; reaching for various objects, e.g. cup for drinking, soap for washing
Shoulder flexion	0-0	10.5mA	Putting on a shirt, towelling off upper limb
Shoulder abduction	0-0	13.0mA	Horizontal wiping of countertops, playing table tennis
Elbow flexion	0-2	8.0mA	Eating, drinking, putting cream on unaffected upper limb
Elbow extension	1-2	7.0mA	Dressing of upper limb, cleaning bedside table

Wrist extension	0-1	11.0mA	Transfers (lying to sitting, sitting to standing), stabilising, various grasp activities using a grasp board
Finger extension	0-0	13.0mA	Rubbing cream on hands, release during various activities, e.g. grasp board, releasing cup or spoon during eating, drinking activities
Wrist flexion	0-1	8.0mA	Dressing and undressing of upper body
Finger flexion	0-2	12.5mA	Grasps in various activities, e.g. using a grasp board, fasteners, holding cup or spoon during eating and drinking activities
Thumb extension	N/A	11.0mA	Lifting finger when typing on cell phone
Thumb opposition	0-1	8.0mA	Various grasps using grasp board, grooming tasks e.g. holding tweezers)
Thumb abduction	N/A	60.5mA	Holding a cup
Supination	0-0	10.0mA	Turning a key
Pronation	0-0	7.5mA	Turning a key, pouring water

3.5.2.5 Programme for Participant 003

Where the activities did not provide an adequate amount of repetition necessary for neuroplasticity, the movement was always practiced first but the session always ended with activity that was important for the participant. Participant 003 had an electrical business with his sons and these activities were included in the programme (Table 3.5).

Table 3.5: Programme for Participant 003

Muscles targeted	**FMA Score (Initial - final)**	**Amplitude**	**Activities used**
Scapular retraction	0-0	12.5mA	Forward wiping of counter tops; reaching for various objects, e.g. cup for drinking, soap for washing
Shoulder flexion	0-0	10.5mA	Putting on a shirt, towelling off upper limb, various reaching during activities
Shoulder abduction	0-0	13.0mA	Horizontal wiping of countertops, playing table tennis
Elbow flexion	0-1	8.0mA	Eating, drinking
Elbow extension	0-0	7.5mA	Dressing of upper limb, cleaning bedside table
Wrist extension	0-2	12.5mA	Transfers (lying to sitting, sitting to standing), stabilising, various grasp activities using a grasp board, rubbing cream on hands, using various tools associated

			with job as electrician
Finger extension	0-0	12.5mA	Release during various activities e.g. grasp board, releasing cup or spoon during eating, drinking activities
Wrist flexion	0-1	8.0mA	Dressing and undressing of upper body
Finger flexion	2-2	11.0mA	Grasps in various activities, e.g. using a grasp board, fasteners, holding tools necessary for his work as an electrician
Thumb extension	N/A	11.0mA	Lifting finger when typing on cell phone
Thumb opposition	1-1	11.0mA	Various grasps using grasp board, manipulating tools associated with his work as an electrician, bolt and nut board
Thumb abduction	N/A	7.0mA	Holding a cup
Supination	0-0	10.0mA	Manipulating a hammer with support from therapist
Pronation	0-0	7.5mA	Manipulating hammer with support from therapist, pouring water in container

3.6 Data analysis

The primary researcher was responsible for the completion of the data collection instruments as well as the intervention. Therefore, blinding the researcher was not possible, but due to the interrater reliability of the instruments, this was not considered a barrier.

The total scores as well as the subtest scores of each instrument were calculated and scores across time points were compared. Microsoft Excel and SigmaStat for Windows were used for all statistical analysis. The treating therapist collected data manually according to the instructions of the tests. The results of the FMA and MBI were separated in each subtest as well as total scores. A Friedman repeated-measure analysis of variance on ranks was used to compare changes across time points in all the assessments over the five treatment sessions for each participant as well as for the participants as a group. This test was selected since the data would not meet parametric assumptions because of the limited sample size; chi square (X^2) and *p* values were generated for each comparison. Significance was set at 0.05.

The change in the FMA scores and the BMI scores were correlated using Spearman's' non-parametric correlation coefficient to determine the association between the changes in the scores over the intervention period of five sessions.

Due to the small number of participants, a descriptive visual analysis of the change in FMA and MBI scores according to dominance, age and cognition, which are known to affect the outcomes of stroke, was completed.

3.7. Rigor of the Study

According to Yin (2014), in case studies construct validity by triangulating of multiple sources of evidence, construct validity, internal validity and external validity as well as reliability should be ensured in the development, data collection and analysis stages of the research. The rigor of a study relates to the quality and confidence in the methods used and how the data is interpreted in the data, interpretation and methodology used. In this section, the various measures used to ensure a reliable and valid quantitative

multiple case study will be described. Firstly, the control of variables will be discussed, which influenced the study's reliability, followed by a discussion on validity.

3.7.1 Validity

3.7.1.1 Construct validity

In this study, multiple sources of evidence were used including the patients' medical history and assessments of motor function and occupational performance over a five day period, This data which were objective measures were triangulated of data. All the standardised questionnaires used have good reported validity and reliability when used with patients with stroke and have been shown to be responsive to change in stroke survivors. The assessments were used by the researcher only in the study and assess variables directly related to recovery in stroke

3.7.1.2. External validity

This refers the generalisability of the findings to a specific population or context (Yin, 2014). The replication logic used in this study addressed external validity and findings can thus be generalised to stroke survivors

- 1-10 days after stroke and medically stable
- No contractures
- Participants must score 7 and above on the Mini Mental-State Exam
- Paresis of the affected upper limb
- Some voluntary movement of the affected upper limb reflected as more than 0 on the Fugl-Meyer assessment (FMA)

Record keeping ensured all specific procedures were carried out all data were collected and stored securely.

3.7.1.3 Internal validity

The assumed causal relationship between the NMES and the changes in motor function and occupational performance in personal management was assumed in the study. This

was supported by the findings with interfering variables in terms of age, gender and side of stroke evaluated. The effects of spontaneous recovery were acknowledged. This validity may have been impacted by the non-blinding of the researcher who completed the assessments and the therapy.

3.5.2. Reliability

Detailed information on the structuring of each participants programme, setting used for NMES and research procedures was reported so that these could be replicated. Control variables included admiration of standardised assessments by the researcher according to the manual instructions. The researcher who also conducted all NMES sessions and the application of the same intensity of treatment for each participant over the same time period was adhered to.

3.8 Ethical Considerations

Ethical clearance was obtained before the commencement of the study from the Human Research Ethics Committee at the University of the Witwatersrand (M160948) (Appendix E) and permission to carry out the study was obtained from the Mpumalanga Health Department, CEO of Themba Hospital, the medical manager at Themba Hospital as well as the head of the occupational therapy department (Appendix F). Participants were provided with an information sheet, which was explained to them in a language of their choosing (English and/or SiSwati) with the assistance of an occupational therapy technician who spoke both languages (Appendix G). Signed informed consent was obtained, individually and independently from the participants, and for those who could not write a thumbprint for consent was witnessed (Appendix H) (Van Niekerk, 2011). Participants were informed about the aims of the study, the method of intervention and data collection. Participants could refuse to be a part of the study and could withdraw at any time without consequence. Participants were informed that if they did not wish to participate or withdraw, this would not have an impact on the therapy they receive. During the study all information, with regard to tasks/activities, stimulation etc. was communicated to the participant in a clear and understandable manner. The researcher

was available to answer any questions the participants might have had. All information was treated as confidential (including demographic information and results of assessments). No names appeared on the data collection sheets – only codes. Documents with identifying information were and are being stored in a secured locked place for six years after the research study according to HPCSA guidelines (*Guidelines for good practice in the health care professions*, 2016). The above measures were put in place to ensure the ethical principle respect for persons were met (Van Niekerk, 2011).

Participants were provided with the results of the FMA and MBI after each treatment session and the conclusion of the study were provided on request. Participants who were illiterate a diagram was used to explain their progress. No participants requested feedback on the conclusion of the study.

NMES intervention has few side-effects and participants were treated on an in-patient basis, thus minimising costs to the participants and ensuring the ethical principle beneficence to the participants of the study (Van Niekerk, 2011).

CHAPTER 4: RESULTS

4.1 Introduction

This case-study design was based on the recruitment of first incident stroke survivors accessing in-patient care at a public institution. All participants consented to the study and received five treatment sessions. One pre-treatment assessment and five post treatment assessments were completed making six assessments per participant in total.

The results are presented in three parts. Firstly, the demographic information of each participant is presented, secondly the results of activity-based NMES on motor function and participation in personal ADLs are considered. Lastly, the results on the effect of activity-based NMES on dominance, age and cognition are presented.

4.2 Demographic information

During the study period, three stroke survivors met the inclusion criteria for the study. The participant's ages ranged from 33 to 68 years, with one female and two males. Participants were admitted to hospital due to symptoms associated with stroke and hypertension. The aetiology of the stroke is unknown due to a lack of imaging studies. Table 4.1 below provides a summary of the information from the demographic information sheet.

Table 4.1 Summary of demographic information findings

Participant	Age	Gender	Dominance	Affected side	Co-morbid features	Other factors	Days post incident	MMSE
001	68	Male	Right	Right	Hyperten-sion	Below knee amputation	5 days	15
002	33	Female	Left	Right	HIV	Bowel and bladder incontinence	1 day	14
003	58	Male	Right	Right	Hyperten-sion	Secondary complication	9 days	8

Participant 001 suffered a stroke affecting the right side of the body and he was right hand dominant. He had hypertension as a co-morbidity and was complaint with therapy; he had a previous below knee amputation. Participant 001 was admitted to hospital on the day of the incident, and intervention was started five days post incident. The participant scored 15 on the MMSE, which indicated that he had a moderate cognitive impairment, required as part of the inclusion criteria.

Participant 002, the only female in the study, suffered a stroke affecting the right side of the body and was left hand dominant. She was HIV positive, and compliant to treatment before admission; she initially experienced a loss of bowel and bladder control due to the stroke. Participant 002 was admitted the day of the incident and intervention was started one-day post hospital admission. Participant 002 scored 14 on the MMSE, which indicated she had a moderate cognitive impairment but met the inclusion criteria.

Participant 003 suffered a stroke affecting their right side and was right hand dominant. Participant 003 was diagnosed with hypertension on admission to hospital and hypertensive treatment was initiated. Participant 003 was admitted to hospital nine days post incident due to transport problems and was recruited on the day of hospitalisation. He had hypertension as a co-morbidity. His score on the MMSE was lower than 10, which

indicates a severe cognitive impairment but is still above the 7 points required as part of the inclusion criteria. The more severe effects of the stroke resulted in secondary complications such as pain and joint stiffness before the intervention was performed.

4.3 Motor ability - Fugl-Meyer assessment

4.3.1 Overall Fugl-Meyer assessment score

The scores for each participant were analysed over the six assessment periods for the Fugl-Myer assessment overall score. A Chi-squared test was used to show if the change in scores exceeded the amount that was greater than would be expected by chance, and therefore shows a statistically significant difference.

Participant 001 had an initial pre-test score of nine, and at the end of the five-day period an overall score of 41. A 32-point (48%) change in the score shows a statistically significant change (p=0.0001) and a clinically important change of more than 6 points in the participants overall function (Table 4.2).

Table 4.2 Fugl-Myer assessment overall scores for each participant

	Fugl-Myer assessment overall score			
	Initial to final assessment	**Change**	**Chi-squared**	**p value**
Participant 001	9-41	32	42.25:df5	0.000
Participant 002	5-28	23	38.19:df5	0.000
Participant 003	6-15	9	8.99:df5	0.156

Participant 002 had an initial pre-test score of five, and at the end of the five-day period an overall score of 28. A 23-point (35%) difference in the score shows a statistically significant change (p=0.0001) and a clinically important change of more than six points in the participant's overall function (Table 4.2).

Participant 003 had an initial pre-test score of six, and at the end of the five-day period an overall score of 15. A nine-point (14%) change in the score shows no statistically significant change (p=0.156), but a clinically important change of more than six points in the participant's overall function (Table 4.2).

Figure 4.1 indicates there was no change from pre-test to session 1 and while participant 001 improved consistently over the five sessions, both participants 002 and 003 only showed improvement at session 3 and then continued to improve over the next two sessions.

When the scores of the group of participants were considered together, repeated-measurement analysis revealed a statistically significant effect was observed over time for the overall score of the Fugl-Myer assessment. A Friedman's ANOVA was performed and the difference in the values at each time point was greater than what would be expected by chance (p=0.018), indicating that the NMES training had a positive effect on overall performance over five treatment sessions.

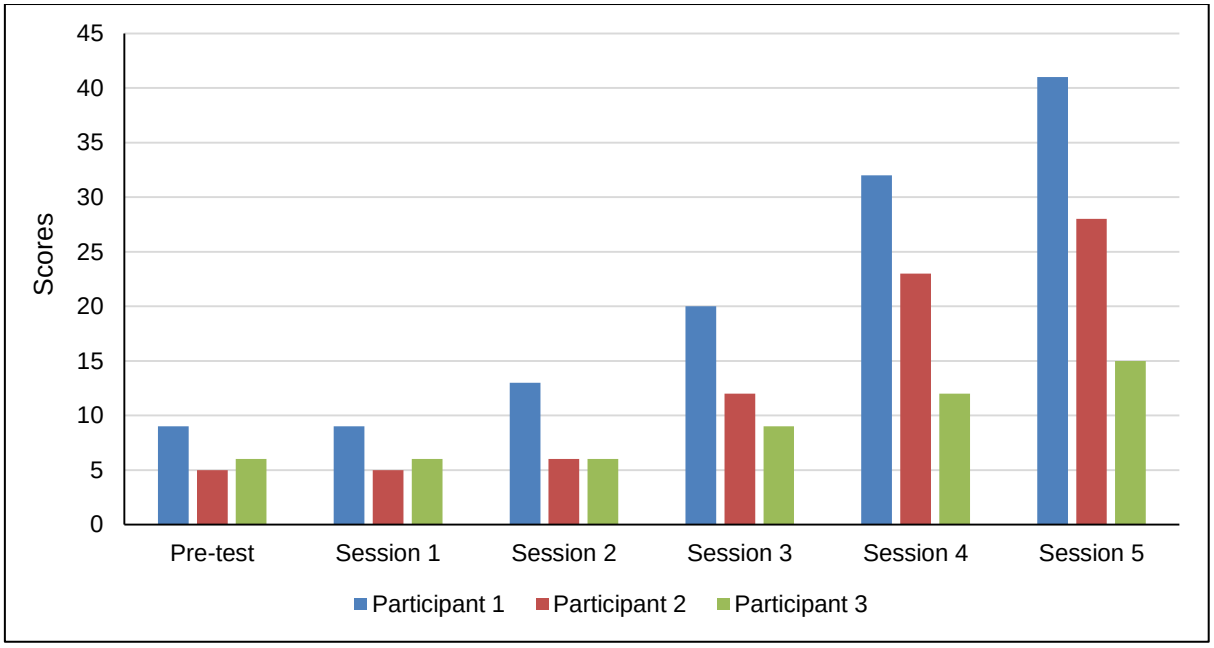


Figure 4.1 Fugl-Myer assessment overall score for each participant

Figure 4.2 confirms the greater improvement after session 3 for the overall score across five treatment sessions for the group of participants.

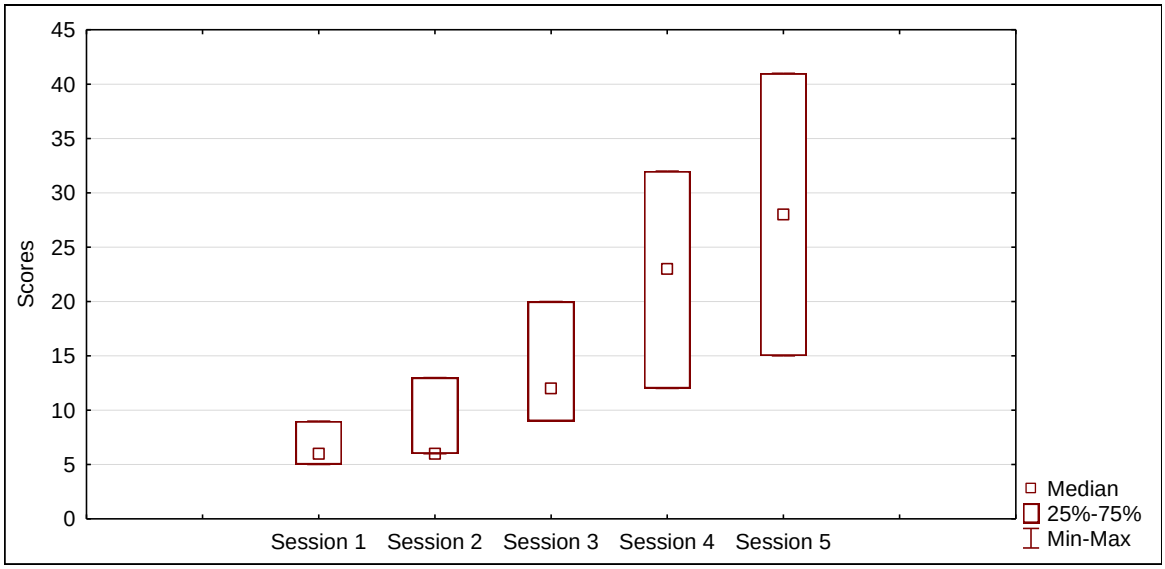


Figure 4.2 Fugl-Myer assessment overall scores between the sessions for the group of participants

4.3.2 Upper limb subtest

The scores for each participant were analysed over the six assessment periods for the FMA upper limb score. A Chi-squared test was used to show if the change in scores exceeded the amount that was greater than would be expected by chance, and therefore shows a statistically significant difference.

Table 4.3 Fugl-Myer assessment upper limb subtest for each participant

	Fugl-Myer upper limb subtest			
	Initial to final assessment	**Change**	**Chi squared**	**p value**
Participant 001	8-25	17	14.84:df5	0.010
Participant 002	5-20	15	20.93:df5	0.000
Participant 003	2-3	1	0.60:df5	0.988

Participant 001 had an initial pre-test score of eight, and at the end of the five-day period a score of 25. A 17-point (47%) change in the score shows a statistically significant change (p=0.010) and a clinically important change of more than six points in the participant's upper limb function (Table 4.3).

Participant 002 had an initial pre-test score of five, and at the end of the five-day period a score of 20. A 15-point (42%) change in the score shows a statistically significant change (p=0.007) and a clinically important change of more than six points (Table 4.3).

Participant 003 had an initial pre-test score of two, and at the end of the five-day period a score of three. A one-point (2%) change in the upper limb subtest does not show a clinically important or statistically significant (p=0.988) change in the upper limb function of the participant (Table 4.3).

Figure 4.3 indicates there was no change from pre-test to session 1 and while participant 001 improved consistently over five sessions, participant 002 had greater improvement at session 4 and 5; participant 003 showed little improvement in upper limb movement.

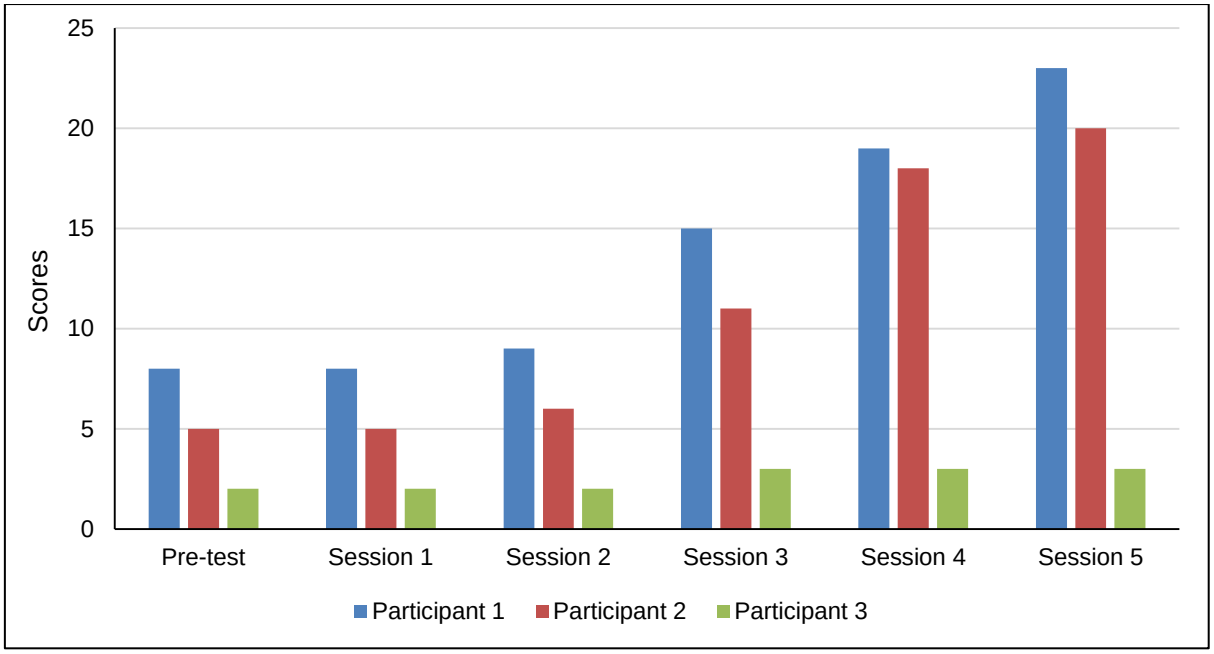


Figure 4.3 Fugl-Myer assessment upper limb subtest score for each participant

When the scores of the group of participants were considered together, a statistically significant effect was observed for the upper limb subtest of the FMA over the five sessions. A Friedman ANOVA indicated the difference in the scores at each time point was greater than what would be expected by chance (p=0. 014), indicating that the activity-based NMES programme had a positive effect across the upper limb subtest over five treatment sessions.

Figure 4.4 confirms the greater improvement in session 4 and session 5 for the upper limb subtest across the five treatment sessions for the group of participants.

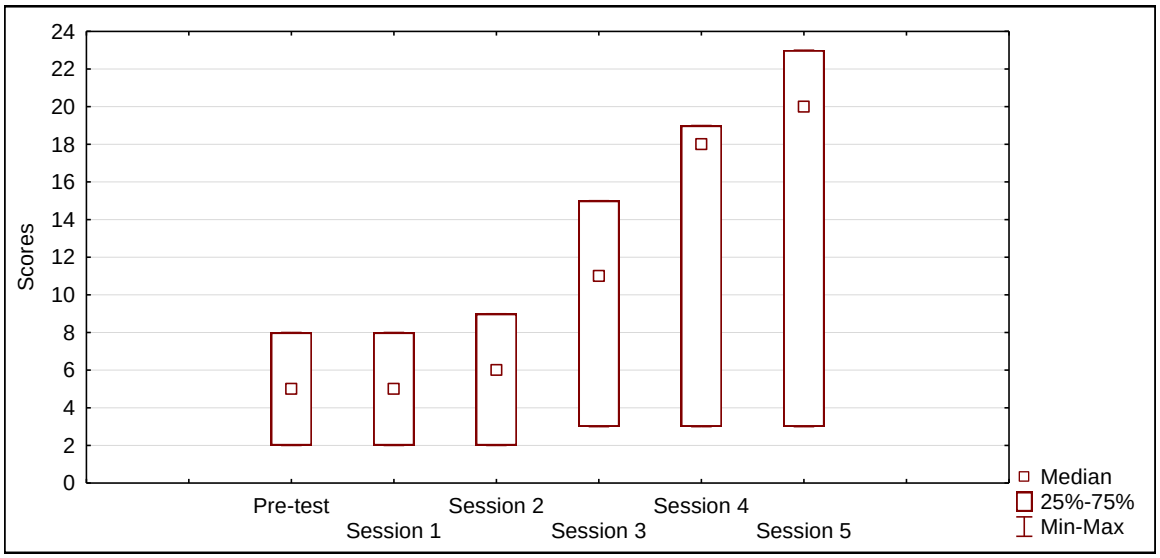


Figure 4.4 Fugl-Myer assessment upper limb subtest scores between the sessions for the group of participants

4.3.3 Wrist subtest

The scores for each participant were analysed over the six assessment periods for the FMA wrist subtest. A Chi-squared test was used to show if the change in scores exceeded the amount that was greater than would be expected by chance and therefore shows a statistically significant difference.

Participant 001 had an initial pre-test score of zero, and at the end of the five-day period a score of six. A change of six-points (60%) shows no statistically significant change in wrist function (p=0.093) but a clinically important change (Table 4.4).

Participant 002 had an initial pre-test score of zero, and at the end of the five-day period a score of four. A four-point (40%) change in the wrist subtest does not show clinically important change and the p value of 0.683 showed no statistically significant change (Table 4.4).

Participant 003 had an initial pre-test score of zero, and at the end of the five-day period a score of five. A change of five (50%) points shows no statistically or clinically important change in wrist function (Table 4.4).

Table 4.4 Fugl-Myer assessment wrist subtest for each participant

	Fugl-Meyer wrist subtest			
	Initial to final assessment	**Change**	**Chi squared**	**p value**
Participant 001	0-6	6	6.38:df5	0.093
Participant 002	0-4	4	0.16:df5	0.683
Participant 003	0-5	5	2.66:df5	0.263

Figure 4.5 indicates there was no change from pre-test to session 1 and while participant 001 improved from session 2, the greatest improvement for all participants was seen at sessions 4 and 5. Participant 003 had greater improvement in wrist movement than participant 002.

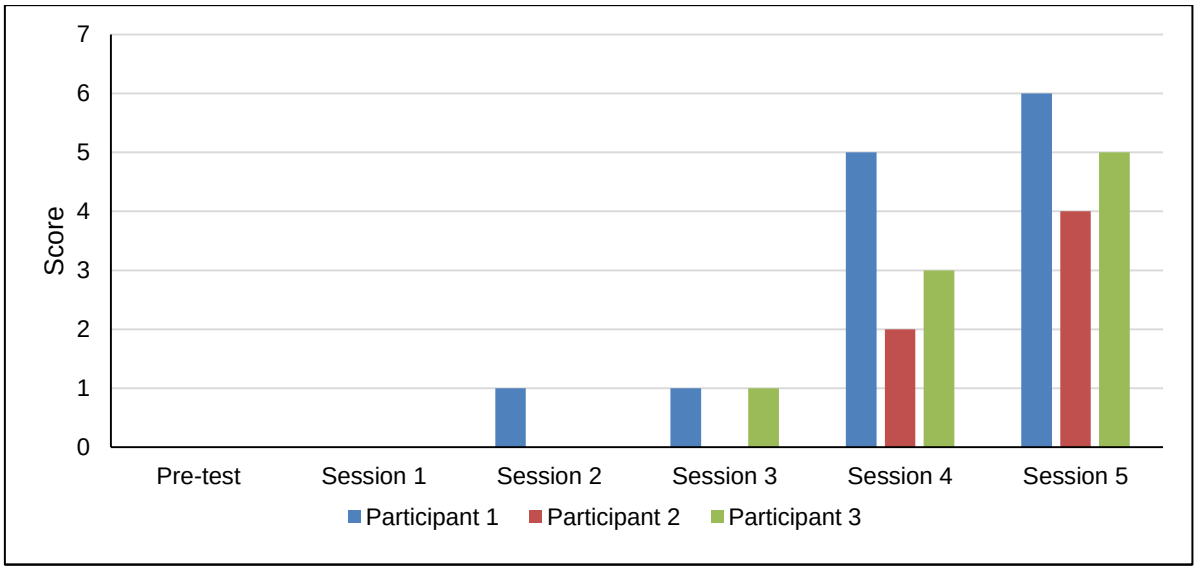


Figure 4.5 Fugl-Myer assessment wrist subtest score for each participant

When the scores of the group of participants were considered together, the differences in change over the five sessions were greater than would be expected by chance in the wrist subtest. A Friedman ANOVA indicated the difference at each time point was greater than what would be expected by chance (p =0.016), which indicated a statistically significant change over time in the score of the wrist subtest of the FMA (Figure 4.6).

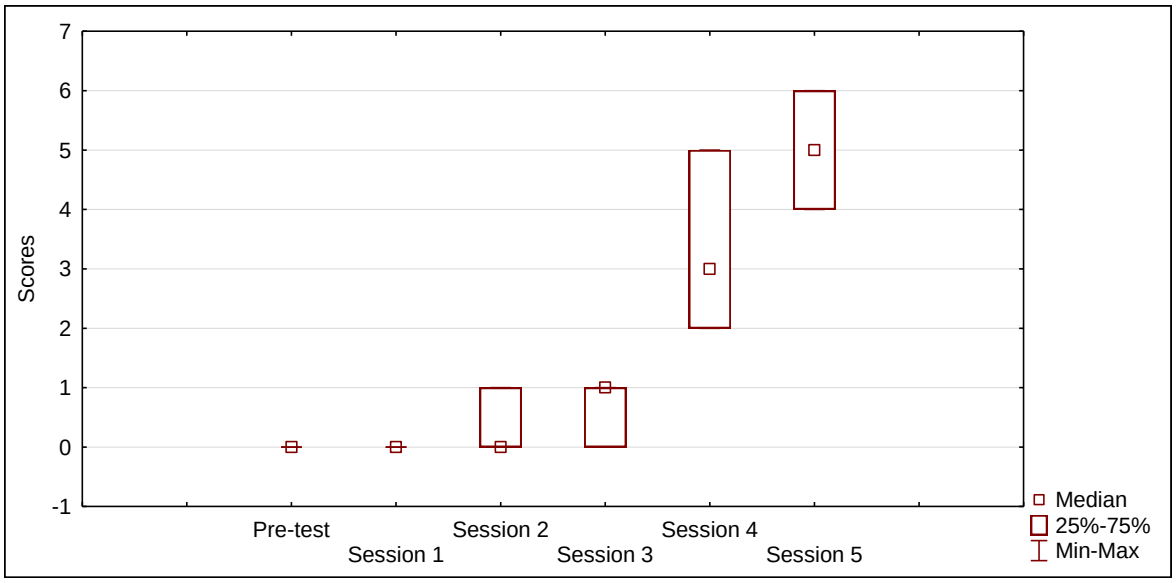


Figure 4.6 Fugl-Myer assessment wrist subtest scores between the sessions for the group of participants

Figure 4.6 confirms the greater improvement in sessions 4 and 5 for the wrist subtest across the five treatment sessions for the group of participants.

4.3.4 Hand subtest

The scores for each participant were analysed over the six assessment periods for the FMA hand subtest. A Chi-squared test was used to show if the change in scores exceeded the amount that was greater than would be expected by chance, and therefore showed a statistically significant difference. Participant 001 had an initial pre-test score of one, and at the end of the five-day period a score of eight. A seven-point (50%) change in the score shows a statistically significant change (p=0.032) as well as a clinically important change

of more than six points. Participant 002 had an initial pre-test score of 0, and at the end of the five day period a score of four (p=0.061). A four-point (29%) change in the hand subtest does not show a statistically significant change (p=0.012) or a clinically important change. Participant 003 had an initial pre-test score of four, and at the end of the five-day period a score of seven. A three-point (21%) change in the hand subtest does not show a statically significant change (p=0.916) or a clinically important change (Table 4.5).

Table 4.5 Fugl-Myer assessment hand subtest for each participant

	Fugl-Meyer hand subtest			
	Initial to final assessment	**Change**	**Chi-squared**	**p value**
Participant 001	1-8	7	12.20:df5	0.032
Participant 002	0-4	4	1.75:df5	0.416
Participant 003	4-7	3	1.60:df5	0.916

Figure 4.7 indicates there was no change from pre-test to session 1 and while participant 001 improved from session 2, the greatest improvement was seen at sessions 4 and 5.

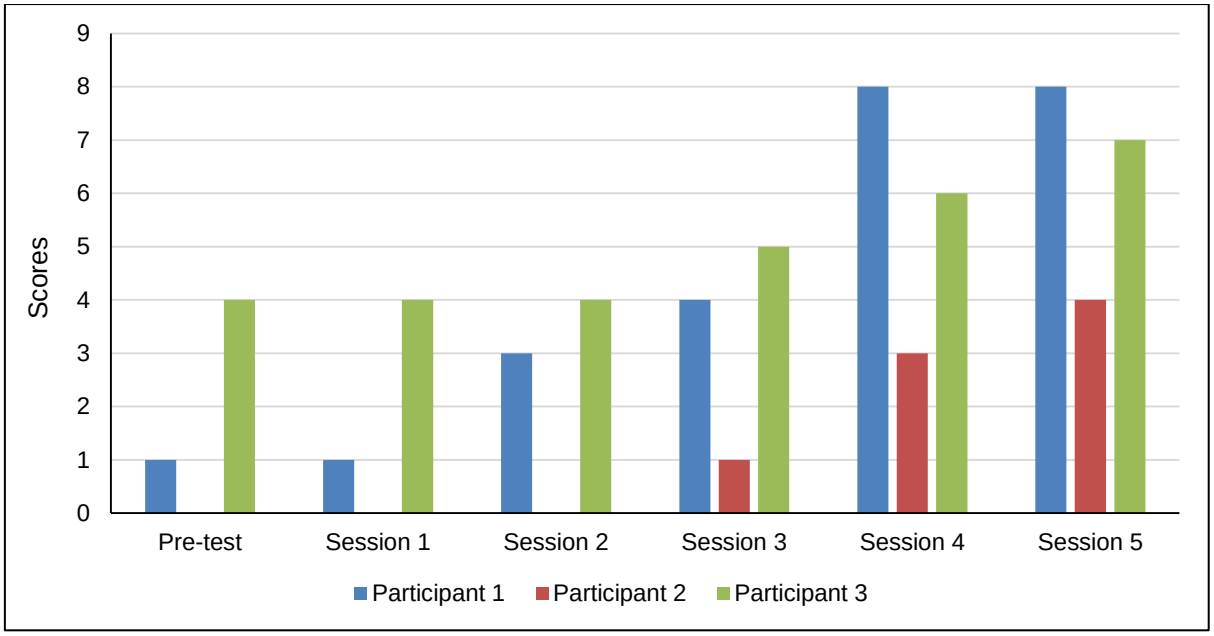


Figure 4.7 Fugl-Myer assessment hand subtest score for each participant

Participants 002 and 003 showed consistent improvement in sessions 3 to 5. When the scores of the group of participants were considered together, a statistically significant effect was observed for the hand subtest of the FMA over the five sessions.

A Friedman ANOVA indicated the difference in the scores at each time point was greater than what would be expected by chance ($p=0.014$), indicating that the activity-based NMES programme had a positive effect across the hand subtest over five treatment sessions.

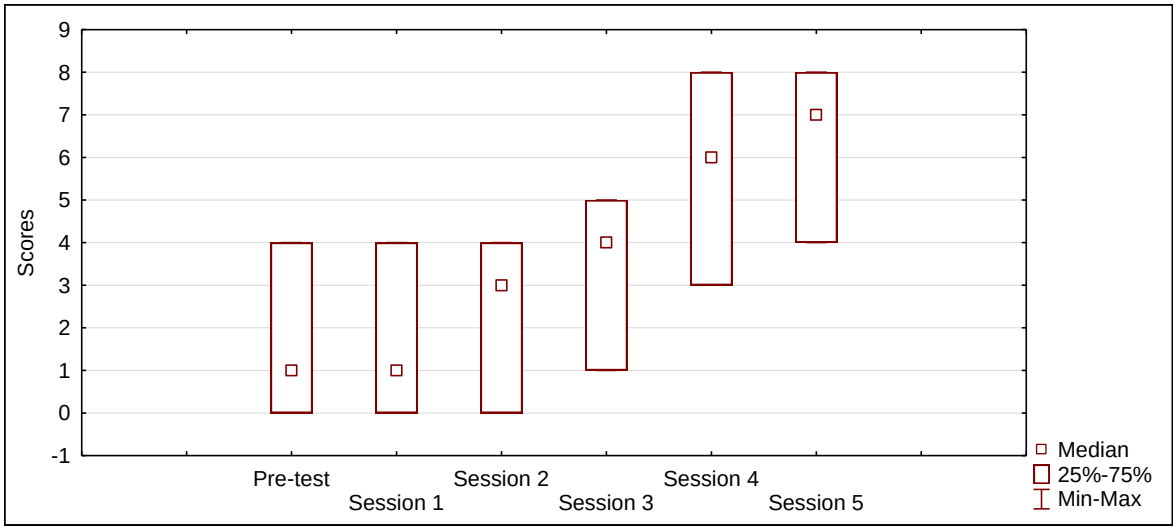


Figure 4.8 Fugl-Myer assessment hand subtest scores between the sessions for the group of participants

4.3.5 Coordination subtest

The scores for each participant were analysed over the six assessment periods for the FMA coordination subtest. A Chi-squared test was used to show if the change in scores exceeded the amount that was greater than would be expected by chance, and therefore showed a statistically significant difference. Participant 001 had an initial pre-test score of zero, and at the end of the five-day period a score of four. A four-point (66%) change in the coordination subtest does not show statistically significant or clinically important change (Table 4.6).

Table 4.6 Fugl-Myer assessment coordination subtest for each participant

	Fugl-Meyer coordination subtest			
	Initial to final assessment	**Change**	**Chi-squared**	**p value**
Participant 001	0-4	4	0.80:df5	0.370
Participant 002	0-0	0	n/a	1.000

Participant 003	0-0	0	n/a	1.000

Participants 002 and 003 had an initial pre-test score of zero, and at the end of the five-day period a score of zero, with no change found for the coordination subtest (Table 4.6).Only Participant 001 had a change in score in session 5, all other scores were 0 for all the participants thus graphic representation of the results does not provide useful information.

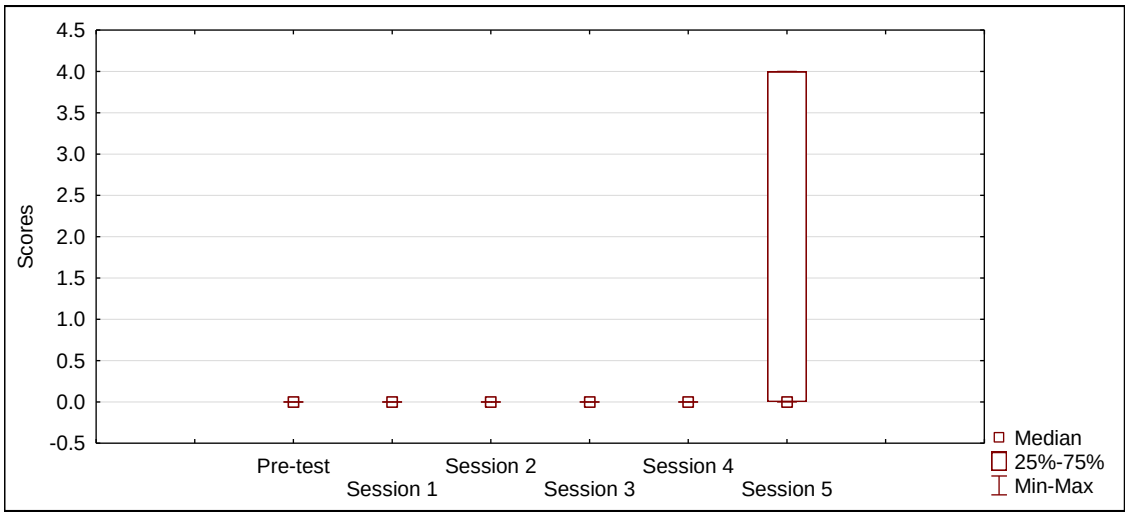


Figure 4.9 Fugl-Myer assessment coordination subtest scores between the sessions for the group of participants

When the scores of the group of participants were considered together, no statistically significant effect was observed for the coordination subtest of the FMA over the five sessions. A Friedman ANOVA indicated the difference in the scores at each time point was not greater than what would be expected by chance (p=0.415), indicating that the activity-based NMES programme had very little positive effect across the coordination subtest over five treatment sessions (Figure 4.9).

4.4 Modified Barthel Index assessment

4.4.1 Total score

The scores for each participant were analysed over the six assessment periods for the MBI assessment. A Chi-squared test was used to show if the change in scores exceeded the amount that was greater than would be expected by chance, and therefore shows a statistically significant difference.

Table 4.7 Modified Barthel Index assessment scores for each participant

	Modified Barthel Index assessment			
	Initial to final assessment	**Change**	**Chi Squared**	**p value**
Participant 001	33-60	27	10.95:df5	0.052
Participant 002	16-67	51	34.95:df5	0.001
Participant 003	22-39	17	8.07:df5	0.152

Participant 001 had an initial pre-test score of 33, and at the end of the five-day period a score of 60. The Chi-squared test showed a 27-point (27%) difference in the pre-test session and final session of the programme showing no statistically significant difference (p=0.052), but a clinically important difference of more than 9.25 points out of 100 and that the participant was at a level of moderate dependency.

Participant 002 had an initial pre-test score of 16, and at the end of the five-day period a score of 67. A Chi-squared test showed a statistically significant difference (p=0.001), and the 51-point (51%) difference in the pre-test session and final session of the programme also showed a clinically important change of more than 9.25 points out of 100, and a level of moderate dependency.

Participant 003 had an initial pre-test score of 22, and at the end of the five-day period a score of 39. A Chi-squared test showed that the change that occurred with the treatment was not great enough to be statistically significant (p=0.152), but the 17-point (17%) difference in the pre-test session and final session of the programme showed a clinically important change of more than 9.25 points out of 100, although the participant remained at a level of severe dependency.

Figure 4.10 indicates there was no change from pre-test to session 1 and while all participants improved from session 2, the greatest improvement was seen for Participant 002 at session 5. Participant 003 had the least improvement on the MBI scores.

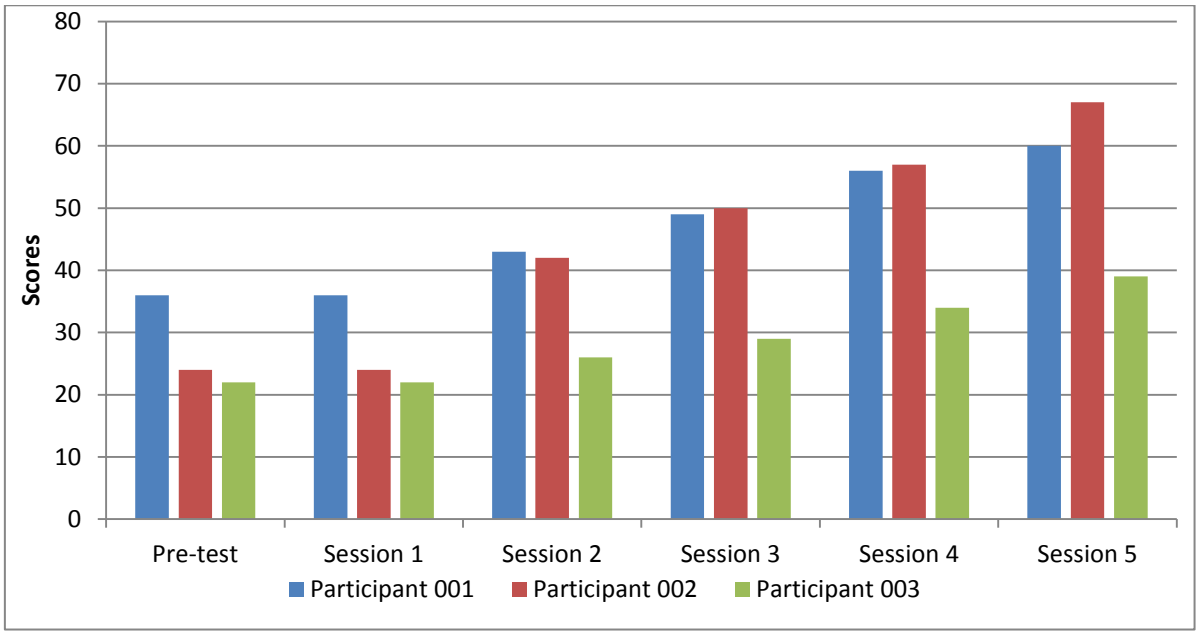


Figure 4.10 Modified Barthel Index assessment scores between the sessions for the group of participants

A statistically significant effect was observed for the MBI assessment. A Friedman analysis of variance was performed and the changes over the assessments at each time point were greater than what would be expected by chance (p = 0.010), indicating a positive effect on performance in personal ADLs across the five treatment sessions (Figure 4.11).

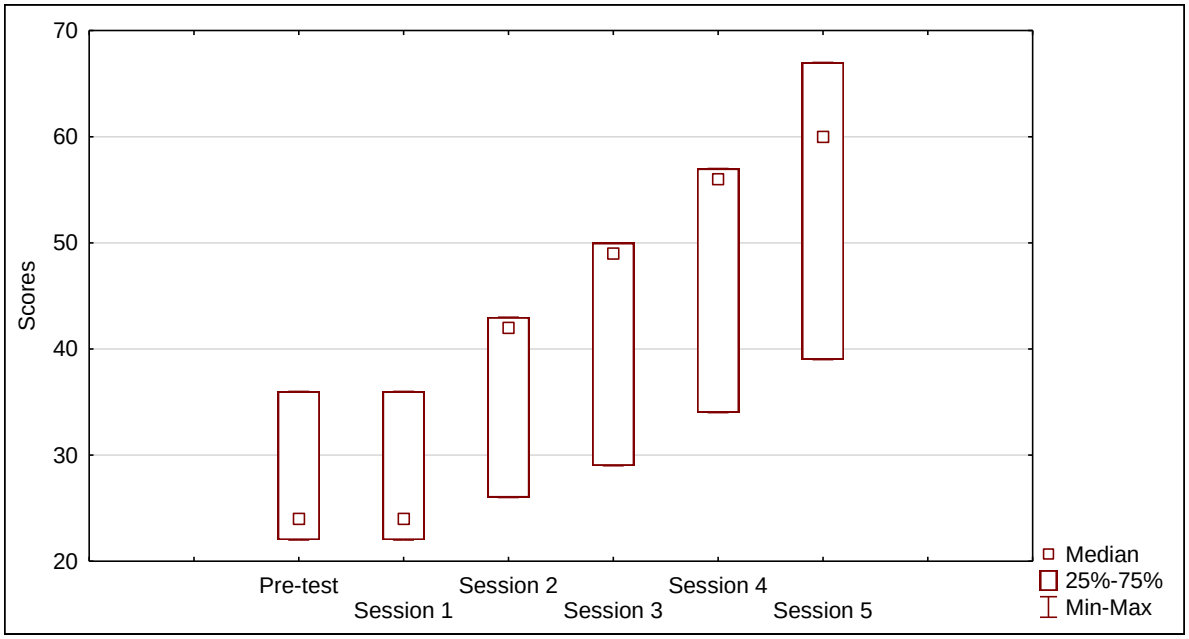
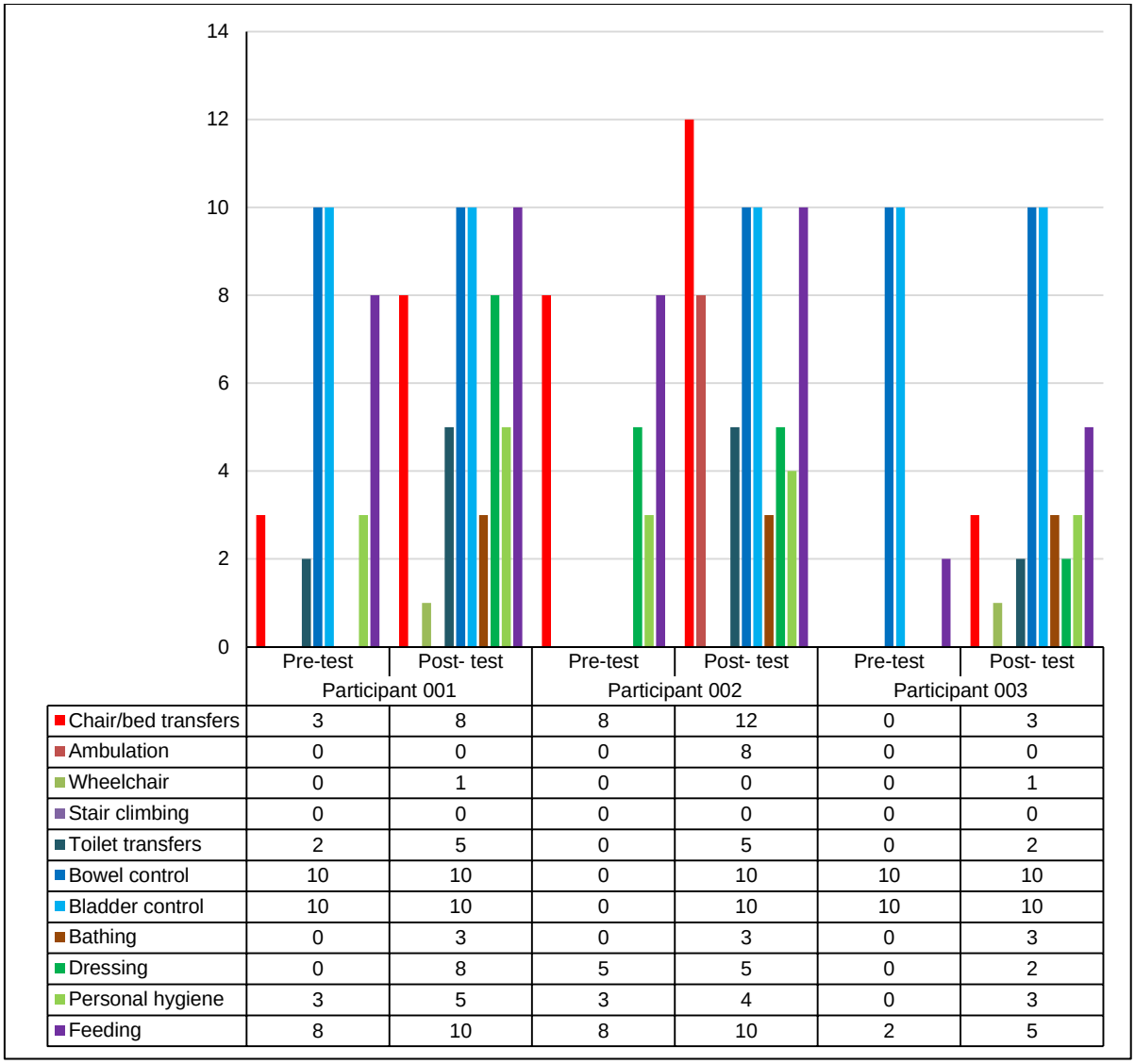


Figure 4.11 Modified Barthel Index assessment scores between the sessions for the group of participants

4.4.1 Modified Barthel Index subtests

The percentage improvement on the subtests of the Barthel index was determined for the three participants to establish the change from pre-test to post test scores achieved in the Session 5 assessment (Figure 4.12).



	Pre-test	Post- test	Pre-test	Post- test	Pre-test	Post- test
	Participant 001		Participant 002		Participant 003	
Chair/bed transfers	3	8	8	12	0	3
Ambulation	0	0	0	8	0	0
Wheelchair	0	1	0	0	0	1
Stair climbing	0	0	0	0	0	0
Toilet transfers	2	5	0	5	0	2
Bowel control	10	10	0	10	10	10
Bladder control	10	10	0	10	10	10
Bathing	0	3	0	3	0	3
Dressing	0	8	5	5	0	2
Personal hygiene	3	5	3	4	0	3
Feeding	8	10	8	10	2	5

Figure 4.12 Change in Modified Barthel Index assessment subtest scores from pre-test to post-test (Session 5) for each participant

At the end of the five-day period, bowel and bladder control were the only two items in which the participants achieved full independence. This was due to Participant 002, who initially had no bowel and bladder sensation or control, regaining this function. Bathing had the greatest change (60%), followed by personal hygiene (40%) and toilet transfer (37%). Other items that showed improvement included dressing and feeding (33% respectively). Items of the MBI that had the lowest change were items that required

lower limb ability and included ambulation/wheelchair (13%), ambulation (18%) and chair/bed transfers (27%) (Table 4.8).

Table 4.8 Change in the Modified Barthel Index subtest scores at pre-testing and post-test (Session 5) for the group of participants

	Pre-test score and percentage score	**Post- score and percentage score**	**Percentage improvement**
	Score (%)	Score (%)	
Chair/bed transfer	11 (24)	23 (51)	27%
Ambulation	0 (0)	8 (18)	18%
Ambulation/wheelchair	0 (0)	2 (13)	13%
Stair climbing	0 (0)	0 (0)	0%
Toilet transfer	**2 (7)**	**12 (40)**	**37%**
Bowel control	20 (67)	30 (100)	33%
Bladder control	20 (67)	30 (100)	33%
Bathing	**0 (0)**	**9 (60)**	**60%**
Dressing	5 (17)	15 (50)	33%
Personal Hygiene	**6 (40)**	**12 (80)**	**40%**
Feeding	12 (40)	25 (83)	33%

4.5: Correlation of Fugl-Meyer assessment and Modified Barthel Index assessment

The overall scores from the FMA and the MBI total scores were correlated to determine the association between the participants' motor function and their independence in activities of daily living. There were excellent correlations over the six assessments in the

study indicating improvement in upper limb motor function was strongly associated with improvement in the MBI scores (Table 4.9). The correlation between the scores on the two tests was also excellent when the participant's results were considered together as a total group.

Table 4.9 Correlation between the Modified Barthel Index total scores and the Fugl-Meyer overall scores for each participant and for the group of participants

	Fugl-Meyer assessment overall scores	**Modified Barthel Index total scores**	**rho**
	Median (Lower and upper quartile)		
Participant 001	16.5 (9-32)	46 (36-56)	0.98*
Participant 002	9 (5-23)	46 (24-57)	0.91*
Participant 003	7.5 (6-12)	27.5(22-34)	0.98*
Total group	11 (6-20)	39.83 (26-50)	0.85*

Significant p≤0.05*

4.6 Change in Fugl-Meyer assessment and Modified Barthel Index assessment scores according to demographic and medical factors

A descriptive visual analysis of the change in Fugl-Meyer assessment and Modified Barthel Index assessment scores, using graphs, was used to determine difference for dominance, age and cognition, which are known to affect the outcomes of stroke.

4.6.1 Dominance

4.6.1.1 Fugl-Meyer assessment

As can be seen in Figure 4.13, participants 001 and 003, with dominant upper limb affected, achieved higher overall scores on the Fugl-Meyer assessment except for session 4. Participants whose dominant arm was affected achieved higher scores at session 5. For participants whose dominant and non-dominant limb was affected, no changes were observed for the first two assessments, but improvement started to occur from session 2.

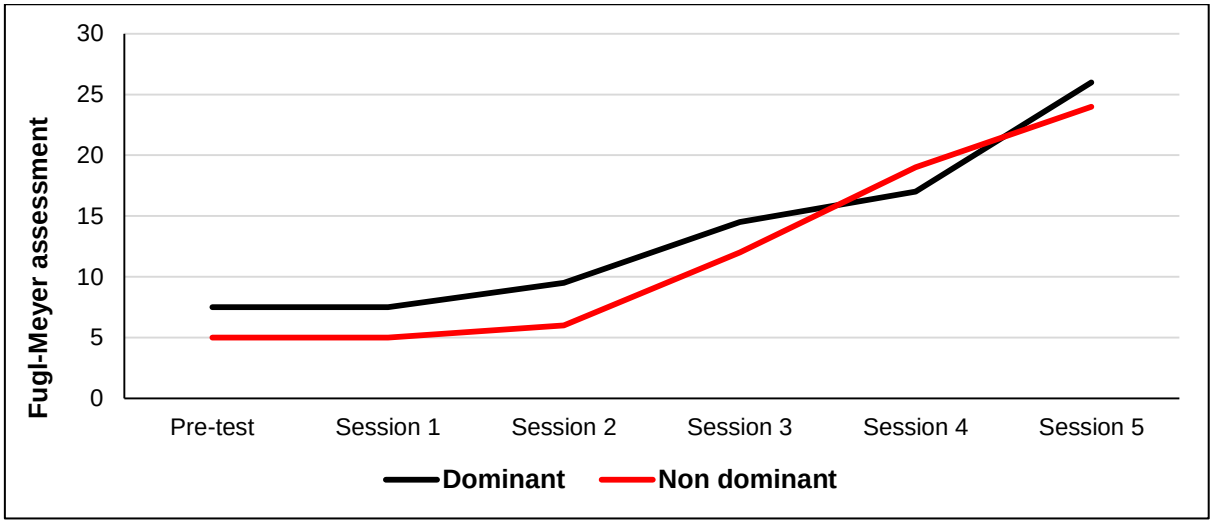


Figure 4.13 Overall score of Fugl-Myer assessment for the participants with dominant and non-dominant upper limb affected by stroke

4.6.1.2 Modified Barthel Index assessment

Due to the small number of participants, a descriptive visual analysis of the effect of dominance on the return of personal activities of daily living was completed. As can be seen in Figure 4.14, although participants 001 and 003, with dominant upper limb affected, had lower scores initially, they achieved higher overall scores on the MBI assessment after session 2.

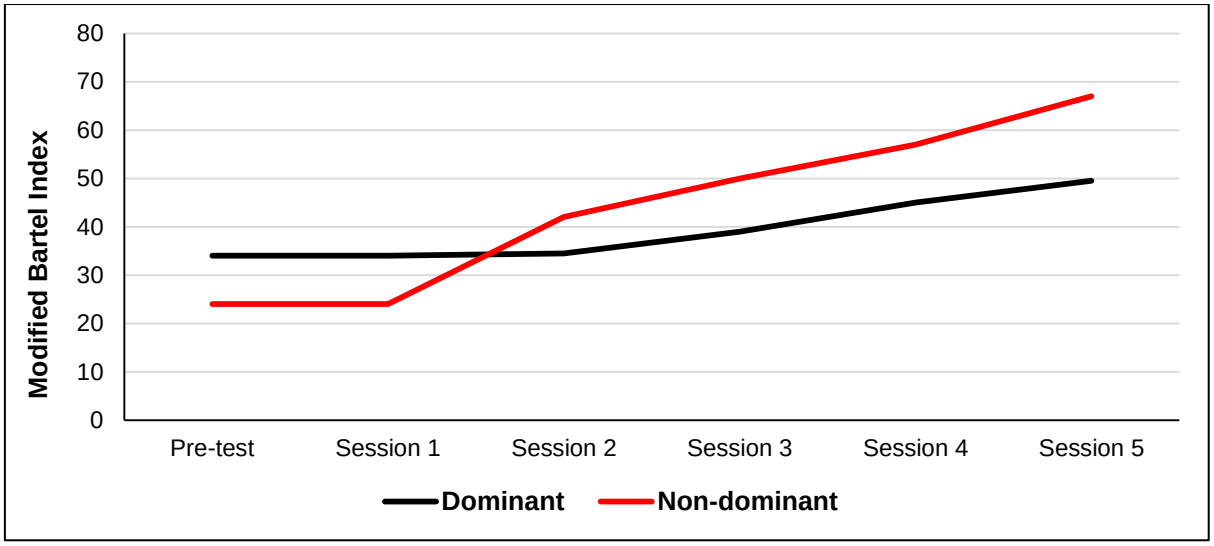


Figure 4.14 Scores on the Modified Barthel Index assessment for the participants with dominant and non-dominant upper limb affected by stroke

Participants whose non-dominant limb was affected showed improvement from session 2, while participants whose dominant limb was affected showed changes in function at the end of session 3.

4.6.2 Age

4.6.2.1 Fugl-Meyer assessment

As can be seen in in Figure 4.15, the oldest participant (68) achieved the highest score with the youngest participant (33) achieving a higher score than the second oldest participant (58). The oldest participant started to show improvement at session 1, while the 33-year-old and 58-year-old participants showed improvement from session 2. All participants maintained an upward trend in scores until session 5.

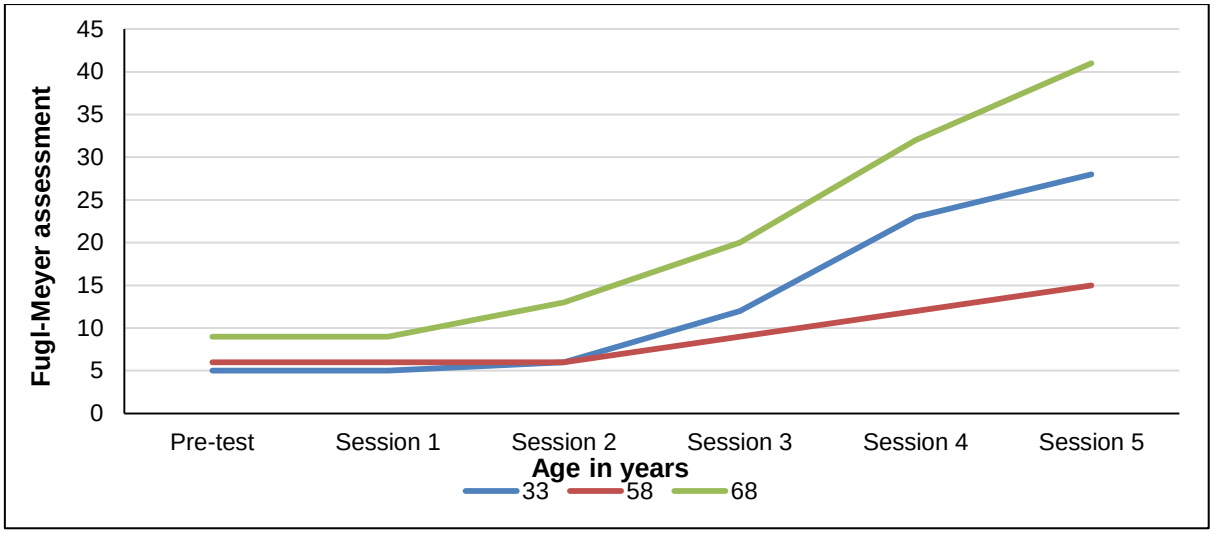


Figure 4.15 Overall score of Fugl-Myer assessment for the participants for age.

4.6.2.2 Modified Barthel Index assessment

As can be seen in Figure 4.16, the participant with the highest age had the highest score on admission to the study followed by the youngest then the 58-year-old participants.

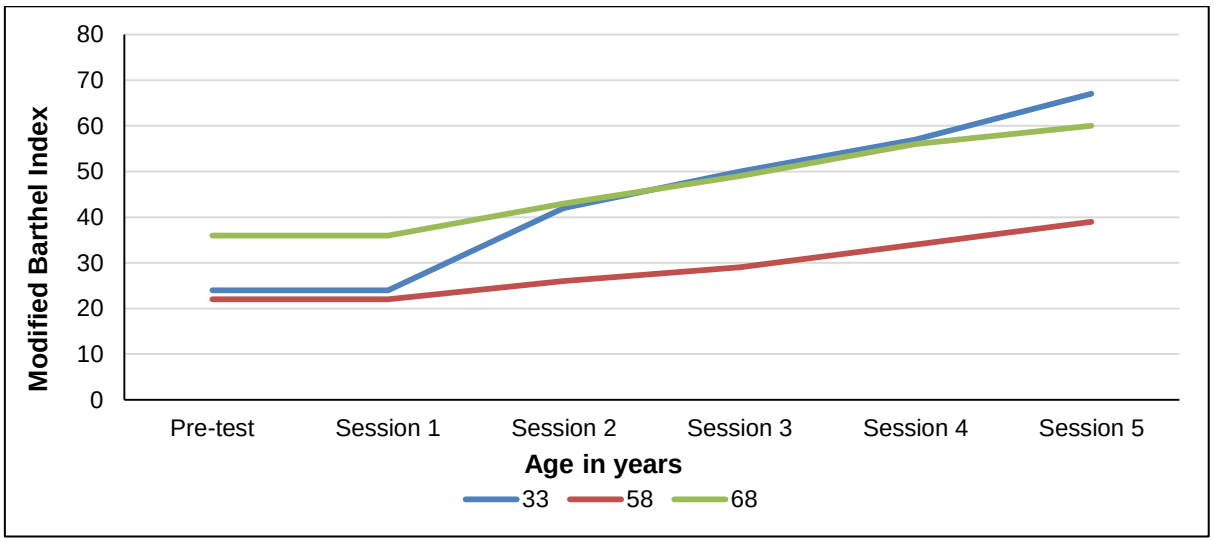


Figure 4.16 Scores on the Modified Barthel Index assessment for age

All participants had no change from pre-test to session 2, and then maintained a steady gain. At the end of the study, the youngest participant achieved the highest score, followed by the oldest participant, with the 58-year-old being the lowest.

4.6.3 Cognition

4.6.3.1 Fugl-Meyer assessment

As can be seen in Figure 4.17, participants with higher MMSE scores had the highest score at the end of the study period. Participants who had higher scores on the MMSE showed significant improvement from session 2 onwards compared to the participant who scored the lowest. The participants who had the highest score started to show improvement from session 1; the participant who had the lowest score started to show improvement from session 2.

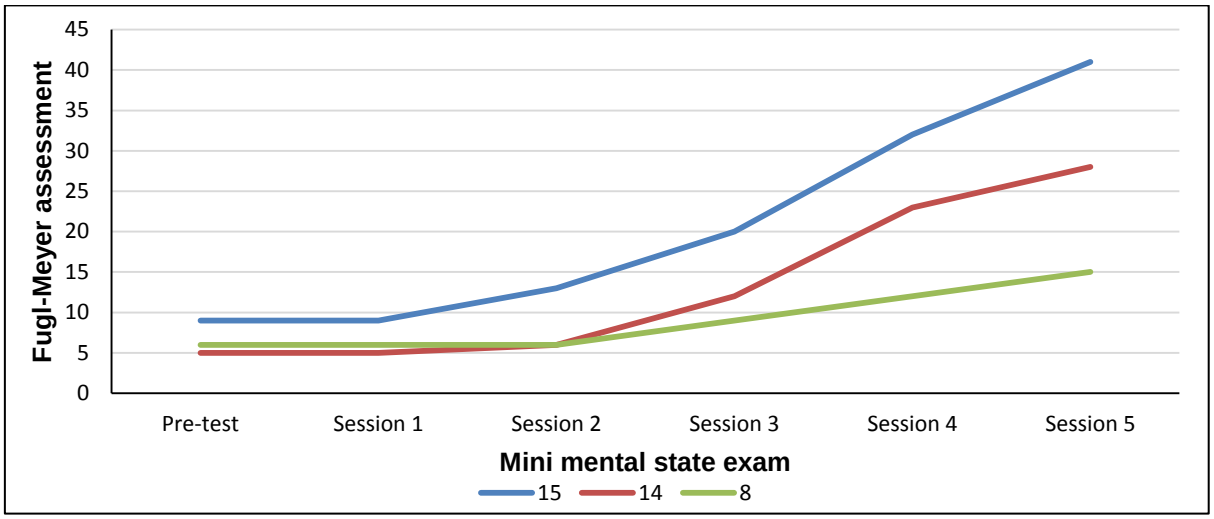


Figure 4.17 Overall score of Fugl-Myer assessment for the Mini mental state exam scores

4.6.3.2 Modified Barthel Index assessment

As can be seen in Figure 4.18, participants who had higher Mini mental scores achieved higher overall scores on the MBI assessment over all six sessions. All participants started to show improvement from session 1.

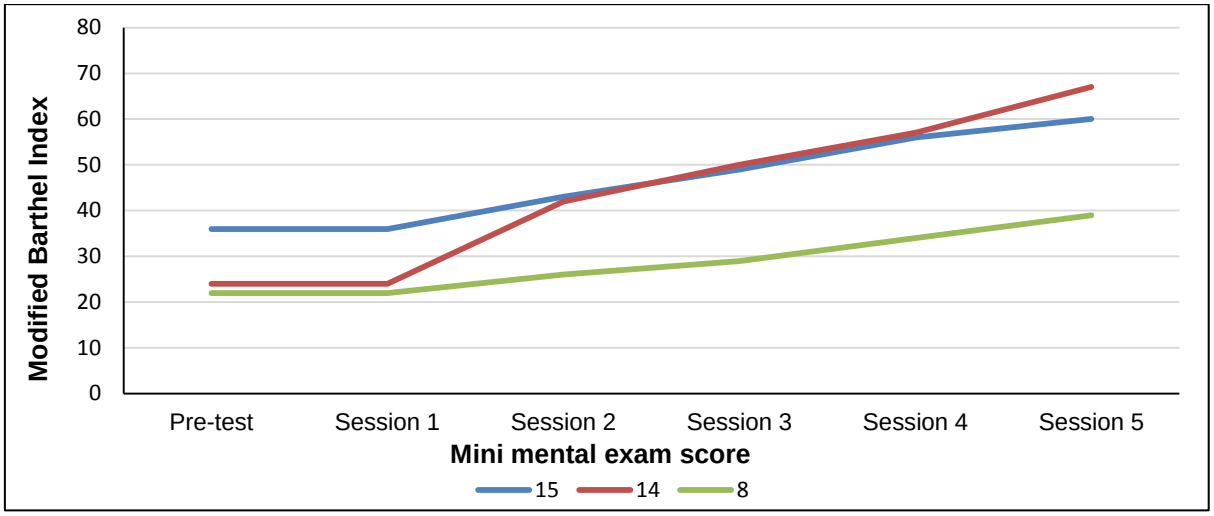


Figure 4.18 Scores on the Modified Barthel Index assessment for the Mini mental state exam

4.7 Summary

In conclusion, it was found that an activity-based NMES programme, of a daily intensity of one hour (two 30 minute) sessions over a one-week period (five working days), showed a clinically and statistically significant change in motor ability, except coordination subtest, and personal activities of daily living level of acute stroke survivors in a rural setting.

Due to the small sample size, it was not possible to determine the effect of dominance, age and cognition on the outcome of motor function and participation using the FMA and MBI assessment respectively during an activity-based NMES programme.

A visual analysis of the change in FMA and MBI assessment scores showed a trend, based on the initial scores, indicating severity of stroke rather than age or dominance. Participants whose dominant arm was affected scored higher on the overall score, wrist and hand subtest of the FMA. However, the participants whose non-dominant arm was affected scored higher on the MBI assessment.

A visual analysis of the change in the MBI showed younger participants had a better result than participants with higher ages, while the results of the FMA did not have clear results for age, with the participant with the highest age scoring higher as he had higher scores initially and the second oldest participant with the lowest score.

A visual analysis of the change in Fugl-Meyer assessment and the Modified Barthel Index assessment shows that participants who had a higher score on the mini mental state exam had better results than participants who had a lower score.

CHAPTER 5: DISCUSSION

5.1 Introduction

The results of the demographics of each participant will be discussed, followed by the implications for the combined results on NMES on upper limb motor function as measured by the FMA, which will be discussed according to the objectives. The results of the activity-based NMES on personal ADL using MBI assessment will be with the effect of dominance, age and cognition and the efficacy of an activity-based NMES programme reviewed last.

5.2 Demographics

The age of the participants varied, with two participants above 50 years, which is the most common age reported for stroke in South Africa (Bertram et al., 2013). Both these participants presented with the highest risk factor for stroke, hypertension (Shehatah, 2010). The younger participant, 002, can be considered as falling into the young stroke group and this may be related to the comorbidity of HIV, which is associated with young stroke (Griffiths and Sturm, 2011).The older stroke survivors more often had major dominant stroke syndrome (*P*=.018).

5.3 Outcomes of upper limb motor function and personal activities of daily living for each participant

The outcomes for each participant, related to the change in upper limb motor function and personal ADLs achieved during the five-day activity-based NMES programme in addition to the standard rehabilitation therapy, are considered. The association between the change in motor function and personal ADLs in stroke survivors is discussed as well as the change in upper limb impairment and personal ADLs in stroke survivors according to appropriate demographic and medical factors that affect the outcome of stroke.

5.3.1 Participant 001

Although Participant 001 was advanced in age, it appears the scores for the initial deficits, related to his stroke severity rather than his age, reflected his outcomes after intervention. Studies show that age alone cannot determine post discharge function, but rather stroke severity based on initial BMI or NHISS scores, previous functioning, type and site of stroke and cognitive impairments must also be considered (Jeon et al., 2017; Kammersgard et al., 2004). These factors along with age should be used to determine rehabilitation and outcomes following stroke. The findings for Participant 001 are consistent with other studies that found that the severity of a stroke is a strong indicator of functional outcome at discharge. Other studies show that stroke survivors with minimal to moderate upper limb deficits have a 71% chance of achieving dexterity at 6 months at the end of the intervention period (Kelly et al., 2003).

Participant 001 had a score of nine initially on the overall FMA and showed improvement in all assessments, except for the initial to session 3, hand subtest of the FMA. This participant made significant improvements of 48% overall and 47% in upper limb movement. This indicates marked improvement on the GROC for the FMA proposed (Page et al., 2012) within a five day period, which represented improvement in movement at the shoulder, elbow and forearm. Movements that improved included shoulder flexion, extension, internal rotation, external rotation, elbow flexion, extension and forearm supination and pronation. There was also a significant improvement of six points (60%) and seven points (50%) in the wrist and hand movement respectively. Participant 001 had excellent improvement for the wrist and hand on the GROC for the FMA, which reflects change from no movement initially in the hand and wrist to movement in all directions in the wrist as well as the return of finger movement and grasps in the hand. Movement includes wrist stability, wrist flexion and extension, finger extension as well as the hook grasp, lateral prehension and mass flexion. Participant 001 was also the only participant who showed improvement in the coordination subtest (66%) of the FMA, with speed of movement improving although this change was not significant and did not show a CID.

It would appear that the use of the activity-based NMES programme has assisted Participant 001 to achieve a significant marked and excellent improvement in motor function in a shorter period. This is supported by the evidence provided by Wolf et al. (2016) and Ward, Kelly and Brander (2015) that activity-based specific, intensive, high-dose upper limb rehabilitation promotes upper limb recovery. Thus, the use of NMES with this participant supported the moderate quality evidence that NMES could be integrated into stroke rehabilitation at an acute stage with a view to improving upper limb motor impairments (Hatem et al., 2016).

The improvement in upper limb function was reflected in the improvement seen in his personal ADLs, with an excellent significant correlation over the six treatment sessions between the FMA and MBI. Participant 001 had a pre-test score of 33 on the MBI assessment, indicating severe dependence, and showed improvement of 27% on the final assessment with a score of 60, which indicates a move from severe dependency to assisted independence. Participant 001 was therefore still moderately dependent on someone else to perform personal ADLs and his percentage improvement in personal ADLs was less than that in his upper limb mobility. This may well reflect his inability to walk, mobilise in a wheelchair and climb stairs, which are lower limb related functions. Washing also remained challenging in terms of transfers, but these deficits were compromised by his lower limb amputation. Most improvement was seen in activities requiring upper limb movement and bilateral hand function. The improvement in personal ADLs in a five-day period of inpatient treatment also provided Participant 001 with the ability to continue with assisted ADLs at home, with moderate to slight assistance on discharge as he was no longer severely dependent. This provides an outcome that is preferable for stroke survivors who are unable to attend outpatient rehabilitation and reduces caregiver burden (Mamabolo et al., 2009).

Participate 001 also had a score of 15 on the MMSE, which indicated moderate cognitive impairment. This cognitive level meant he had the ability to follow directions, which resulted in better gains in hand and upper limb function (Barreca et al., 1999). The cognitive ability of this stroke survivor was not a barrier to achieving functional

independence, with MBI scores achieving high scores except where mobility and transfers were required (Jaywant et al., 2019).

The following diagram illustrates all the systems that had an influence on Participant 001's recovery in ADL and upper limb function.

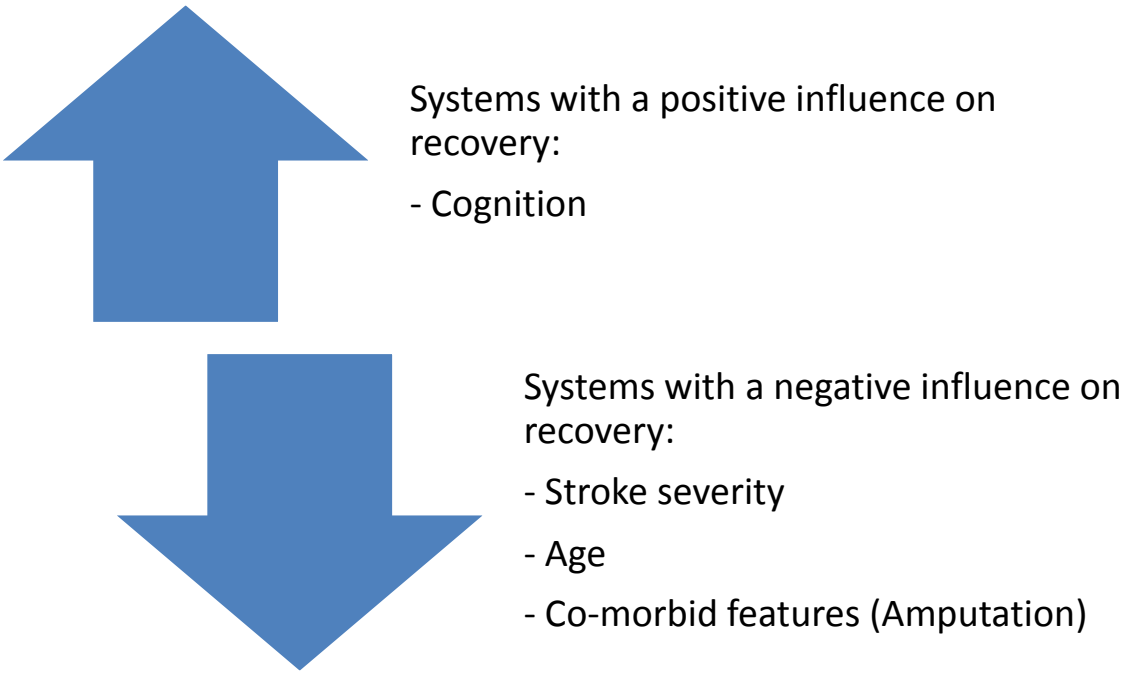


Figure 5.1 Influence of various systems on Participant 001 recovery

5.3.2 Participant 002

Participant 002 had bowel and bladder impairments indicating specific localised effects of her stroke more likely caused by cardio embolism, coagulopathy, or non-HIV infective vasculitis, or directly through HIV-associated vasculopathy, which is congruent with her HIV status (Benjamin et al., 2012). HIV as a possible risk factor for stroke was discovered in the 1980s, when younger patients were diagnosed with stroke without common risk factors (Singer et al., 2013). Furthermore, it appears that HIV is an independent risk factor amongst women as incidence of stroke is higher than for men (Chow et al., 2018). There

is also a five times greater risk of ischemic stroke amongst HIV positive women aged 18-35 than their HIV negative counterparts, after adjusting for demographics and traditional stroke risk factors (Chow et al., 2018). This correlates with the results for Participant 002 who was aged 33 years.

Participant 002 had a score of five initially on the overall FMA and a significant improvement of 28% on this score. The upper limb achieved a significant improvement of 42% in this subtest. Movement at both the shoulder and elbow improved, which indicates marked improvement on the GROC for the FMA within a five-day period. Improved movements included shoulder retraction, shoulder elevation, shoulder abduction, shoulder external rotation, elbow flexion and extension, and forearm pronation and supination. The improvement of four points (40%) for the wrist and four points (29%) for the hand were not significant or a CID, however they did reflect a marked improvement for the wrist and a moderate improvement for hand movement on the GROC for the FMA. Change from no movement initially in the hand and wrist to movement in some directions in the wrist, as well as the return of mass finger movement in the hand was seen. Improved movements included wrist stability, wrist flexion and extension, as well as mass flexion grasp and lateral prehension grasp. Participant 002 had no improvement in the coordination subtest of the FMA.

Participant 002 started treatment one day after admission, as she was medically stable and referred to occupational therapy. She showed no improvement in all assessments for the first 3 sessions for the upper limb, and movement in the wrist and hand was only seen after session 4. It would appear the activity-based NMES programme was started too early, although this was done to allow for five days of treatment before the participant was discharged. Perhaps NMES should therefore only be started a few days post admission if it is to be effective (Chen et al., 2010); this is a dilemma that needs further investigation in terms of the short admission periods for stroke survivors in South Africa (Mamabolo et al., 2009). Participant 002 achieved a marked and moderate improvement in motor function in an even shorter period supporting the evidence for activity-based NMES and intensive, high-dose upper limb rehabilitation promotes upper limb recovery (Ward et al., 2015; Wolf et al., 2016) in acute stroke (Hatem et al., 2016).

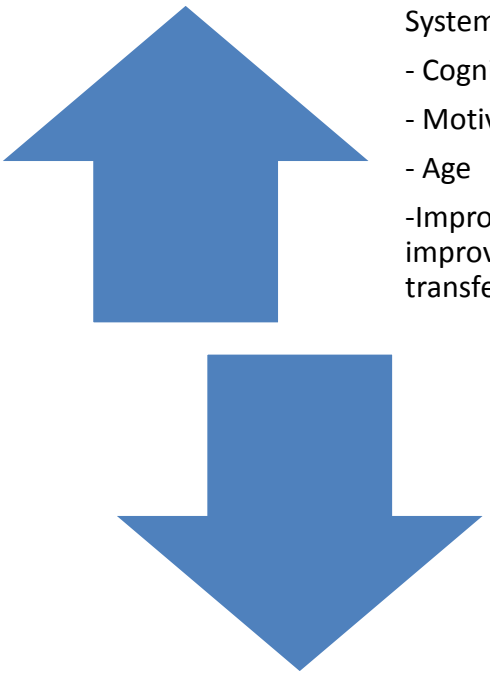
The improvement in upper limb function was reflected in the improvement seen in Participant 002's personal ADLs, with an excellent correlation over the six treatment sessions between the FMA and MBI. She regained continence, achieving a 51% improvement in independence at discharge, and was fully independent in bowel and bladder control. Although literature on a British population-based study reported that stroke survivors who experienced initial incontinence have a poorer outcome (BI<15) after stroke (Kammersgard et al., 2004), the results for this participant do not correspond to the above finding probably due to the age and cause of the stroke for Participant 002.

She had a final score of 67, which indicated a move from total dependency, with a score of 16 on admission, to assisted independence. Participant 002 improved significantly but was still moderately dependent on someone to perform personal ADLs, although her percentage improvement in personal ADLs was more than that in her upper limb mobility. However, significant improvement in personal ADLs was related more to her mobility and ambulation as well as her bowel and bladder control, but she still presented with dependence in dressing, washing, personal hygiene and managing clothes during toilet transfers since her dominant hand was affected by the stroke. These activities require more improvement in upper limb movement and bilateral hand function, which was congruent with the lower improvement on the hand subtest on the FMA. Participant 002 remained totally dependent longer after the five day period, which provided an outcome that is preferable for stroke survivors who are unable to attend outpatient rehabilitation and reduces caregiver burden (Mamabolo et al., 2009). She will require moderate to slight assistance with personal ADLs at home.

Participant 002 showed consistent improvement from the pre-test assessment up until the final assessment in both the FMA and the MBI. Many factors contributed to the improvement in both these assessments. Young age, motivation, and cognitive ability all had a positive effect on the outcome of the study (Prigatano and Wong, 1999). She had a score of 14 on the MMSE, which indicated moderate cognitive impairment. Her ability to follow directions resulted in better gains in hand and upper limb function (Barreca et al., 1999). The cognitive ability of this participant was not a barrier to achieving functional independence, with MBI scores achieving high scores except where bilateral hand

function was required (Jaywant et al., 2019). This participant was very motivated, which also appeared to contribute to her improvement. This factor was not assessed in the current study as studies do not consider social and emotional factors, such as motivation, when predicting outcome post stroke, even though studies have shown that a stroke survivor's motivation levels and goal setting are important factors in rehabilitation outcomes (Hakkennes et al., 2011).

The following diagram illustrates all the systems that had an influence on Participant 002's recovery in ADL and upper limb function.



Systems with a positive influence on recovery:

- Cognition
- Motivation
- Age

-Improved function of lower limb resultiing in improvement in ADL's such as walking and transfers.

Systems with a negative influence on recovery:

- Co-morbid features (HIV)
- Initial impairment in bowel and bladder function
- Upper limb function negatively impacting ADL's such as dressing
- Early initiation of therapy

Figure 5.2 Influence of various systems on Participant 002 recovery.

5.3.3: Participant 003

Participant 003 had a delay of 9 days before being admitted to the hospital. Evidence for early intervention post stroke is well established and the delay in care could be a reason for the limited improvement compared to the other participants in the study (Bettger et al., 2013). This was due to lack of access to transport to the hospital, as well as a lack of understanding of the family about the urgency for admission and medical attention for stroke. The participant also had undiagnosed hypertension, which is common in South

Africa as 48.7% of the population with hypertension are unscreened and undiagnosed (Berry et al., 2017).

The participant reported that his wife and family did try to improve motor function before admission, but he was found to have low scores for MMSE, FMA and BMI on admission. This indicated a more severe stroke, which may have been affected by his delay in admission (Kleim and Jones, 2008). He had already experienced associated impairments of pain and joint stiffness on admission to the study that required intervention by the researcher. This is consistent with the findings of Kwakkel, Kollen and Twisk (2006), who found that time between stroke and admission accounted for 19% of functional recovery in upper limb function as assessed with the ARAT during the first 2 months following stroke.

Participant 003 had a score of six initially on the overall FMA and showed improvement in some subtests on the FMA. This participant made the improvement of 14% overall and 2% in upper limb movement, which was not significant or a CID. This indicates moderate improvement overall and a slight improvement for upper limb on the GROC for the FMA within a five-day period. This represented slight improvement in movement at the shoulder, which was consistent with research findings that stated that if no upper limb movement was present on admission, limited progress can be expected (Houwink et al., 2013).

At baseline, the participant had movement in his hand and presented with mass flexion and a hooked grasp. Change was found during intervention with more improvement in his wrist movement as he had improvement of five points (50%) for his wrist movement, which had a CID but was not significant. The change in the wrist was from no movement initially to movement in all directions, and this reflects excellent improvement on the GROC for the FMA. He had non-significant improvement of two points (21%) in the hand, which reflected moderate improvement on the GROC for the FMA but did not have a CID. Participant 003 was able to use two grasps, namely the lateral prehension and palmar prehension after five days, showing neuroplastic changes that occurred over time. Participant 003 however showed no improvement in the coordination subtest of the FMA. These findings are congruent with those of Houwink et al. (2013), who found that

stroke survivors who had some movement in the paretic hand on admission did recover more dexterity at eight months post stroke. Literature indicates that regaining of movement in the upper limb was thought to occur proximally to distally, but this has since been disproved (Woodson, 2008), as shown with Participant 003 who had limited shoulder and elbow movement but improved with wrist and hand function after five days of treatment with an activity-based NMES programme.

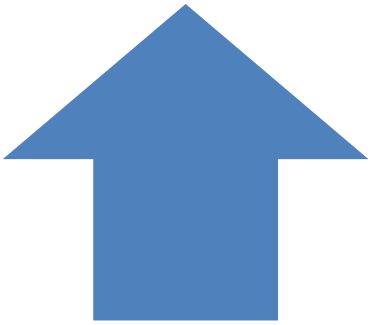
For Participant 003 at 58 years, it appears that the scores for the initial deficits related to the severity of his stroke, which also reflects his outcomes after intervention. Studies show that the stroke severity based on initial BMI or NHISS scores, which in his case were low, and cognitive impairments must be considered (Jeon et al., 2017; Kammersgard et al., 2004). The findings are consistent with other studies that found that the severity of a stroke is a strong indicator of functional outcome at discharge (Kwakkel et al., 2008). The activity-based NMES programme appeared to have had a limited effect on the improvement in motor function over a short period, possibly due to the delay in Participant 003 accessing therapy, as well as the severity of the deficits with which he presented. The use of NMES with this participant did support some change when NMES was integrated into stroke rehabilitation at an acute stage, but marked change was only found in hand and wrist function (Hatem et al., 2016).

The lack of improvement in upper limb function was reflected in the lack of improvement in his personal ADLs, with an excellent correlation over the five treatment sessions between the FMA and MBI. Participant 003 had a pre-test score of 22 on the MBI assessment, indicating severe dependence, and showed non-significant improvement of 17% on the final assessment with a score of 39, which indicated he was still severely dependent. He was dependent on someone else to perform personal ADLs and his percentage improvement in personal ADLs was less than that in his upper limb mobility. This reflected his inability to walk, mobilise in a wheelchair or climb stairs, as well as poor scores for personal hygiene, dressing, washing and toileting, which remained challenging. Although he had function in the affected non-dominant hand, the lack of movement in his upper limb compromised engagement in activities requiring bilateral function. Participant 003 was unable to continue ADLs at home without full time care on discharge.

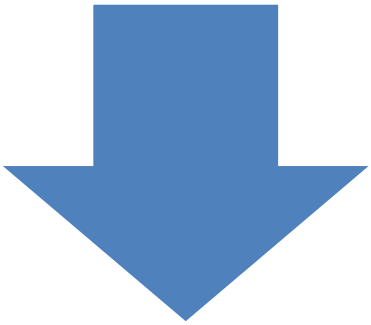
This outcome is undesirable for stroke survivors who are unable to attend outpatient rehabilitation and increases caregiver burden (Mamabolo et al., 2009).

The participant also scored a nine on the MMSE and his severe cognitive deficit could also have contributed to the limited improvement found on both the FMA and MBI. Cognitive function on admission is a strong indicator of overall function in stroke survivors (Kelly et al., 2003) and had an impact on the participant's ability to follow instructions, as well as his memory, as 81% of the variance for improvement in upper limb mobility is attributed to cognitive functioning (Barreca et al., 1999). The cognitive ability of this participant was a barrier to achieving functional independence, with MBI scores remaining low for all aspects except bladder and bowel control (Jaywant et al., 2019).

The following diagram illustrates all the systems that had an influence on Participant 003's recovery in ADL and upper limb function.



Systems with a positive influence on recovery:
- Presence of movement following stroke



Systems with a negative influence on recovery:
- Late admission/delay in therapy
- Cognition
- Stroke severity
- Co-morbid features (uncontrolled Hypertension)
- Associated impairments (joint stiffness and pain)
- Loss of function influencing ADL recovery

Figure 5.3 Influence of various systems on Participant 003 recovery

5.4 Change in the outcomes of upper limb motor function and personal activities of daily living

The first objective of the study was to assess the change in upper limb motor function and personal ADLs in stroke survivors who received a NMES activity-based programme. This has been considered for each participant and the combined effect of the programme in relation to other studies is discussed next.

5.4.1 Upper limb motor function

Initially, none of the participants had any changes in motor function from pre-test to post test on day 2, which could be explained by numerous factors. Stroke rehabilitation guidelines recommended that therapy should start once stroke survivors are stable and preferably 1-2 days post stroke (Rudd et al., 2017) and not in the first 24 hour period as therapy may be harmful (Coleman et al., 2017). Decrease in oedema and the removal of debris from inflammation still present in the brain could be a possible reason for the initial changes, as discussed above for Participant 002 (Chen et al., 2010). Other factors, such as motivation and understanding of task, as well as emotional reactions to the onset of a stroke, could also have played a role as well as the introduction of a new treatment technique that requires specific effort on the part of the stroke survivor. Any of these could have had an impact on the initial poor results and need further investigation. All participants started to show results after three days of NMES treatment.

Overall, the results correlate with research findings that an intensive course of NMES early after stroke can have a positive influence on motor function (Chan, 2008; Hatem et al., 2016). However, as in the current study, the stroke survivors should have some voluntary movement or spontaneous recovery of upper limb function. Houwink et al. (2013) noted that this is an important indicator for the initiation of a treatment technique such as NMES.

Research on the use of NMES in acute stroke survivors within the first two weeks after stroke has been limited due to the inability to exclude return of this voluntary movement or spontaneous recovery during this period (Ghaziani et al., 2018). Neuroplasticity during

this early period post stroke can be augmented by the introduction of therapy. This is especially important to ensure stroke survivors reach their full potential for upper limb recovery and function even in the presence of spontaneous recovery. The activity-based NMES programme in the current study appeared to support the spontaneous recovery that occurred, and further facilitated the improvement in strength, dexterity and participation in personal ADLs. The participants were showing little to no further recovery or improvement in upper limb function, as seen by the lack of change from baseline to session 2, but exhibited a statistically significant improvement on the overall score of the FMA and all subtests of the FMA, except for co-ordination, between sessions 3 and 5. Thus, the use of an activity-based NMES programme appeared to facilitate spontaneous recovery for these participants, which allowed for the use of the affected upper limb with practice in functional activities before discharge. It can therefore be debated that without an optimal environment that has a 'just right' challenge, spontaneous recovery would not occur as optimally as it should. This is particularly true in the short duration of hospitalisation in public institutions in South Africa (Cunningham and Rhoda, 2014).

Other studies on the use of NMES post stroke have reported contradictory results, however, most support the use of NMES in the acute phase of stroke. Research has reported improvement in the acute phase but in most studies, the length of the NMES programme is much longer than five days. A study by Ghaziani et al. (2018) yielded positive results when electrical stimulation was administered for seven days a week for four weeks. The participants used an electrical stimulation glove for 45 minutes before 20 minutes of task-oriented practice, supplementary to usual therapy. The authors concluded that electrical stimulation administered soon after stroke in patients with mild to moderate stroke and moderate upper limb impairment is a viable treatment option, as was seen with Participants 001 and 002 in the current study. This was supported by Au-Yeung and Hui-Chan (2014), who showed a positive effect of electrical stimulation on hand movement and grip strength in early rehabilitation for stroke survivors with mild to moderate stroke.

Ghaziani et al. (2018) concluded that for stroke survivors with limited movement it is still unclear whether electrical stimulation is a viable option, which is congruent with the

results for Participant 003 in the current study. His nine-point difference on the FMA did not achieve a significant difference or a CID, supporting no difference in the outcome of participants who received NMES and sham NMES as found by Ghaziani et al. (2018). The lack of change was ascribed to insufficient dose and frequency of electrical stimulation to induce changes more than what is expected from spontaneous recovery (Ghaziani et al., 2018).

According to an evidence-based review of stroke rehabilitation by Marquez-Chin et al. (2017), functional electrical stimulation therapy is one of the most effective techniques to improve voluntary movement in stroke survivors, particularly with severe impairments after stroke. They found that NMES was a viable option for 21 stroke survivors with severe impairments in the acute stroke setting. In their study, participants received 1-hour NMES sessions for five days per week over eight weeks. The participants had a mean difference of 27.2 on the FMA upper limb subtest indicating a CID (Marquez-Chin et al., 2017). A longer programme therefore may have had more effect for Participant 003 who was the one participant in the current study with severe stroke who showed little improvement possibly due to the limited duration and intensity of therapy.

The use of NMES with stroke survivors, in a setting similar to the current study was completed in Ahmedabad, India, another developing country. In this study, Sharma et al. (2015) found their group treated with NMES showed significant improvement ($p=<0.5$) compared to their control group, and recommend that this treatment be considered for stroke survivors who still have residual impairment two weeks post stroke. They felt the stroke survivors needed to be very motivated to participate in the treatment and their participants received a higher intensity of treatment (one hour for five days per week for one month) as they had better access to healthcare services (Sharma et al., 2015) than the participants in the current study. Other studies discussed above also indicated a longer period of treatment with NMES may be more beneficial, as spontaneous recovery can be expected for up to 10 weeks post stroke and improvement can still be expected six months following stroke (Kwakkel et al., 2006). Even though access to therapy after a few days of inpatient treatment was limited for the participants in the current study, the results support the use of an activity-based NMES programme for selected stroke

survivors, even over a five-day period. A follow up study would be beneficial to determine whether the upper limb function was maintained and strengthened and recommendations for stroke survivors with severe stroke in particular should be made to provide further treatment with NMES by requesting a longer admission or step down inpatient care.

Very little research has been published that considers the effect of NMES on both upper limb motor function and participation in personal ADLs, as it has been widely accepted that NMES should only be used to improve motor function and not activity participation.

5.4.2 Personal activities of daily living

Contradictory evidence for the use of NMES as an adjunct to typical care to support participation in ADLs still exists. A feasibility study by Meadmore et al. (2014) showed a statistically significant difference on the Fugl-Myer score as well as the ARAT for function and participation in personal ADL in participants with chronic stroke. Their results support the findings of the current study, where all participants had improvement in personal ADLs (Meadmore et al., 2014).

However, in a recent study by Guo et al. (2018) it was found that electrical stimulation had no influence on function and ADL as a secondary outcome using the Barthel Index assessment. This could possibly be due to the severity of stroke in their study population who did not present with active movement. This was supported by Eraifej et al. (2017) in a systematic review that reported stroke survivors also improved more on ADL measures in conjunction with upper limb recovery if the neuromuscular electrical stimulation was applied when voluntary movement was present in the first two months post stroke.

The results of the current study indicated that changes in personal ADLs were affected by other factors other than upper limb recovery. The severity of the participant's stroke in terms of lower limb function and pre-existing conditions, such as a lower limb amputation, meant two of the participants required a wheelchair to mobilise safely. Thus, aspects related to ambulation, transfers and mobility affected the level of independence

recorded on the MBI. Due to the nature of the study and the limited time available to treat stroke survivors, the focus was only on the upper limb function.

The outcomes for personal ADLs in the current study differed from other studies for stroke survivors in South Africa. Cunningham and Rhoda (2014) reported that stroke survivors in the Eastern Cape scored, on average, 81.5 on the MBI and required minimal to moderate assistance with ADLs after discharge from hospital. This indicated more independence in personal ADLs than the moderate to severe levels between 39 and 69 achieved by participants in the current study. Mamabolo et al. (2009) also reported that the greatest functional improvements in stroke survivors in South Africa were the ability to transfer and mobilise independently, while in the current study toilet transfers, bathing and personal hygiene were the items that had the greatest improvement. The items that showed the least improvement in their study was in bowel continence as well as feeding and washing, while in the current study the ability to ambulate and transfer had the least improvement (Mamabolo et al., 2009).

It would appear that the use of an activity-based NMES programme focusing on the upper limb could result in greater improvement in aspects requiring bilateral upper limb movement and hand function. The inclusion and repetition of activities with stimulated active movement, while participating in toilet transfers, managing clothes, bathing all parts of their body and personal hygiene, including hair care and shaving, is a possible hypothesis. Dressing showed less improvement due to problems related to fine motor skills required for fastenings as well as lower limb dressing for participants who were dependent in mobility. In the current study, the improvement assessed on the MBI correlated strongly with the improvement in upper limb movement measured by the FMA.

5.5 Correlation of motor ability and personal ADLs

The second objective of the study was to determine the association between the change in motor function and personal ADLs in stroke survivors who received a NMES activity-based programme.

All the participants in the current study had excellent correlations of r=0.85 between their FMA and MBI scores indicating similar improvement in the overall scores for the assessments. These findings were similar to those of Wood-Dauphinee, Williams and Shapiro (1990), who also found a strong relationship between motor ability and functional performance using the FMA and Barthel Index assessment scores (r=0.70) in their study with 172 stroke survivors. As in the current study, they assessed their participants in a short period post stroke where a correlation between the participants' motor ability and personal ADLs is possible as the effects of therapy support change in both variables in the acute phase. The inclusion of activities as part of the current research design compared to the traditional and repetitive movement therapy in the study by Wood-Dauphinee, Williams and Shapiro (1990), may account for the slightly higher correlations found in the current study. Participants were encouraged to use the affected limb in ADL activities and not compensate by using unilateral techniques in the five days they received the NMES intervention.

Contrary to the findings in the current study, literature suggests that an improvement in upper limb abilities do not translate to improvement in ADL measures (Kwakkel et al., 2008). In these studies, data were collected at three to six months post stroke. Studies on upper limb dressing by Walker and Lincoln (1991) and Suzuki et al. (2006) found no significant relation between dressing and motor ability. In the study by Suzuki et al. (2006), the lack of a final assessment of motor ability affected their results, along with the use of descriptive statistics and variables not being tested as independent predictors, making comparison to the current study difficult. Kwakkel and Kollen (2013) also reported that motor function and different intensities of rehabilitation of the upper limb did not correlate with ADL scores. They suggested that stroke survivors compensate with ADL tasks by using the unaffected limb and this is more likely to occur in the months post-stroke. However, consensus has still not been reached and Walker and Lincoln (1991) did report that lower limb dressing three months post-stroke was associated with motor ability. There still is no clear understanding of the role of neurological impairment on the ability to relearn dressing.

Thus, the role of time since stroke and spontaneous recovery must be considered in light of the findings, as well as other demographic and medical factors having an impact on recovery.

5.6 Influence of demographic and medical factors in the change in upper limb movement and personal activities of daily living

Another objective of this study was to describe the change in upper limb impairment and personal ADLs in stroke survivors, according to demographic and medical factors, which affect the outcome of stroke in a NMES activity-based programme.

5.6.1 Dominance

In terms of dominance, only one participant presented with stroke that affected the dominant upper limb. The small sample size made it difficult to determine whether dominance has an influence on personal ADLs and motor function of stroke survivors in an activity-based neuromuscular electrical stimulation programme.

Similar motor recovery was seen for participants with dominant and non-dominant upper limb strokes overall, with all participants having had a stroke in the left hemisphere. It is reported that the left hemisphere appears to be dominant for planning, sequencing and modifying motor patterns compared to the right hemisphere, which appears dominant for visuospatial and sensory aspects (Harris and Eng, 2006). Studies suggest hemispheric asymmetry rather than dominance could result in different outcomes following stroke since left hemispheric lesions can result in contralateral and ipsilateral arm movement deficits, whereas right hemispheric lesions result in contralateral deficits only (Harris and Eng, 2006). Thus, it is possible that the participants in this study could have had some effect on the ipsilateral unaffected side due to motor planning or other deficits. Assessment of fine motor function of the participants' unaffected side fell outside of the scope of the study therefore this component was not investigated.

A stroke in the dominant side may also result in less motor impairments due to stronger muscles, better grip strength and more efficient motor unit recruitment resulting in

better performance. This stems from the extensive practice, experience and the development of motor programmes and skills in the dominant upper limb. It was found that this could provide a protective factor and possible better recovery if the stroke occurs on the dominant side in stroke survivors with mild to severe stroke. Therefore, if the dominant hand is affected by the stroke it may demonstrate less impairment immediately following the stroke due to this protective effect. Moreover, it is hypothesised that stroke survivors whose dominant arm is affected after stroke would be more motivated to use that limb and thus increase use after stroke. The sample in the current study was however too small and diverse to draw any conclusions about the effect of dominance in stroke (Harris and Eng, 2006).

While it has been indicated that dominance may affect the MBI scores due to lack of dexterity in the non-dominant hand initially (Harris and Eng, 2006), in the current study Participants 001 and 003, whose dominant upper limbs were affected, did have higher MBI scores initially, while the scores for Participant 002 were higher after session 2. This may have reflected the use of her dominant hand in tasks in activities such as washing and dressing, which were normally done with this hand.

Yoo et al. (2010) found no difference in functional outcomes amongst right and left sided strokes and that dominance should not play a role in the outcome of stroke survivors. Harris and Eng (2006) found that a person whose non-dominant upper limb was affected by stroke showed no advantage over those with the dominant side affected for personal ADLs. Both these studies were conducted on participants with chronic stroke and it was stated that these stroke survivors used compensatory strategies to minimise the effect of hand dominance. Therefore, different study populations could be a possible reason for the conflicting results.

Harris and Eng (2006) indicated that the influence of dominance in stroke outcomes could be pain. Stroke survivors who suffered a right hemispheric stroke are more likely to complain of pain and have higher levels of pain compared to those who have suffered a left hemispheric stroke. This may be attributed to the specialisation of the right hemisphere for sensory processing (Harris and Eng, 2006). In the current study, this was

not a factor and only Participant 003 presented with pain due the presence of associated factors, such as contractures and muscle stiffness.

More research is needed in on the influence of dominance on stroke recovery especially during the acute and sub-acute phase to be able to prescribe effective treatment such as NMES. No published research on dominance and the effect of NMES was found. It is important to note that activities in the NMES programme in the current study usually made use of bilateral hand function and not on unilateral function, which could mean that dominance might not have had as much influence on outcome (Harris and Eng, 2006).

5.6.2 Age

The results of the current study correspond with numerous studies that conclude that age alone cannot predict outcomes following stroke (Li et al., 2018; Shehatah, 2010). Although the results were mixed for age, the youngest participant, Participant 002, did not have better outcomes in terms of motor recovery on the FMA, but she did have better outcomes at the end of the intervention period than the older stroke survivors for personal ADLs on the MBI assessment. Comparison to other research was difficult as most studies indicate age has an effect on the outcome of stroke for those over 75 years of age. Karaahmet et al. (2018) found that older participants had less improvement in Brunnstrom stages, while Sawaki et al. (2003) found that older participants had more difficulty encoding motor patterns as rehearsed in motor training. Since Participant 001, who was the oldest participant, had better motor recovery it would appear in the current study that a combination of age and other risk factors, such as stroke severity, gender, premorbid functioning and incontinence, are the reason for the re-acquisition of motor ability, as assessed with the FMA, rather than age alone (Li et al., 2018; Shehatah, 2010).

The better personal ADLs outcomes for Participant 002 may be attributed in part to her age. Regarding change in personal ADLs, it has been found that younger stroke survivors may have significantly better outcomes and achieve higher Modified Barthel Index scores during their hospital stay (Kalra, 1994). This was corroborated by Kwakkel, Kollen and Krebs (2008) who reported strong evidence that age is strongly associated with the final

personal ADL outcomes beyond three months post-stroke. Participant 002, being younger, also had less co-morbidity affecting her mobility, thus influencing the improvement in personal ADLs. This finding is congruent with literature, which reports that age-related comorbidities, such as mobility disorders and arthritis, affect functional outcomes after stroke (Karaahmet et al., 2018).

5.6.3 Cognition

The results confirm that cognitive impairment after stroke onset may have an effect on the prognosis of regaining upper limb function, as assessed with the FMA, as well as personal ADLs as assessed by the MBI. Two of the participants had a moderate impairment in cognitive function and participant 003 had a severe cognitive impairment. Lower scores on cognitive assessments may indicate more severe neurological deficits, as recorded for Participant 003 in the current study, which supports the lower scores for his motor ability on the FMA. Due to the small sample size, it was not possible to distinguish which cognitive ability had the effect on motor ability and only the total score for the MMSE and FMA were considered in the analysis.

The two participants with moderate impairment in cognitive function, Participants 001 and 002, experienced significant improvement in both FMA and MBI scores. These findings were congruent of those reported by Jaywant et al. (2019), who found that acute stroke survivors with a higher score on the MOCA had better outcomes on the Functional independence measure (FIM). This confirmed the results of Abzhandadze et al. (2018) who found that cognitive functions assessed at least 36 hours after stroke can reflect the stroke survivors ADL performance, supporting the conclusion that combination of stroke-related neurological severity and cognitive functions may explain much of the personal ADL dependence at early stages of stroke (Abzhandadze et al., 2018). Prigatano and Wong (1999) reported that at discharge, stroke survivors with higher scores in awareness, affect, visual spatial skills, memory, and attention/concentration on the Barrow Neurological Institute Screen for Higher Cerebral Functions were more likely to be independent in personal ADLs and have better motor recovery irrespective of the initial level of performance.

5.7 Limitation to study

Limitations to the study included a small sample size, and a lack of blinding of the researcher and the participants. Furthermore, a lack of control had an influence on this study and treating stroke survivors when spontaneous recovery was occurring could be a reason for the improvement that occurred. Due to the study design, the researcher was unable to conclude whether the changes from the study were permanent since there was no follow up with participants once discharged from the study. Motivation to participate in therapy was also not assessed.

Although not part of the study, it is important to note that the researcher experienced some challenges during the study. As part of the methodology, the participants received two 30-minute sessions of NMES intervention. The sessions included 30 minutes of actual NMES stimulation and did not include the time to prepare participants as well as the placement of the electrodes or position changes. Some sessions were 45 minutes, which was not feasible for therapists. The observations by the researcher were similar to what other therapists experience (Auchstaetter et al., 2016). The time needed to ensure accurate placements of the electrodes decreased as the sessions continued over time.

The MBI assessment is not without criticism. Some authors are of the opinion that the MBI assessment does not measure an improvement in participation in personal ADLs, but rather it is a measure of how well a stroke survivor compensates (Houlden et al., 2006). This was the main reason why the FIM/FAM was created and yet, even with this measure, stroke survivors would still compensate and score higher on the measure than their function predicted (Houlden et al., 2006). The MBI assessment remains widely used due to its ease of use, and quick and simple scoring (Leung et al., 2007). A study by Leung, Chan and Shah (2007) found that some items in the MBI did not take cultural differences of stroke survivors into consideration. Different eating utensils, types of bathing methods and equipment (sponge and bowl washing,) could have an influence on scoring (Leung et al., 2007). A similar effect can also be expected in the context of the current study, where participants may prefer using their hand rather than knife and fork for eating; this could

have an influence in the measure of independence that they could achieve (Breytenbach, 2016).

The use of the MMSE may have also provided limited insight into the specific nature of the cognitive dysfunction, since it does not assess executive functioning (Oliver, 2004; Prigatano and Wong, 1999). The MMSE was reported as the most widely used screening tool for cognitive functioning in the South African context but has limitations due to age, educational level, ethnicity and language of administration, which have been shown to influence frequency of errors and scores on the MMSE (Oliver, 2004; Ostrosky-Solís et al., 2004). Some of the items on the test, such as the drawing of a shape, placed the participants with dominant side strokes at a disadvantage since they had to use their non-dominant hand. The results of the MMSE could have underscored cognitive function in this sample, but they did allow for comparison in terms of motor recovery and personal ADL scores for the three participants.

The researcher has no conflict of interest in the role as researcher or treating practitioner but this may have led to potential bias since there was no blinding of the assessor. The situation in which the research was carried out did not allow for assessments to be completed by another therapist and thus may have resulted in a Type 1 error.

CHAPTER 6: CONCLUSION

6.1 Main findings

A case study research design was used with three stroke survivors who complied with the inclusion and exclusion criteria associated with the application of NMES after stroke. A NMES programme of two 30-minute sessions was administered in addition to a routine occupational therapy programme for a duration of five days during the participant's short inpatient admission.

Neuromuscular electrical stimulation is a treatment technique recommended for the treatment of motor function for stroke survivors when voluntary movement has returned (Bracciano, 2008). This is because effective motor restoration after stroke depends on repeated and intensive practice to speed up the process of motor recovery (Chae et al., 2008).

The participants achieved a significant statistical improvement in overall motor function as assessed by the Fugl-Meyer assessment (FMA) ($p=0.002$). Scores on all subtests of the FMA improved significantly for two participants, except for the coordination subtest. The NMES programme had a positive effect on the motor function of participants in a regional hospital in rural Mpumalanga, South Africa.

The use of an activity-based NMES programme focusing on the upper limb resulted in greater improvement in aspects requiring bilateral upper limb and hand function due to the inclusion and repetition of activities with stimulation of active movement while participating in meaningful tasks. Two participants had significant change and a CID in upper limb function, which supports the studies that have shown positive results in patients with mild to moderate stroke. The improvement, which occurred after session 2, indicated improvement that was not seen prior to the use of NMES at baseline and session 1. This indicates that NMES appears to have facilitated recovery of movement above that which had occurred due to spontaneous recovery. For severe stroke impairments, more research is needed before NMES can be recommended as a

treatment technique for severe stroke (Rosewilliam et al., 2012). For a short inpatient programme, as in used in the current study, the participant with severe deficits did not have a CID in his motor function.

In the current study, the improvement assessed on the MBI correlated excellently with the improvement in upper limb movement measured by the FMA. This finding was similar to that found for other stroke survivors during acute inpatient rehabilitation (Nascimento et al., 2014), and improvement in personal activities of daily living assessed on the Modified Barthel Index (MBI) also showed statistically improvement ($p = <0.001$) for one participant. This finding was based on the assumption that if underlying upper limb movement were improved there would be improvement in personal ADLs (Wood-Dauphinee et al., 1990). The inclusion of activities of daily living in the NMES treatment programme in the current study appears to support this assumption. It would appear that the use of an activity-based NMES programme focusing on the upper limb could result in greater improvement in aspects requiring bilateral upper limb and hand function due to the inclusion and repetition of activities with stimulation active movement while participating in feeding, dressing and washing. In the current study, this improvement assessed on the MBI correlated strongly with the improvement in upper limb movement measured by the FMA.

Greatest improvement was found for toilet transfer, personal hygiene and washing, which indicated participants may be using their affected arm to assist with these activities in managing clothes when toileting, washing and during hair care.

Scores on the FMA and MBI indicated that initial deficits or severity of the stroke determined outcomes rather than age and/or dominance. Cognition appeared to play a role in outcomes and participants with better cognitive function had higher scores on the MMSE, and better outcomes after the intervention. The small sample and case study design precluded any definite conclusions being drawn from the data in the current study. The results are however congruent with the literature for stroke survivors in the acute phase and confirmed that the effectiveness of NMES may depend on medical and demographic factors which differ for each stroke survivor.

It is important to note in this case study that each participant presented with a different level of function and each was unique. Due to the difference in their motor recovery and cognitive function, the activities which were meaningful to them, their occupations, comorbidities and the need for support during therapy, the clinical reasoning of the therapist for each stroke survivor had to be individualised, and the outcomes indicated the importance of using a case study to present the outcomes for each participant when taking into consideration demographic and medical factors.

6.2 Implication for clinical practice

The current study assisted in providing evidence for NMES as a possible treatment technique in acute stroke based on different factors, in the weeks after stroke to improve upper limb movement and personal ADLs. Even though access to therapy after a few days of inpatient treatment was limited for the participants in the current study, the results support the use of an activity-based NMES programme for selected stroke survivors over a five-day period.

Stroke is increasing in developing countries, with the indirect costs associated with stroke surpassing the direct costs. Stroke survivors in South Africa are discharged before they have reached functional independence, and due to the high cost of transport, have difficulty accessing outpatient services (Mamabolo et al., 2009). As a tool, NMES should be considered by therapists in the acute setting to improve both motor function and participation in ADLs. The use of NMES is relatively inexpensive with few side effects, and may be cost effective in terms of the outcomes obtained. However, it is time intensive for the therapist using it and requires individual sessions in addition to routine therapy for practice and repletion of movement and skills.

Neuromuscular electrical stimulation is not taught at undergraduate level in occupational therapy training and therapists may be unfamiliar with the use of NMES in clinical practice (Austaetter et al. 2016). It is important that postgraduate courses be made available to guide the introduction of this technique into occupational therapy practice, emphasising its use as an adjunctive to an activity-based programme.

6.3 Recommendations

Since contradictory results are reported in literature, with regard to using NMES as an adjunctive to routine occupational therapy, it is suggested that further research on the effectiveness in the acute phase of stroke is completed. Larger samples, as well as the inclusion of a control group, should be considered.

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APPENDIX A

Demographic information sheet:

Participant no:_____

1. Age: _____
2. Gender(tick appropriate box):

Female	Male

3. Dominant arm(tick appropriate box):

Left	Right

4. Date of incident (DD:MM:YY):

_____

5. Date of admission: (DD:MM:YY):

_____

6. Date of commencement of therapy: (DD:MM:YY):
   _____
7. Co-morbid features (tick appropriate box):

Hypertension	Diabetes
Cholesterol	Depression
Peripheral vascular disease	Arthritis
Dementia	Other

8. Other factors (tick appropriate box):

Dependent in essential ADL's pre-stroke	Bowel and bladder incontinence
Hemi-neglect	Pusher syndrome present
Altered level of consciousness	Severe visuospatial deficits
Severe cognitive impairments	

9. Type of stroke (tick appropriate box)

Haemorrhagic	Ischaemic

FOR OFFICE USE ONLY:

	1, 2, 3
	4, 5
	6
	7
	8-14
	15-21
	22-28
	29-36
	37-42
	43, 44

APPENDIX B

Participant no:_____

Fugl-Myer Assessment

Pre-testing

Date:

Shoulder/elbow/forearm				
Stage	**Instruction**	**Response**	**Scoring criteria**	**Score**
I & II Reflex activity	Tap the biceps & finger flexor tendons	Stretch reflex at elbow and/or fingers	0 = no reflex can be elicited 2= reflex can be elicited	
	Tap the triceps tendon	Stretch reflex		
III Voluntary Movement within Synergy	"Turn your affected hand palm up and touch your ear"	**Flexor synergy**	0 = cannot perform 1 = can perform partly 2 = can perform faultlessly	
		Shoulder retraction		
		Shoulder elevation		
		Shoulder abduction to 90°		
		Shoulder external rotation		
		Elbow flexion		
		Forearm supination		
	"Turn your hand palm down and touch your unaffected knee"	**Extensor synergy**		
		Shoulder adduction & internal rotation		
		Elbow extension		
		Forearm pronation		
IV Voluntary Movement mixing	"Show me how you would put a belt	Affected hand moves to lumbar	0=cannot perform 1= hand must actively pass	

Flexor & extensor Synergy	around you [or tie an apron]	spine area	ASIS 2= faultless	
	'Reach forward to take object" [held in front of patient]	Reaches into 90° of shoulders flexion	0=elbow flexes or shoulder abducts immediately 1= if these occur later in motion 2= faultless	
	''Put your arm to your side & bend your elbow. Turn your palm up & down.''	Pronates and supinates forearm with elbow at 90° and shoulder at 0°	0= if cannot position arm or cannot pronate or supinate 1= shoulder and elbow joints correctly positioned and supination seen 2= faultless	
V:Voluntary movement outside of synergies	"Turn your palm down and reach to touch object held out to side"	Abducts shoulder to 90° with elbow extended to 0° forearm pronated	0= initial elbow flexion or loss of pronation 1= partial motion or elbow flexes and forearm supinates later in motion 2= faultless	
	"Reach as high as you can toward the ceiling"	Flexes shoulder from 90° to 180°	0= elbow flexes or shoulder abducts immediately 1= if these occur later in motion 2 = faultless	
	"Reach your arm directly forward and turn your palm up and down"	Flexes shoulder to 30-90°; extends elbow to 0°; and supinates and pronates	0 = if cannot position arm or cannot rotate 1 = correct position and beginning rotation 2 = faultless	
VI: Normal Reflex Activity (tested if patient scores 6 in stage V tests)	Tap on biceps, triceps and fingers flexor tendons	Normal reflex response	0 = 2 reflexes are markedly hyperactive 1 = 1 reflex hyperactive or 2 reflexes lively 2 = no more than 1 reflex lively and none hyperactive	

		Total points		
Wrist				
Stage	**Instruction**	**Response**	**Scoring criteria**	**Score**
Wrist stability with elbow flexed	Put the shoulder in 0°, elbow in 90° Flexion and forearm pronated. "Lift your wrist and hold it there"	Patient extends wrist to 15°. Therapist can hold upper arm position.	0 = cannot extend 1 = can extend, but not against resistance 2 = can maintain against slight resistance.	
Wrist stability with elbow extended	Put the elbow in 0°. "Lift your wrist and hold it there	Patient extends wrist to 15°. Therapist can hold upper arm position.	0 = cannot extend 1 = can extend, but not against resistance 2 = can maintain against slight resistance.	
Active motion with elbow flexed and shoulder at 0°	"Move your wrist up and down a few times".	Patient moves smoothly from full flexion to full extension. Therapist can hold upper arm.	0 = no voluntary movement 1 = moves but less than full range 2= faultless	
Active motion with elbow extended	"Move your wrist up and down a few times"	Patient moves smoothly from full flexion to full extension. Therapist can hold upper arm.	0 = no voluntary movement 1 = moves but less than full range 2= faultless	
Circumduction	"Turn your wrist in a circle like this" [demonstrate]	Makes a full circle, combining flexion and extension with ulnar and radial deviation.	0 = cannot perform 1 = jerky or incomplete motion 2 = faultless	
		Total points		

Hand				
Stage	**Instruction**	**Response**	**Scoring criteria**	**Score**
III: Mass Flexion	"Make a fist"	Patient flexes fingers	0 = no flexion 1 = less than full flexion as compared to other hand 2 = full active flexion	
III: Hook Grasp	" Hold this shopping bag by the handles"	Grasp involves MCP extension And PIP & DIP flexion	0 = cannot perform 1 = active grasp no resistance 2 = maintains grasp against great resistance	
IIIB-VI: Finger extension	" Let go of the shopping bag" "Open your hands wide"	From full active or passive flexion, patient extends all fingers	0 = no extension 1=partial extension or able to release grasp 2 = Full range of motion as compared to other hand	
IV: Lateral Prehension	"Take hold of this sheet of paper [or playing card]."	Patient grasps between thumb & index finger	0 = cannot perform 1 = can hold paper but not against tug 2 = holds paper well against tug	
V: Palmar Prehension	"Take hold of this pencil as if you were going to write"	Therapist holds pencil upright and patient grasps it	0 = cannot perform 1 = can hold pencil but not against tug 2 = holds pencil well against tug	
V: Cylindrical grasp	"Take hold of this paper cup" [or pill bottle]	Therapist holds the object and patient grasps with 1st and 2nd fingers together	0 = cannot perform 1 = can hold cup but not against tug 2 = holds cup well against tug	
	"Take hold of this tennis ball [or apple]	Patient grasps with fingers	0 = cannot perform	

VI: Spherical grasp		abducted	1 = can hold ball but not against tug	
			2 = holds ball well against tug	
		Total points		

Coordination				
Stage	**Instruction**	**Response**	**Scoring criteria**	**Score**
VI Normal Movement	"Close eyes = Now, touch your nose with your fingertip. Do that as fast as you can 5 times"	Patient does finger-to-nose test		
		Tremor	0 = marked 1 = slight 2 = none	
		Dysmetria	0 = pronounced and unsystematic 1 = slight and systematic 2 = none	
		Speed	0 = > 6 sec slower 1 = 2-5 sec slower 2 = < 2 sec slower	
		Total points		

Fugl-Myer Assessment

Post-testing

Date:

Shoulder/elbow/forearm				
Stage	**Instruction**	**Response**	**Scoring criteria**	**Score**
I & II Reflex activity	Tap the biceps & finger flexor tendons	Stretch reflex at elbow and/or fingers	0 = no reflex can be elicited 2= reflex can be elicited	
	Tap the triceps tendon	Stretch reflex		
III Voluntary Movement within Synergy	"Turn your affected hand palm up and touch your ear"	**Flexor synergy**	0 = cannot perform 1 = can perform partly 2 = can perform faultlessly	
		Shoulder retraction		
		Shoulder elevation		
		Shoulder abduction to 90°		
		Shoulder external rotation		
		Elbow flexion		
		Forearm supination		
	"Turn your hand palm down and touch your unaffected knee"	**Extensor synergy**		
		Shoulder adduction & internal rotation		
		Elbow extension		
		Forearm pronation		
IV Voluntary Movement mixing Flexor & extensor Synergy	"Show me how you would put a belt around you [or tie an apron]	Affected hand moves to lumbar spine area	0=cannot perform 1= hand must actively pass ASIS 2= faultless	
	'Reach forward to take object" [held in front of patient]	Reaches into 90° of shoulders flexion	0=elbow flexes or shoulder abducts immediately 1= if these occur later in	

			motion 2= faultless	
	''Put your arm to your side & bend your elbow. Turn your palm up & down.''	Pronates and supinates forearm with elbow at 90° and shoulder at 0°	0= if cannot position arm or cannot pronate or supinate 1= shoulder and elbow joints correctly positioned and supination seen 2= faultless	
V:Voluntary movement outside of synergies	"Turn your palm down and reach to touch object held out to side"	Abducts shoulder to 90° with elbow extended to 0° forearm pronated	0= initial elbow flexion or loss of pronation 1= partial motion or elbow flexes and forearm supinates later in motion 2= faultless	
	"Reach as high as you can toward the ceiling"	Flexes shoulder from 90° to 180°	0= elbow flexes or shoulder abducts immediately 1= if these occur later in motion 2 = faultless	
	"Reach your arm directly forward and turn your palm up and down"	Flexes shoulder to 30-90°; extends elbow to 0°; and supinates and pronates	0 = if cannot position arm or cannot rotate 1 = correct position and beginning rotation 2 = faultless	
VI: Normal Reflex Activity (tested if patient scores 6 in stage V tests)	Tap on biceps, triceps and fingers flexor tendons	Normal reflex response	0 = 2 reflexes are markedly hyperactive 1 = 1 reflex hyperactive or 2 reflexes lively 2 = no more than 1 reflex lively and none hyperactive	
		Total points		

Wrist

Stage	Instruction	Response	Scoring criteria	Score
Wrist stability with elbow flexed	Put the shoulder in 0°, elbow in 90°	Patient extends wrist to 15°.	0 = cannot extend 1 = can extend, but not	

	Flexion and forearm pronated. "Lift your wrist and hold it there"	Therapist can hold upper arm position.	against resistance 2 = can maintain against slight resistance.	
Wrist stability with elbow extended	Put the elbow in 0°. "Lift your wrist and hold it there	Patient extends wrist to 15°. Therapist can hold upper arm position.	0 = cannot extend 1 = can extend, but not against resistance 2 = can maintain against slight resistance.	
Active motion with elbow flexed and shoulder at 0°	"Move your wrist up and down a few times".	Patient moves smoothly from full flexion to full extension. Therapist can hold upper arm.	0 = no voluntary movement 1 = moves but less than full range 2= faultless	
Active motion with elbow extended	"Move your wrist up and down a few times"	Patient moves smoothly from full flexion to full extension. Therapist can hold upper arm.	0 = no voluntary movement 1 = moves but less than full range 2= faultless	
Circumduction	"Turn your wrist in a circle like this" [demonstrate]	Makes a full circle, combining flexion and extension with ulnar and radial deviation.	0 = cannot perform 1 = jerky or incomplete motion 2 = faultless	
		Total points		

Hand

Stage	Instruction	Response	Scoring criteria	Score
III: Mass Flexion	"Make a fist"	Patient flexes fingers	0 = no flexion 1 = less than full flexion as compared to other hand	

			2 = full active flexion	
III: Hook Grasp	" Hold this shopping bag by the handles"	Grasp involves MCP extension And PIP & DIP flexion	0 = cannot perform 1 = active grasp no resistance 2 = maintains grasp against great resistance	
IIIB-VI: Finger extension	" Let go of the shopping bag" "Open your hands wide"	From full active or passive flexion, patient extends all fingers	0 = no extension 1=partial extension or able to release grasp 2 = Full range of motion as compared to other hand	
IV: Lateral Prehension	"Take hold of this sheet of paper [or playing card]."	Patient grasps between thumb & index finger	0 = cannot perform 1 = can hold paper but not against tug 2 = holds paper well against tug	
V: Palmar Prehension	"Take hold of this pencil as if you were going to write"	Therapist holds pencil upright and patient grasps it	0 = cannot perform 1 = can hold pencil but not against tug 2 = holds pencil well against tug	
V: Cylindrical grasp	"Take hold of this paper cup" [or pill bottle]	Therapist holds the object and patient grasps with 1st and 2nd fingers together	0 = cannot perform 1 = can hold cup but not against tug 2 = holds cup well against tug	
VI: Spherical grasp	"Take hold of this tennis ball [or apple]	Patient grasps with fingers abducted	0 = cannot perform 1 = can hold ball but not against tug 2 = holds ball well against tug	
		Total points		
Coordination				

Stage	Instruction	Response	Scoring criteria	Score
VI Normal Movement	"Close eyes = Now, touch your nose with your fingertip. Do that as fast as you can 5 times"	Patient does finger-to-nose test		
		Tremor	0 = marked 1 = slight 2 = none	
		Dysmetria	0 = pronounced and unsystematic 1 = slight and systematic 2 = none	
		Speed	0 = > 6 sec slower 1 = 2-5 sec slower 2 = < 2 sec slower	
		Total points		

APPENDIX C

Barthel Index information sheet:

Participant no:

Total: Chair/bed transfer:	
Total: Ambulation	
Total: Ambulation/wheelchair	
Total: Stair climbing	
Total: Toilet transfers	
Total: Bowel Control	
Total: Bladder Control	
Total: Bathing	
Total: Dressing	
Total: Personal Hygiene (Grooming)	
Total: Feeding	
Total for all sub scores	

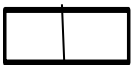
FOR OFFICE USE ONLY:



1, 2, 3



4, 5



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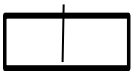

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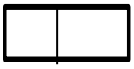

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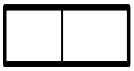

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21, 22



23, 24, 25

Modified Barthel index

Index/Item	Score	Description of score
Chair/bed transfers	**0**	Person is unable to transfer alone. Two attendants are required to transfer the person with or without a mechanical device.
	3	Person able to participate but requires maximal assistance of one person in all aspects of the transfer.
	8	Person able to transfer but requires the assistance of one other person. Assistance may be required in any aspect of the transfer.
	12	The presence of another person is required either as a confidence measure, or to provide supervision for safety.
	15	The person can safely approach the bed, walking or in a wheelchair, lock the brakes of the wheelchair, lift footrests, or position walking aid, move safely to the bed, lie down, come to a sitting position on the side of the bed, change the position of the wheelchair, transfer back into it safely and/or grasp aid and stand. The person must be independent in all the aspects above.
Ambulation	**0**	Dependent in ambulation.
	3	Constant presence of one or more assistant is required during ambulation.
	8	Assistance is required with reaching aids and/or their manipulation. One person is required to offer assistance.
	12	The person is independent in ambulation but unable to walk 50 metres without help, or supervision is needed for confidence or safety in hazardous situations.
	15	The person must be able to wear braces if required, lock and unlock these braces assume standing position, sit down, and place the necessary aids into position for use. The person must be able to crutches, canes or a walkarette, and walk 50 metres without help or supervision.
Wheelchair	**0**	Dependent in wheelchair ambulation.

(if unable to walk). Only applicable if person rated "0" for ambulation and only if person is trained in w/c management	**1**	Person can propel self, over short distances on flat surface, but assistance is required for all other steps of wheelchair management.
	3	Presence of one person is necessary and constant assistance is required to manipulate chair to table, bed, etc.
	4	The person can propel self for a reasonable duration over regularly encountered terrain. Minimal assistance may still be required in "tight corners," or to negotiate a kerb 100mm high.
	5	To propel wheelchair independently, the person must be able to go around corners, turn around, manoeuvre the chair to a table, bed, toilet, etc. The person must be able to push a chair at least 50 metres and negotiate a kerb.
STAIR CLIMBING	**0**	The person is unable to climb stairs.
	2	Assistance is required in all aspects of chair climbing, including assistance with walking aids.
	5	The person is able to ascend/descend but is unable to carry walking aids and needs supervision and assistance.
	8	Generally, no assistance is required. At times supervision is required for safety due to morning stiffness, shortness of breath, etc.
	10	The person is able to go up and down a flight of stairs safely without help or supervision. The person is able to use handrails, cane or crutches when needed and is able to carry these devices as he/she ascends or descends.
TOILET TRANSFERS	**0**	Fully dependent in toileting.
	2	Assistance required in all aspects of toileting.
	5	Assistance may be required with management of clothing, transferring, or washing hands.
	8	Supervision may be required for safety with normal toilet. A commode may be used at night but assistance is required for emptying and cleaning.

	10	The person is able to get on/off the toilet, fasten clothing and use toilet paper without help. If necessary, the person may use a bedpan, commode or urinal at night, but must be able to empty it and clean it.
BOWEL CONTROL	**0**	The person is bowel incontinent.
	2	The person needs help to assume appropriate position, and with bowel movement facilitatory techniques.
	5	The person can assume appropriate position, but cannot use facilitatory techniques or clean self without assistance and has frequent accidents. Assistance is required with incontinence aids such as pad, etc.
	8	The person may require supervision with the use of suppository or enema and has occasional accidents.
	10	The person can control bowels and has no accidents, can use suppository, or take an enema when necessary.
BLADDER CONTROL	**0**	The person is dependent in bladder management, is incontinent, or has indwelling catheter.
	2	The person is incontinent but is able to assist with the application of an internal or external device.
	5	The person is generally dry by day, but not at night and needs some assistance with the devices.
	8	The person is generally dry by day and night, but may have an occasional accident or need minimal assistance with internal or external devices.
	10	The person is able to control bladder day and night, and/or is independent with internal or external devices.
	0	Total dependence in bathing self.
	1	Assistance is required in all aspects of bathing, but person can make some contribution.

BATHING	**3**	Assistance is required with either transfer to shower/bath or with washing or drying, including inability to complete a task because of condition or disease, etc.
	4	Supervision is required for safety in adjusting the water temperature, or in the transfer.
	5	The person may use a bathtub, a shower, or take a complete sponge bath. The person must be able to do all the steps of whichever method is employed without another person being present.
DRESSING	**0**	The person is dependent in all aspects of dressing and is unable to participate in the activity.
	2	The person is able to participate to some degree, but is dependent in all aspects of dressing.
	5	Assistance is needed in putting on, and/or removing any clothing.
	8	Only minimal assistance is required with fastening clothing such as buttons, zips, bra, shoes, etc.
	10	The person is able to put on, remove corset and braces, as prescribed.
PERSONAL HYGIENE (Grooming)	**0**	The person is unable to attend to personal hygiene and is dependent in all aspects.
	1	Assistance is required in all steps of personal hygiene, but person can make some contribution.
	3	Some assistance is required in one or more steps of personal hygiene.
	4	Person is able to conduct his/her own personal hygiene but requires minimal assistance before and/or after the operation.
	5	The person can wash his/her hands and face, comb hair, clean teeth and shave. A male person may use any kind of razor but must insert the blade, or plug in the razor without help, as well as retrieve it from the drawer or cabinet. A female person must apply her own make-up, if used, but need not braid or style her hair.
	0	Dependent in all aspects and needs to be fed, nasogastric needs to be administered.

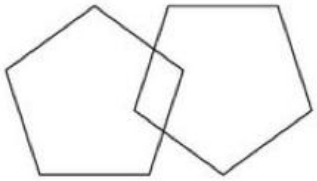
FEEDING	**2**	Can manipulate an eating device, usually a spoon, but someone must provide active assistance during the meal.
	5	Able to feed self with supervision. Assistance is required with associated tasks such as putting milk/sugar into tea, salt, pepper, spreading butter, turning a plate or other "set up" activities.
	8	Independence in feeding with prepared tray, except may need meat cut, milk carton or jar lid opening, etc. The presence of another person is not required.
	10	The person can feed self from a tray or table when someone puts the food within reach. The person must put on an assistive device if needed, cut food, and if desired use salt and pepper, spread butter, etc.

APPENDIX D

The Mini-Mental State Exam

Patient_____ Examiner _____ Date_____

Maximum	Score	
		Orientation
5	( )	What is the (year) (season) (date) (day) (month)?
5	( )	Where are we (state) (country) (town) (hospital) (floor)?
		Registration
3	( )	Name 3 objects: 1 second to say each. Then ask the patient all 3 after you have said them. Give 1 point for each correct answer. Then repeat them until he/she learns all 3. Count trials and record. Trials _____
		Attention and Calculation
5	( )	Serial 7's. 1 point for each correct answer. Stop after 5 answers. Alternatively spell "world" backward.
		Recall
3	( )	Ask for the 3 objects repeated above. Give 1 point for each correct answer.
		Language
2	( )	Name a pencil and watch.
1	( )	Repeat the following "No ifs, ands, or buts"
3	( )	Follow a 3-stage command: "Take a paper in your hand, fold it in half, and put it on the floor."
1	( )	Read and obey the following: CLOSE YOUR EYES
1	( )	Write a sentence.
1	( )	Copy the design shown.



_____ Total Score

ASSESS level of consciousness along a continuum _____

Alert Drowsy Stupor Coma

APPENDIX E

R14/49 Miss Alexis Badenhorst

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M160948

NAME: (Principal Investigator)	Miss Alexis Badenhorst
DEPARTMENT:	Occupational Therapy Themba Hospital, Ehlazeni District Mpumalanga
PROJECT TITLE:	Efficacy of an Activity Based Neuro Muscular Electrical Stimulation (NMES) Program in the Treatment of the Upper Limb
DATE CONSIDERED:	30/09/2016
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Lebogang Maseko
APPROVED BY:	Professor P. Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	31/03/2017

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 10004,10th floor, Senate House/2nd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand. I/We fully understand the the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to resubmit to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially review September and will therefore be due in the month of September each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

Date 31/03/2017

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX F

Department of Occupational Therapy

7 York Road, Parktown, 2193 South Africa • Telegrams 'Witsmed' • Tel: +27-11-717-3701 • Fax: +27-11-717-3709

e-mail: Leilane.Bogoshi@wits.ac.za

Date: 21/11/2016

Department of Health Ethics Committee,
7 Government Boulevard, Building 3,
Riverside Park Governmental Complex,
Nelspruit
1200

CEO: Mr. Shabangu,
Themba Hospital,
1213 Kabokweni Main Road,
Kabokweni
1245

Medical Manager: Dr. Dhlodhlo,
Themba Hospital,
1213 Kabokweni Main Road,
Kabokweni
1245

Chief Occupational Therapist:
Mr. S. Dhlamini,
Themba Hospital,
1213 Kabokweni Main Road,
Kabokweni
1245

To whom it may concern.

RE: Application to conduct a research study

Dear Sir/Madam

I am currently doing my Masters in Occupational Therapy (Coursework and Research Report) at the University of the Witwatersrand, and I am expected to conduct a research study as part of the degree. This letter is to request permission to conduct this study at Themba Hospital.

The topic of my research is “Efficacy of an activity-based neuromuscular electric stimulation on the upper limb specifically, looking at the function and participation in personal activities of daily living of stroke survivors.

At Themba Hospital, we serve a population that are of a low income and face many challenges (money for transport for rehabilitation etc.). It is important to treat these patients with the highest of standards in the shortest time. Most stroke survivors never fully return to their previous function due to their impaired arm function; therapeutic electrical stimulation is a technique that can be used to treat arm function.

This is a quantitative experimental study where participants will be divided in an experimental group and a control group, on admission to Themba Hospital, on obtaining informed consent.

The control group will receive the standard occupational therapy treatment programme that is currently in place at Themba Hospital for the duration of their hospital stay (5 days). The experimental group will receive two 30 minutes therapeutic electrical stimulation sessions with the standard treatment programme for the same period. This is a therapeutic technique, which is proving to be effective in speeding up recovery of movement in the limbs of patients with stroke. After this period, if the participants still require therapy they will receive the standard therapy at Themba Hospital, regardless of the group in which they found themselves.

After the study has been completed, if therapeutic electrical stimulation has a positive effect, participants of the control group will be offered treatment using therapeutic electrical stimulation.

All tests and therapeutic equipment to be used in this study is the property of WITS University and there are no financial implications to the Mpumalanga Department of Health. Ethical clearance, which has been requested from the Human Research Ethics Committee of WITS University, is still pending.

Thanking you in anticipation.

Yours sincerely,

_____

Alexis Badenhorst

Gr 1 Occupational therapist (UFS)

Contact no: 076 458 0936

Email: alexisbadenhorst@yahoo.com

PERMISSION TO DO RESEARCH

I _____ hereby give permission to Alexis Badenhorst to complete the study "Efficacy of an activity-based neuromuscular electrical stimulation programme on the upper limb" at Themba Hospital, pending ethical clearance from WITS university.

Signed: _____

At: _____

Date: _____

PERMISSION TO DO RESEARCH

I SIMON DHLAMINI hereby give permission to Alexis Baderhorst to complete the study "Efficacy of an activity based neuromuscular electrical stimulation program on the upper limb" at Themba hospital pending ethical clearance from WITS university.

Signed: _____

At: Kabokweni, Themba Hospital

Date: 23/11/2016

PERMISSION TO DO RESEARCH

I [redacted] hereby give permission to Alexis Badenhorst to complete the study "Efficacy of an activity based neuromuscular electrical stimulation program on the upper limb" at Themba hospital pending ethical clearance from WITS university.

Signed: [redacted]

At: Themba Hospital

Date: 1/12/2016.

To commence with the study after Provincial Ethics has granted permission in writing, but the Hospital supports the execution of the study.

PERMISSION TO DO RESEARCH

I Dr JB Dhlodhlo hereby give permission to Alexis Badenhorst to complete the study "Efficacy of an activity based neuromuscular electrical stimulation program on the upper limb" at Themba hospital pending ethical clearance from WITS university.

Signed: _____

At: Themba Hospital

Date: 2016/11/21

Home Submit New Proposal Manage Proposals Manage Researchers

Proposal Details:

MP 2016RP25_885

MPUMALANGA HEALTH RESEARCH COMMITTEE

APPLICATION DETAILS

TITLE OF RESEARCH PROJECT

Efficacy of an activity based Neuro muscular electrical stimulation (NMES) program in the treatment of the upper limb

TYPE OF STUDY

Non-academic

STATUS OF APPLICATION

Approved

STATUS OF PROJECT

On-Going

PROPOSAL SUBMISSION DATE

2017/02/02

You will find a list of all comments made on the selected research application. The list below displays comments visible to both the Applicant and Research Committee

COMMENTS

Comment	Comment Date	Comment By

PRIMARY INVESTIGATOR OF THE PROJECT/PROPOSAL

APPENDIX G

INFORMATION DOCUMENT

Study title: Efficacy of an activity-based electrical stimulation programme on the upper limb.

Good Day,

I am Alexis Badenhorst, a Master's student at the University of the Witwatersrand in Occupational Therapy. I am doing a research project to look at treatment of a patients' arm after they have had a stroke. When a person has a stroke, they may have different problems, some of which may be with movement in the arm and leg. As occupational therapists, we work with patients with stroke to assist them to use the arm and leg affected by stroke so they can do their everyday activities. This research is about using different therapy methods to assist with recovery of movement in the arm and hand.

What will I be asked to do if I agree to participate?

I am inviting you to take part in the study. You will be required to attend occupational therapy during your hospital stay (5 days) and will be treated with the programme of usual occupational therapy.

You will be asked to complete different activities and different exercises and this may be assisted by a small machine that can help activate the muscles in your arm and hand. If the machine is used on your hand, it is perfectly safe and you will have patches put on the different muscles in your arm to help with movement. The machine will make small electrical impulses, but should be painless.

While you are in hospital, a therapist will test your arm to see how well it is moving. These assessments will take 30 minutes to complete.

What are the risks of this research?

There may be some risks from participating in this research study if you receive electrical stimulation, as it can be uncomfortable but not painful. However, the minimal amount of electrical stimulation will be used to cause the muscle to contract and that is within your pain threshold. The therapist will ask you at regular intervals about the stimulation and you can ask the therapist to stop at any time. The doctor would also give confirmation that you are medically fit to participate in the study.

What are the benefits of this research?

There may be benefits in terms of the recovery in your arm and the ability to perform tasks and activities at home. This will also improve the services we render at Themba Hospital for future stroke survivors.

Do I have to be in this research and may I stop participating at any time?

Your participation in this research is voluntary; you may choose not to take part at all. If you decide to participate in this research, you may stop at any time. If you decide not to participate, or if you stop at any time, you will not be penalised or lose any benefits to which you otherwise qualify. If you do not want to participate in the research, you will still receive the usual occupational therapy at Themba Hospital.

Would my participation in this study be kept confidential?

We will do our best to keep your personal information confidential. To help protect your confidentiality, all the data collected from the demographic sheet and assessments will be kept in a secure filing cabinet. The data collected will be used for academic purposes only. Your name will not be used on data collection sheets in the research study/report, as we will be using a coding system. The researchers can publish the research but all confidential information will be protected.

What if I have questions?

Should you have any questions regarding this study, or wish to report any problems you have experienced related to the study, please contact the researcher.

Name: Alexis Badenhorst

Telephone: (013) 796 9400

Cell: 076 458 0936

Email: alexisbadenhorst@yahoo.com

This research has been approved by the University of the Witwatersrand Research Committee and Ethics Committee (M160948). If you have any concerns about ethics in this project please contact the chairperson of the Human Research Ethics Committee at the University of the Witwatersrand, Professor Peter Cleaton Jones on 011 7171234, or at Zanele.ndolvu@wits.ac.za

APPENDIX H

CONSENT FORM

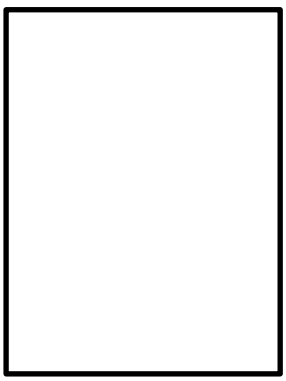
Title of Research Project: Efficacy of an activity-based neuromuscular electrical stimulation programme on the upper limb

The study has been described to me in a language that I understand and I freely and voluntarily agree to participate. I understand that the research project is for research purposes and that all information will be kept confidential. I also understand that I can, at any time, refuse to continue with the study and this will not negatively affect me in any way. I understand that I will not receive any remuneration to take part in this study

Participant's name……..

Participant's signature …….

Participant's thumbprint



Witness…….

Date……

APPENDIX I

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Department of Occupational Therapy
Wits Education Campus

School of Therapeutic Sciences, Faculty of Health Sciences, 7 York Road, Parktown, 2193, South Africa
Tel: +27 11 717 3701 | Fax: +27 717 3709 | Email: leilane.bogoshi@wits.ac.za | **www.wits.ac.za**

7.6.2018

Prof C Penny,
Chairperson
Ethics Committee
University of the Witwatersrand

Department of Health Ethics Committee
7 Government Boulevard, Building 3,
Riverside Park Governmental Complex,
Nelspruit, 1200

Student Alexis Badenhorst

Study title: Efficacy of an activity based electrical stimulation programme on the upper limb.

Wits Ethics no: M160948

To whom it may concern.

RE: Change in participant numbers and research design in study

Dear Sir/Madam

This letter is to inform you that due to the reduced number of suitable participants available for the study indicated above the student will be changing the number of participants originally sited for the study. The study methods will also change and will now be a multiple case study design.

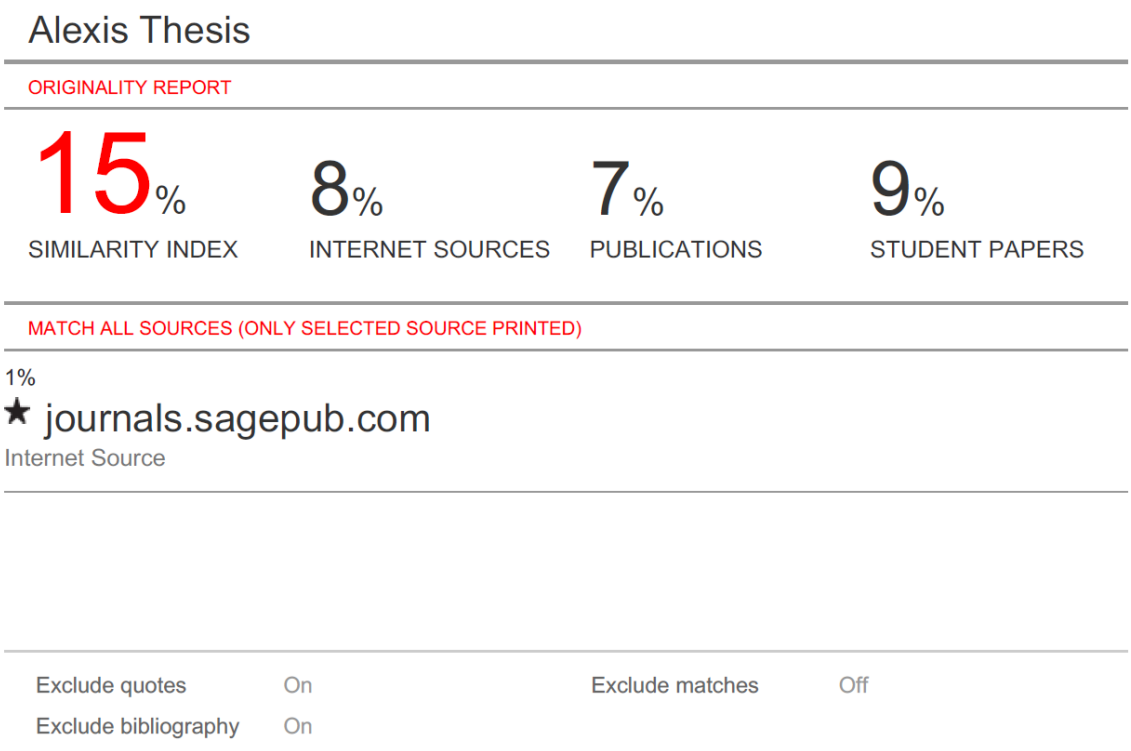
The mythology for which ethics was obtained has not changed other than that there will be no control group. All procedures and research tools and the intervention will be carried out as per the approved protocol and thus all ethical principles will be applied as described in the ethics applications.

Yours sincerely,

Dr. Denise Franzsen

Supervisor

APPENDIX J



Alexis Thesis

ORIGINALITY REPORT

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MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

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