Stroke in Young Adults: The influence of an outdoor-walking rehabilitation programme on walking performance and quality of life

R J Clarke

PhD 2024

Stroke in Young Adults: The influence of an outdoor-walking rehabilitation programme on walking performance and quality of life

REBECCA JAYNE CLARKE

A thesis submitted in partial fulfilment of the requirements of Manchester Metropolitan University for the degree of Doctor of Philosophy

Department of Life Sciences
Manchester metropolitan University
in collaboration with Brecon Beacons National Park

2024

Acknowledgements

The biggest of thanks goes to my supervisory team. It has been a hard three years. However, the unwavering support and incredible expertise from my Supervisory team, Dr Hannah Jarvis, Prof Neil Reeves and Dr Gina Cavan were invaluable. Special thanks go to Dr Hannah Jarvis, my principal supervisor who surpassed in all expectations as a supervisor, you are an amazing role model, always having time to answer my questions and to share your expert/ professional knowledge and experiences in academia. You helped me through hard periods when I lost focus and I appreciate everything you have done and more to guide me through my PhD journey and I am proud to be a member of your growing research team at MMU.

I would like to say a very special thanks to the twelve participants, who supported me in so many ways throughout this research project, seeing you all grow in confidence, independence and becoming more free walking outdoors was such an insightful experience. Your enthusiasm and determination to giving your all was the push I needed in wanting to continue this area of research. Your life stories, before and after stroke were wonderful, sometimes humorous and yet humbling to listen to. The sharing of tips and tricks between each other to cope with the effects of stroke were fascinating and it is great that you have all continued to participate in outdoor-walking after the end of the study.

I am so grateful to the participating health boards and the physiotherapists, who believed in this research project wholeheartedly and managed to make it happen with recruitment, despite coming out of a worldwide pandemic and navigating through tough and sometimes unclear social distancing guidelines. The Brecon Beacons National Park Authorities also deserve a massive thank you, for agreeing to enter this venture, investing in me and this research project to improve the lives of many young stroke survivors who want to enjoy time in the great outdoors.

My family, Mum and Dad, thank you. You are my bedrock and you have both kept me somewhat sane throughout these past three years. You have witnessed the highs and lows and I will forever be grateful that you somehow managed to put up with me! Thank you especially to Mum, you make a great research assistant!

A big thanks is needed for the amazing technical team, you were always being available and supportive throughout my time at MMU. And thank you to my two undergraduate research assistants; Isaac and Robyn. Remote data collection could not have been done without them!

"In every walk in nature one receives far more than he seeks"

- John Muir

Financial Acknowledgements

This independent research was conducted following the receipt of a funded award from the Sustainable Development Fund and Brecon Beacons National Park Authorities. This award funded the feasibility study and the main larger-scale study.

Publications

Clarke, R. Reeves, N, D. Tzoulas, K. Cavan, G. Griffiths, A. Walker, L. Rees, N. Jackson, K. Clayton, A. Jarvis, H, L. (2022) 'An Outdoor-Based Rehabilitation Programme For Young Stroke Survivors- A Feasibility and Pilot Study'. Submitted to Disability and Rehabilitation

Conference Presentations

Clarke R, Reeves N, Tzoulas K, Cavan G, Griffiths A, Walker L, Rees N, Jackson K, Jarvis H. Would rehabilitation in outdoor environments benefit young stroke survivors? Manchester Metropolitan University Annual Postgraduate Research Conference. Manchester. September 2019

Clarke R, Reeves N, Tzoulas K, Cavan G, Griffiths A, Walker L, Rees N, Jackson K, Jarvis H. 'The long trail ahead in stroke recovery' Manchester Metropolitan University Images of Research Competition. Manchester. January 2020
Winner of Judge's Choice Award

Clarke R, Reeves N, Tzoulas K, Cavan G, Griffiths A, Walker L, Rees N, Jackson K, Jarvis H. (2022) Stroke in Young Adults: The influence of an outdoor-walking rehabilitation programme on walking performance and quality of life [Abstract]. In: Stroke Hub Wales Symposium.; 7 March 2022 Cardiff. Invited to speak

Clarke R, Reeves N, Tzoulas K, Cavan G, Griffiths A, Walker L, Rees N, Jackson K, Jarvis H. (2022) Stroke in Young Adults: The feasibility of an outdoor rehabilitation programme investigating walking performance and quality of life [Abstract]. In: European Stroke Organisation Conference.; 4-6 May 2022; Lyon. Accepted

Clarke R, Reeves N, Tzoulas K, Cavan G, Griffiths A, Walker L, Rees N, Jackson K, Jarvis H. (2022) Stroke in Young Adults: The influence of an outdoor-walking rehabilitation programme on walking speed, energy cost and quality of life [Abstract]. In: European Stroke Organisation Conference.; 4-6 May 2022; Lyon. Accepted

Contents

List of Abbreviations

WHO	World Health Organisation
EE	Energy Expenditure
CERT	Consensus for Exercise Reporting Template
QoL	Quality of life
RoM	Range of motion
SSWS	Self-selected walking speed
10MWT	10 metre walk test
3-MWT	3-minute walk test
PIC	Participant Identification Centre
CI	Confidence Interval
SAQOL	Stroke and Aphasia Quality of Life Scale
CaSM	Confidence after Stroke Measure
NR	Nature-Relatedness
PI	Principal Investigator
OEC	Outdoor Education Centre
HRA	Healthcare Research Authority
NHS	National Health Service
MRC	Medical Research Council
CAST	Calibrated Anatomical Systems Technique
PPIE	Patient and Public Involvement and Engagement

List of Figures

List of Tables

List of Appendices

Abstract

Stroke is a debilitating neurological condition, affecting twenty-six percent of adults under the age of 65 years. Most are unable to complete activities of daily living, return to work, participate in social, leisure and outdoor activities. There is very little research and limited clinical guidelines to support their care. A plethora of previous research has reported that exercising outdoors can improve psychological health, confidence and physical function for healthy populations and a paucity of research regarding other health conditions such as dementia. This gives premise for natural outdoor environments to be used as settings for an alternative form of stroke rehabilitation.

The aim of this research project is to design, develop and deliver a rehabilitation programme, using the outdoor natural environment as an alternative setting, specific to the needs and requirements of young stroke survivors with mild to moderate physical impairments.

As part of this research project, a three-week feasibility study was conducted, assessing whether an outdoor-based rehabilitation programme that included activities such as walking, canoeing and archery chosen by the stroke participants as part of a focus group, was feasible as a form of rehabilitation for young adults who have had a stroke (n=5). Walking speed and was measured during three minutes of walking in indoor at baseline. Quality of life was assessed using the EuroQoL EQ-5D-5L Quality of Life scale pre and post-intervention.

A larger scale case controlled study examined the effects of a ten-week outdoor-walking rehabilitation programme and home exercise programme on walking performance and quality of life in young adults who have had a stroke (n=12). Walking speed and metabolic energy cost was measured during three minutes of walking in indoor and outdoor environments at baseline and post-rehabilitation. Quality of life was assessed using Stroke and Aphasia Quality of Life Scale.

Walking performance parameters such as walking speed, walking efficiency, key joint kinematic and kinetic measures and quality of life were impaired as a result of stroke. Participants walked quicker indoors (pre: 0.82m/s, post: 0.91m/s post-intervention (p=0.01)), outdoors (pre: 0.79m/s, post: 0.89m/s (p=0.005)) and more efficiently (indoor, pre: 0.75 beats/m, post: 0.57 beats/m (p=0.56), outdoor, pre: 0.83 beats/m, post: 0.60 beats/m (p=0.168) post-intervention. Self-reported quality of life improved from 2.76 to 3.21 (p=0.024).

The outdoor-walking rehabilitation programme was feasible and highly beneficial to walking performance, confidence and health-related quality of life. Therefore, outdoor-walking is an innovative approach to improving walking performance and managing the physical and mental challenges of stroke in young adults and in doing so motivate the young stroke population to better engage in their rehabilitation and maintain independence.

Chapter One

1. Introduction

Stroke is a major health problem and one of the leading causes of disability. Stroke occurs when there is a haemorrhage (a bleed to the area of the brain) or an infarct (loss of blood to an area of the brain), which results in damage to, or death of brain tissue that can affect the way it functions (Kramer et al., 2016). The most commonly affected system after experiencing a stroke is 'motor control', how the nerves and muscles function to enable and coordinate movements, including relatively 'complex' tasks such as walking and activities of daily living.

Although stroke primarily affects the older population, 26% of adults in the United Kingdom are under the age of 65years (defined here as 'young adults') (Mallick and O'Callaghan, 2009). Epidemiological studies (Feigin et al., 2016) consistently report an increasing incidence and proportion of young adults who have had a stroke within the total stroke population (Ekker et al., 2018). The increasing incidence of young adults experiencing a stroke are often commonly associated with traditional vascular risk factors seen in an unhealthy lifestyle such as, diabetes mellitus, obesity, smoking, alcohol consumption and other complex conditions (e.g. CADASIL) (Ekker et al., 2018; Jarvis et al., 2019). These risk factors combined account for nearly 80% of all strokes in young adults.

Stroke affects all aspects of daily living and many young adults who have had a stroke are unable to return to work, education or participate in social activities, outdoor physical activity (e.g. dog-walking) and activities of daily living (e.g. going to the shops) (Winstein et al., 2016). These can lead to lack of independence, social isolation, decreased life satisfaction (defined here as quality of life) (King, 1996) and increased risk of depression and anxiety (Daniel et al., 2009). Despite these difficulties, young adults are often more motivated, have different functional and personal aims and have a strong desire to gain or remain in employment, compared to older adults.

One of the key defining problems that negatively affects all aspects of daily living for both young and old stroke populations is reduced walking performance. Previous research (Jarvis et al., 2019) reported that young adults who have had a stroke walk much slower (0.79m/s) and less efficiently (e.g. high metabolic cost) (0.63ml/kg/m) compared to age-matched healthy able-bodied controls (1.4m/s and 0.16ml/kg/m) respectively. The reduction in walking speed and efficiency may be due to motor impairments resulting from stroke, such as spasticity and hemiparesis (Platts et al., 2006).

Spasticity and hemiparesis caused by stroke can have significant negative effects (e.g. less efficient) on metabolic cost and biomechanical function due to inactivity, limiting voluntary movements and decreased muscle strength (Gray et al., 2012). After stroke, time spent inactive is greater than 50% (Bernhardt et al., 2004). Damage caused by the stroke, decreased mobility would cause a decline in muscle mass in the paretic limbs, but also non-paretic limbs to a lesser extent. However, this data has only been captured in the older stroke population, who may have muscle and joint degeneration due to the effects of older age regardless of stroke. Consequently, it is not known how affected muscle function is post-stroke without taking in to consideration older age.

Rehabilitation post-stroke has a prominent role in recovery to regain independence and quality of life. However, no specific rehabilitation guidelines exist despite the increased prevalence of stroke in young adults who have different functional requirements and capabilities compared to the older stroke population, which nearly all stroke literature is based (Jarvis et al., 2019). Rehabilitation programmes involving physical activity and exercise have shown to positively influence multiple physical and psychosocial domains post-stroke. Furthermore, there is strong evidence that supports a mixed methods (Billinger et al., 2014; Winstein et al., 2016) approach to exercise and rehabilitation, involving aerobic (e.g. walking) and strength (e.g. muscle strength) exercises post-stroke improves cardiovascular fitness (Pang et al., 2013) and walking performance (Veerbeek et al., 2014).

All post-stroke rehabilitation is delivered indoors, in clinical settings such as leisure centre gyms and hospitals. Research previously conducted by the research team indicate that many young adults who have had a stroke want to exercise outdoors, therefore supporting the need for further research. Over the past two decades, research has investigated exercising in natural outdoor environments and green spaces is found to be associated with better physical and mental health (Maas et al., 2008; Triguero-Mas et al., 2015), wellbeing, longevity and decreased anxiety and depression for other health conditions (Whear et al., 2014).

Despite the positive impact natural outdoor environments has on health and wellbeing, many areas are inaccessible without appropriate support and guidance for the less able-bodied individual. The long-standing concept, called the 'Social Model' of Disability, which 'focuses on the environmental and social barriers which exclude people with perceived physical and mental impairments from mainstream society' (Barnes and Oliver, 1993; Thomas and Smith, 2008), rather than disability being caused by the presence of an impairment (Thomas and Smith, 2008), emphasises further work needs to be done to break down these barriers. Therefore, establishing an effective rehabilitation programme that utilises accessible natural outdoor environments and green spaces, could be undeniably beneficial to young adults who have had a stroke (Outermans et al., 2016), but also to generate a shift in culture within the wider society.

Studies evidencing the positive impact of exercising in natural outdoor environments for both able-bodied individuals (Thompson Coon et al., 2011) and individuals who have other medical conditions, such as dementia (Whear et al., 2014) have used open-ended questionnaires and interview based feedback. However, by using a quantitative approach, the Nature-relatedness scale (NR-21 item) (Nisbet et al., 2009) assesses subjective connectedness with the natural environment. This could be applied in the present novel research project to measure what impact the natural outdoor environment has on young adults who have had a stroke.

1.1 Rationale

Rehabilitation programmes are traditionally considered to be a hospital-based subspecialty of medicine or allied health intervention (Louise Sofia Madsen et al., 2021), often based in indoor clinical settings, where all stroke rehabilitation programmes take place. The majority of research that has investigated the role of rehabilitation to improve walking performance and quality of life in the stroke population, has predominantly involved participants over the age of 65 years (Mallick and O'Callaghan, 2009), yet the prevalence of stroke in young adults has increased substantially over the last two decades (Ekker et al., 2018). Therefore, the first rationale for this thesis is that despite the increased prevalence of stroke in young adults, there are currently no rehabilitation programmes or guidelines that are specifically developed for the needs and priorities of the young stroke survivor, such as increasing independence, confidence and the ability to return to work.

The second rationale for this thesis is that there are no rehabilitation programmes that take into account the role of outdoor natural environments to improve physical health, psychological health and quality of life, which can offer an alternative, holistic and novel approach to stroke rehabilitation. There is a plethora of evidence that supports accessibility to green space and natural environments being associated with a range of health benefits including better self-rated health, lower body mass index and obesity levels and higher levels of physical activity, improved mental health and wellbeing (White et al., 2013) such as anxiety and depression, stress and increased life expectancy (Erickson et al., 2013) in both healthy able-bodied individuals. With only anecdotal evidence for certain clinical and chronic populations, such as dementia (Rappe and Topo, 2007; Tzoulas et al., 2007), traumatic brain injury (Dorsch et al., 2016) and cerebral palsy (James et al., 2018). the disparity in the literature needs to be explored more to understand why natural outdoor environments are not often used for rehabilitation purposes.

Because there are no other studies similar to what is proposed in this research project, a feasibility study was conducted by the research team (Manchester Metropolitan University ethics study number- 11718), discussed further in *Chapter Three,* to explore whether an outdoor rehabilitation programme can be deliverable. This study involved outdoor activities such as walking, archery and canoeing, and was very well received by stroke participants who took part in the study, strengthening the rationale for the development of a larger scale outdoor rehabilitation programme. Participant feedback also included increased motivation and confidence to walk in more challenging terrain and participate in more challenging activities.

Therefore, this thesis aims to demonstrate that there is a unique opportunity to develop a novel outdoor-walking rehabilitation programme for young adults who have had a stroke and become a valuable and original contribution to current knowledge and research literature that focuses on young stroke survivors and the role of natural outdoor environments. This research project will develop a new, alternative and holistic approach to rehabilitation, addressing physical, cognitive, and emotional aspects of recovery, promoting engagement, motivation, and functional gains in a real-world context, contributing to the overall well-being and quality of life for young adults who have had a stroke and has the potential to drive change perceptions and future guidelines for stroke rehabilitation.

1.2 COVID-19

The years 2020 and 2021 have both been difficult for all globally. As a result of the COVID-19 pandemic, this research project has suffered, with the project being postponed on several occasions due to concerns over personal safety and reducing risk of transmission taking the utmost priority. However, due to the nationwide lockdowns throughout the year 2020, these have further highlighted the positive impact of natural outdoor environments on both physical and mental wellbeing and the necessity to improve the lives of young adults who have had a stroke and begin the foundations of implementing outdoor rehabilitation programmes into clinical guidelines.

1.3 Thesis Outline

Chapter 2 (Literature Review) establishes familiarity with and understanding of the current research in the following areas of interest: Stroke in young adults, walking performance post-stroke, quality of life of young stroke survivors, current rehabilitation programme initiatives specific to stroke survivors and exercising in outdoor environments.

Chapter 3 (Feasibility of an outdoor-based rehabilitation programme) investigates whether an outdoor-based programme is feasible as a form of rehabilitation for young adults who have had a stroke. This small-scale pilot study assesses three different forms of outdoor activity and the effectiveness of a home-based exercise programme, over a 3-week period.

Chapter 4 (General Methodology) contains information regarding experimental methods that are common to each subsequent data chapter. Detailed descriptions of equipment and procedures, data processing, data analysis and statistical analysis relating to individual studies are presented within the corresponding chapters.

Chapter 5 (Discussion: Walking Performance) assesses the influence of a 10-week outdoor-walking rehabilitation programme on walking performance parameters, such as walking speed, energy cost and joint kinematics, moments and powers of young adults who have had a stroke.

Chapter 6 (Discussion: Quality of Life) assesses the influence of a 10-week outdoor-walking rehabilitation programme on quality of life and confidence of young adults who have had a stroke.

Chapter 7 (Researcher Insight to the Outdoor-walking Rehabilitation Programme) provides a reflective account of the researcher's feedback regarding the outdoor-walking rehabilitation programme

Chapter 8 (Clinical Implications) provides the clinical implications from this research project and recommended future research.

Chapter 9 (Conclusions) provides a global summary of the key findings from this research project, its limitations and overall conclusion.

Chapter Two

2. Literature Review

2.1 Literature Review Aims

This literature review aims to identify, review and synthesise the current literature surrounding stroke in young adults and is divided into the following sub-sections:

1. The impact of exercising in natural outdoor environments
2. Epidemiology, pathophysiology and cost of stroke in young adults
3. The effect of stroke on walking performance
4. Quality of life of young adults who have had a stroke
5. The effect of stroke on confidence
6. Role of rehabilitation in post-stroke recovery

2.2 Search Strategy

The search was conducted using databases; SPORTdISCUS, MEDLINE, EMBASE and OVID. This search was effected in June 2019 and then updated June 2022. Papers that were relevant to the above research fields, were explored and included in this literature review. If duplicates were found, these were sorted and deleted using the desktop software package Mendeley (Elsevier, Netherlands) version 1.19.8.

The main search terms used in this review initially focused on exploring the free text. The keywords were; Stroke, young adult, rehabilitation, quality of life, outdoor exercise, confidence. To expand the literature search, outdoor walking, community walking, natural outdoor settings, social impact of stroke, mental health and stroke, aerobic exercise, resistance exercise, combined exercise rehabilitation were included to provide a comprehensive search of all relevant papers for this review.

2.3 Exercising in Natural Outdoor Environments

2.3.1 What is "Green Exercise" and what impact does it have?

Over the last twenty years, the awareness of green exercise and the positive impact on physical and mental health for healthy (Thompson Coon et al., 2011) and some clinical populations (Detweiler and Warf, 2005; Rappe and Topo, 2007; Fritz et al., 2011; Fraser et al., 2020) has increased in popularity as a research area of interest. It is considered that any physical activity undertaken in the presence of nature or within natural outdoor environments is generally referred to as "green exercise" (Pretty et al., 2005). The term "green exercise" not only explicitly refers to physical activity taking place in "green" spaces (e.g. environments dominated by the presence of grass and green foliage colours), but this terminology is extended to environments characterised by the presence of water (e.g. blue spaces) (White et al., 2015) and also seasonal changes to outdoor environments, such as autumnal foliage colours (e.g. orange spaces) (Paddle and Gilliland, 2016).

The suggestion that conducting physical activity and exercise in natural outdoor environments offers numerous health benefits is not a new concept. First mentioned by the ancient Greek physician, Hippocrates (c. 450 to c. 380 BCE) for example, advocated that both walking is "man's best medicine" and "nature itself the best physician" (Donnelly and Macintyre., 2019). Modern literature has since investigated the first of Hippocrates' aphorisms extensively, reporting significantly favourable effects of exercise, such as walking, on a range of diseases and health-related outcomes. Leading to the formation of exercise guidelines in recent years by the World Health Organisation (WHO., 2014). The emergence of green exercise and outdoor recreation is now acknowledged by various government departments in the United

Kingdom as fundamental to delivering central government cross-cutting goals in health, education and the economy (Mackintosh et al., 2018).

It is only in recent years that interest to study the health effects of exposure to green spaces and natural outdoor environments has increased. A number of systematic reviews have explored the effect of green exercise (Bowler et al., 2010; Thompson Coon et al., 2011; Gladwell et al., 2013). For instance, the review by Thompson Coon et al (2011) reported statistically beneficial effects of green exercise on a range of psychological outcomes, such as revitalisation, positive engagement, energy, but also a reduction in tension, confusion, anger and depression. Further evidence of the effects of green exercise included greater enjoyment and satisfaction with outdoor activity, with positive indications that individuals had greater intent to repeat the activity. However, this review was limited due to the small number of included papers (*n*=11) and the identified studies were poor in methodological quality as a result of being subject to bias. For instance, none of the identified studies in this systematic review by Thompson Coon (2011) detailed randomisation for allocation of interventions and assessors independent of the interventions were not used to reduce bias. Also, the heterogeneity of outcome measures employed each study identified in this review, prevented a meta-analysis.

Previous literature (Pretty et al., 2005, 2007; Barton and Pretty, 2010; Barton et al., 2012) has established that exercising in green spaces has positive implications to improving mental wellbeing and some markers of physiological health in healthy populations. With anecdotal research that green exercise may play a key role in the prevention of both primary and secondary diseases and conditions by improving physiological, psychological, biochemical and social markers. Furthermore, Gladwell et al (2013) and Barton et al (2012) highlight that there is a place for green exercise in rehabilitation programmes to manage and support recovery from mental and physical ill health. Additionally, having sedentary individuals become more involved in green exercise initiatives has the potential to be effective in promoting behavioural change through improvements in adherence rates to various exercise programmes. Gladwell et al (2013) highlights that there is still a need to explore the reasons behind observed health benefits that occur in the natural outdoor environment in both healthy and clinical populations. Detailed further within this thesis is one of the first intervention studies to evaluate the role of the natural outdoor environment and health effects specifically for young adults who have had a stroke.

132.3.1.1 The Role of Green Exercise in Clinical Populations

There is a severe lack of research that investigates the role of natural outdoor settings on physical and mental health in individuals who are less-able or with a disability, including physical and mental impairments, with no long-term alternatives available, which use natural outdoor environments for rehabilitation purposes. The systematic review by Madsen et al (2021) examined studies which investigated outdoor adaptive activities in natural settings (detailed in table 2.1), reporting that activities in the natural outdoor environment elicited experiences of excitement, adrenaline rush and sense of adventure by the participants (Taylor and McGruder, 1996; Goodwin et al., 2009; Dorsch et al., 2016; James et al., 2018). Most commonly reported from each of the studies being reviewed (table 2.1) was the sense of joy and fun when taking part in outdoor activities. As these findings can provide a strong rationale that outdoor settings can be an environment in which a rehabilitation programme take place for various conditions and disabilities such as cerebral palsy, multiple sclerosis, and traumatic brain injury, the outdoor environment should elicit the same sense of enjoyment and other positive benefits for young stroke survivors and focusing on improving both the physical and mental wellbeing of individuals who are less-able. On the other hand, for participants who have more severe impairments than others or suffer from increased pain, had more negative experiences when engaged in outdoor activities (Goodwin et al., 2009; James et al., 2018).

Table 2.1: Review of qualitative studies to understand the role of the outdoors for individuals with disabilities

Study	Sample size	Age (mean and range)	Disability	Intervention
(James et al., 2018)	6	Not stated	multiple sclerosis, scoliosis, cerebral palsy, stroke, and arthritis	Ethnographic study Five walking sessions
(Dorsch et al., 2016)	5	30 24 - 35	spina bifida, traumatic brain injury, autism spectrum disorder, and scleroderma	Qualitative study Focus Groups
(Goodwin et al., 2009)	4	36 27 - 54	Complete Spinal Cord Injury	Qualitative study One outdoor hiking excursion
(Taylor and McGruder, 1996)	3	Not stated	Complete Spinal Cord Injury	Qualitative study

The research studies stated in table 2.1, offer a personalised insight into the role of the outdoors and outdoor adaptive activities for individuals with varying disabilities, via qualitative research methods (e.g., ethnographic discussion, semi-structured interviews) and is the most common method in investigating the role of the outdoors and outdoor physical activity. However, the aforementioned studies (Taylor and McGruder, 1996; Goodwin et al., 2009; Dorsch et al., 2016; James et al., 2018) first and foremost lack in reporting participant characteristics, with two out of the four studies reporting mean and range for age of participants. It would also be useful to know the individual disabilities and how (if not a congenital disability) the disability was caused and potentially level of function could be included to offer further insight to the participants and the programme.

Although all studies involved qualitative research as method and study design, all studies have very low sample sizes. James et al (2018) for instance, highlights as a limitation that despite overall success with recruitment, researchers were unable to reach saturation given the heterogeneity of participants. These studies offer many variables, and though the findings from each of the studies are favourable to outdoor settings and outdoor adaptive activities, these findings cannot be seen to be transferable to other programmes due to location, and differing business and volunteer models. Dorsch et al (2016) iterates that the outdoor adaptive programme being assessed is not a therapeutic recreation, but simply provides inclusive outdoor recreation opportunities for youth and adults with disabilities.

2.3.1.2 Green Exercise and Mental Health

It is well established that exposure to nature leads to positive mental health outcomes and cognitive affective and behavioural changes (Barton et al., 2012; Fraser et al., 2019, 2020), and further having double beneficial effect on psychological health when compared with urban or indoor environments (Pretty et al., 2005). Two theories can be used to justify the effect of natural outdoor environments on mental health:

1. Stress Recovery Theory (Ulrich et al., 1991), provides an explanation for why natural environments are so important for human functioning, and how natural elements can aid stress recovery.
2. Attention Restoration Theory (Kaplan, 2001) suggests that mental fatigue and concentration can be improved by time spent in, or looking at nature.

Direct exposure to nature is psychologically restorative, has beneficial influences on individuals' emotions and enhances the ability to reflect on life problems Research (Thompson Coon et al., 2011) has validated that exposure to views of natural outdoor environments (e.g. green spaces, nature) can improve people's health and wellbeing through the restorative qualities of the environment from stress and mental fatigue, which would be key for improving recovery and rehabilitation post-stroke. Hartig et al (2003) showed that walks in natural landscapes have a stronger effect on the ability to concentrate than urban walks. Similarly, in a systematic review by Whear et al (2014), benefits of spending periods of time in a garden for dementia patients were thought to be reminiscence and sensory stimulation. Results for this study were collected using qualitative methods, such as testimonies of family members and care workers. While qualitative methods have a place in this area of research, the data collected from family members and care workers could be seen as highly subjective and do not necessarily reflect the patient group, as the perspectives of patients who have dementia were not collected. However, contrary to other research investigating the effects of natural outdoor environments on mental health (Pretty et al., 2005; Thompson Coon et al., 2011), Askari et al (2017) found that the rate of reduction in symptoms of depression and perceived stress was not greater in the green exercise condition, when compared with the indoor exercise condition. This could be due to other studies using more enjoyable green exercise activities like mountain running, kayaking and cycling in natural outdoor settings. For instance, the study conducted by Mackay and Neill (2010) took place in mountainous terrain and forests, which reported positive results in reducing depression and perceived stress. It could be that exercising in a green space, situated in an urban environment cannot double the rate of improvement of clinical depression due to participants perception of the environment. Thompson Coon et al (2011) emphasised that in order to determine the positive impact of green exercise compared to indoor exercise on mental health and wellbeing, further studies involving clinical populations is much needed.

2.3.1.3 Green Exercise and Social Health

Social health is an important dimension of an individual's overall health, and refers to the ability to form and maintain positive, meaningful relationships and interactions with others and natural outdoor environments may provide another setting in which social health and experience can be promoted (Rogerson et al., 2016). Some studies (Peters et al., 2010; De Vries et al., 2013) highlighted that natural outdoor environments facilitate social interactions and experiences within communities. Coley et al (1997) reported that natural outdoor spaces, with trees attracted larger groups of people, as well as more mixed groups of youth and adults, compared with indoor setting and spaces devoid of nature, suggesting that natural elements such as trees promote increased opportunities for social interactions and support.

In the context of exercise, social support and indeed social expectations can be influential to increasing physical activity through self-efficacy. On the other hand, Hug et al (2009) found that individuals had a greater social expectation of indoor exercise when compared to green exercise. However, data was collected during the winter months, generating bias towards indoor exercise. Teas et al (2007) observed that during a group walking exercise in natural outdoor environments, participants often fell into conversation more easily, yet this did not happen during the equivalent indoor exercise condition. Although indoor exercise is a beneficial setting to focus on individual health benefits, the need for social opportunities is greater and individuals are more likely to be persuaded to participate in physical activity, (Schasberger et al., 2009). Therefore, green exercise can play a prominent role in the promotion of future exercise behaviours by facilitating social interaction and increasing enjoyment of participation (Hug et al., 2009; Gladwell et al., 2013).

2.3.1.4 Green Exercise and Physical Health

The natural environment not only offers a venue simply for exercise but has the potential to increase the intention to exercise, enjoyment, and adherence and generate favourable health outcomes. When comparing either exercising in indoor, built or urban environments during physical activity, exercising in natural outdoor environments has substantial beneficial effects on blood pressure, other measures of cardiovascular and autonomic function and endocrine and immune function (Pretty et al., 2005). For instance, several studies reported that during self-paced walking exercise outdoors, individuals walk faster and work harder, but report lower perceived exertion compared to indoors treadmill-based walking (Marsh et al., 2006; Focht, 2009; Dasilva et al., 2011). Furthermore, Gladwell et al (2016) reported that lunchtime walks through natural environments resulted in greater overall heart rate variability and parasympathetic cardiac contribution during sleep. In a study conducted by Ceci et al (1991) comparing the outcome of running exercise performed on a treadmill in indoor laboratory setting and an outdoor field track, participants exercised at greater speeds, heart rate and blood lactate concentration during outdoor exercise than during indoors exercise. In the instance of stroke, Carvalho et al (2010), reported that patients who walk faster than 0.8m/s are also able to walk further in the outdoor setting (assessment of short and long distance walking performance in indoor and calm outdoor environments), though there is no definition detailed in the study of what the outdoor environment is. However, in many of the mentioned studies, indoor exercise is often performed on static ergometers compared to outdoor exercise where the individual is required to move through the environment (Rogerson et al., 2016; Noseworthy et al., 2023).

In a systematic review by Rogerson et al (Rogerson et al., 2016), the manipulation of optic flow (defined as expanding flow on the retina caused by moving through an environment that forms the representational basis of egomotion) (Gibson, 1994; Parry et al., 2012) could be a potential reason as to why perceived exertion during outdoor exercise is greater than indoor exercise. It is possible that, alongside other factors like prior experience, optic flow could have a role in assessing fatigue and exercise exertion. However, restrictions to the optic flow due to static, ergometer-based exercise may influence perceived exertion (Dasilva et al., 2011).

Natural outdoor environments may provide a stimulus by which adherence to exercise behaviours may be influenced. Indeed, in a comparison of outcomes of outdoors walks versus laboratory-based treadmill walks, individuals reported significantly greater intention to engage in future exercise behaviours following outdoors walking (Focht, 2009).

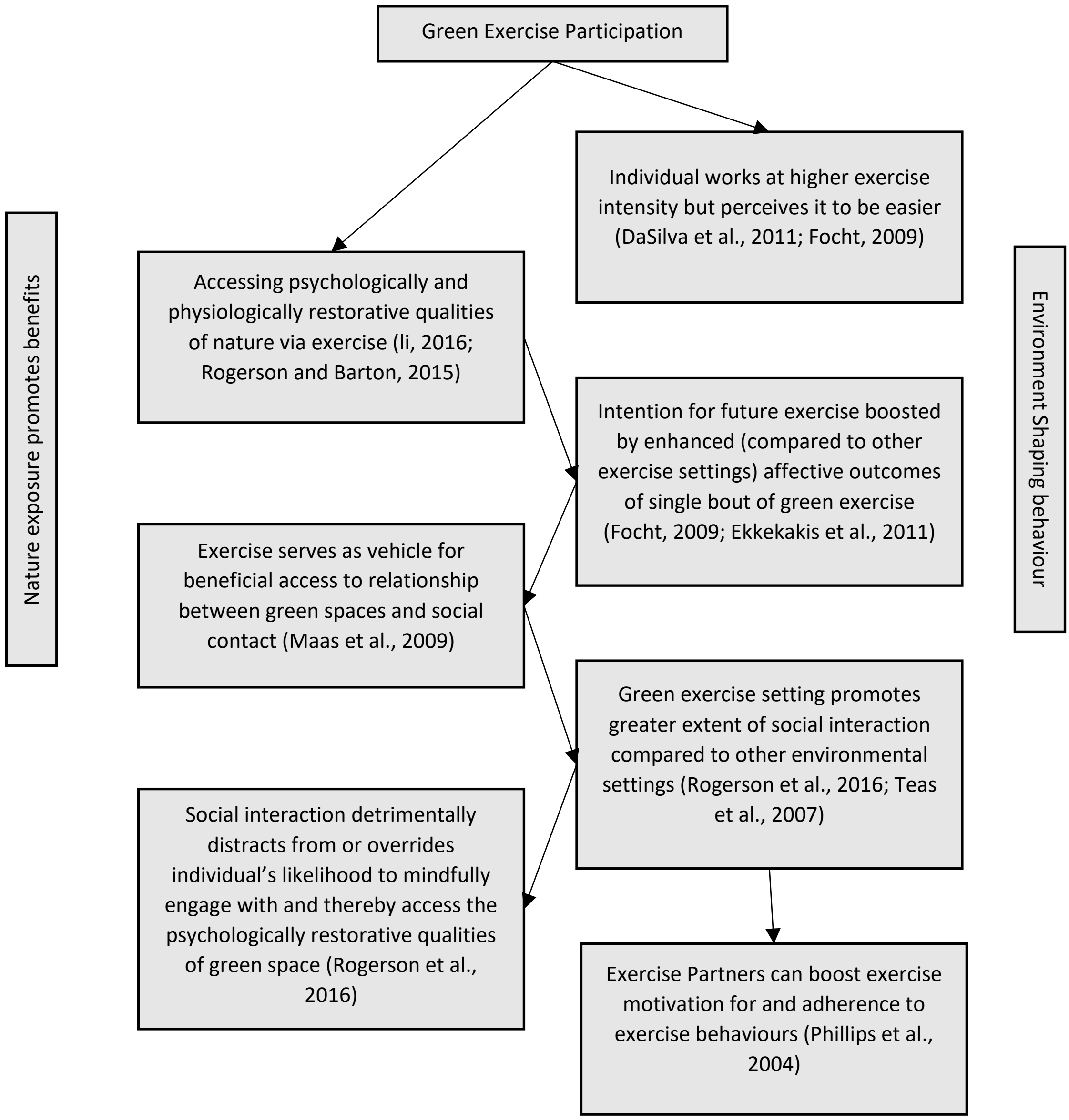


Figure 2.1: Two pathways where nature promotes benefits and environment shaping behaviour (taken from book 'Physical Activity in Natural Settings', page 87)

2.3.3 Current Outdoor Exercise Initiatives

Exercising in the outdoors has further been linked with improvements in social networking and feelings of connectivity and companionship, an increased appreciation of nature, and improvements in self-esteem. These benefits form the basis of the scheme 'Walking for Health', supported and provided by the Ramblers Association. These walks are designed for those who are less active by being short distance and over easy and manageable terrain. Many other outdoor walking initiatives are supported by charity organisations such as the Stroke Association and Headway- The Brain Injury Association. These actively run short walks to promote social participation.

2.3.4 Barriers to Green Exercise for Stroke

However, many barriers to exercising in natural outdoor environments for young adults who have had a stroke exist. There is a disparity to what is available for outdoor rehabilitation and outdoor activities for those who are living with long-term conditions, and the misconceptions about their abilities when they attempt to participate in the community (Madsen et al., 2021). Experiencing a stroke may be a precursor to being a barrier to green exercise due to lack of motor control, and musculoskeletal problems, potentially leading to increased risk of trips and falls due to the confidence of both the stroke survivor and family/carers. A study based in New Zealand (McCluskey and Middleton, 2010), reported people with stroke had continual loss of confidence on ramps, escalators and in large indoor shopping centres despite having several weeks of physiotherapy, resulting in the outcome that improved walking indoors may not transfer to improve walking in outdoor and community environments. Therefore, in order to gain confidence and skills required for community ambulation, people with stroke need community and outdoor-based training. Logan et al (2004), suggested that escorted journeys with a physiotherapist can improve participation and quality of life post-stroke, with other literature (McCluskey and Middleton, 2010; Louise S Madsen et al., 2021) stating that in order to achieve successful results of outdoor activities, safety and trust was often seen as essential.

Professionals can play an important role of establishing safety and trust, whilst creating a positive and joyful experience in helping to overcome barriers to outdoor activity (Taylor and McGruder, 1996; Dorsch et al., 2016; James et al., 2018; Louise S Madsen et al., 2021). However, anecdotal reports indicated that this evidence and escorted outdoor journeys were rarely delivered to people with stroke. This sentiment is further seen in other studies (McCluskey and Middleton, 2010), where some professionals considered that outdoor rehabilitation were not 'real' or did not offer outdoor initiatives in their services, therefore restricting access for individuals who may benefit from it. The social model of disability recognises that both attitudes and the physical environment can present as barriers (Thomas and Smith, 2008). Furthermore, although professionals can play a key role to ensure safety and provide social support, they often express a lack of experience and shared direction on what using outdoor and community environments for rehabilitation involves (Madsen et al., 2021), and further struggle to build confidence in their own ability to deliver community-based rehabilitation in outdoor settings (McCluskey and Middleton, 2010; Dorsch et al., 2016; James et al., 2018). Reports suggest that few healthcare professionals felt obliged to focus on indoor interventions like indoor-walking, because that is the expectation on how to improve the impairment, conceptualising the medical model of disability (Thomas and Smith, 2008; McCluskey and Middleton, 2010). Yet, individuals with disabilities call for professionals to be more creative in rehabilitation approaches (James et al., 2018; Madsen et al., 2021). These different perspectives based on individual needs and the perceptions of individuals with disabilities and physical impairments may complicate the role of professionals and influence their ability to overcome challenges regarding rehabilitation in outdoor settings.

2.3.4.1 The Practicalities and differences of Indoor Exercise and Green Exercise

Practicalities and differences between indoor and green exercise are prevalent and often reported as barriers to motivation to participate. Indoor and green exercise are inherently different because of the nature and scope of the environment. Indoor settings are often portrayed as a safer environment for both exercise and rehabilitation purposes (De Bruin et al., 2010), due to being controllable, structured and consistent, with no dependency on external factors such as weather conditions, unlike exercising in outdoor environments (Hug et al., 2009), and concerns for personal safety is often a key determinant to green exercise. Factors such as neighbourhood crime safety, aesthetics and traffic for green spaces in more urban areas will have a detrimental effect on participation levels. Safety concerns are further highlighted if the area is remote, where injuries or exposure to the outdoors for a prolonged period of time, especially in adverse weather conditions may occur, making indoor exercise more attractive (Leslie et al., 2010; Gladwell et al., 2013; Federici, 2021) Safety concerns may be a strong reason why rehabilitation for stroke is often considered to be a hospital-based subspecialty of medicine or allied health intervention (Louise Sofia Madsen et al., 2021).

On the other hand, accessibility to participating in physical activity for both indoor and outdoor settings present similar issues. Pederson et al (2022) reported that proximity to affordable, well-maintained facilities is often reported as a motivator to take part in physical activity in both indoor and outdoor environments (Keegan et al., 2016). However, Kelly et al (2016) and Downward and Rasciute (2015) detailed that financial implications of participating in organised physical activity in indoor settings is a well-documented barrier for both healthy-bodied and less able individuals. Furthermore, both environments present obstacles to participation, such as transport, e.g., the requirement to drive some distance to participate and lack of transportation possibilities, were reported as significant barriers (Kelly et al., 2016). In a study investigating barriers and enablers to green exercise for individuals who have chronic pain, Selby et al (2019), 19% of participants reported green spaces, such as parks and river paths, are not easily accessible to them on a regular basis. Studies have shown that communities with a lower level of access to such natural environments have a greater incidence of disease and morbidity (Royal College of Nursing Institute (RCNI), 2009).

2.3.5 Summary

Spending time and exercising in natural outdoor environments for healthy able-bodied individuals and those with disability, offer a plethora of positive benefits for physical and mental health. Exercising in natural outdoor environments elicited feelings of enjoyment, adrenaline rush and excitement for those with disability. Despite the positive impact exercising in natural outdoor environments can promote, barriers still exist that reduce accessibility to the outdoors for those who are less able. Therefore, this thesis offers a strong rationale for this research project to develop and offer a new approach to stroke rehabilitation to promote recovery and improve accessibility for all.

2.4 Stroke in Young Adults

2.4.1 Pathophysiology of Stroke

Stroke is defined as potentially one of the most damaging of all neurological conditions for all ages and is seen to be a major cause of death and disability globally (Mukherjee and Patil, 2011; Aigner et al., 2017) and is ranked as the second leading cause of complex disability in adults (Donkor, 2018). The World Health Organisation (WHO) definition of stroke is: "rapidly developing clinical signs of focal (or global) disturbance of cerebral function, with symptoms lasting 24 hours or longer or leading to death, with apparent cause other than of vascular origin" (WHO, 1988; Truelsen et al., 2006). This definition encompasses both ischaemic stroke and haemorrhagic stroke (Mallick and O'Callaghan, 2009).

Stroke occurs when the blood flow within an artery feeding an area of the brain is abruptly interrupted by a clot (infarction) or rupture (haemorrhage). The most frequent cause of infarct stroke, which accounts for 87% of strokes is a thrombotic blockade of the internal carotid or middle cerebral artery or other arterial branches. This causes brain tissue to become necrotic, due to lack of oxygen (Rosamond et al., 2008). A stroke can also be caused by a haemorrhage, which is when a rupture occurs to a blood vessel and produces bleeding into (intracerebral) the brain (Kramer et al., 2016).

2.4.2 The definition of a young adult

There are many definitions in which a young adult who has had a stroke is classified. The vast majority of literature defines a "young adult" to be between the ages of 18 and 50 years (Griffiths and Sturm, 2011; Maaijwee et al., 2014, 2016; Smajlović, 2015; Ekker et al., 2018). However, using this age range to define a "young adult" subsequently excludes those individuals who are between the ages of 50 and 65 years and have the potential to return to work. Therefore, an age group of 18-65 years encompasses the whole working age group category. For the purpose of this literature review and subsequent chapters, “young adults” will be defined to be between the ages of 18 and 65 years (Daniel et al., 2009; Saka et al., 2009; Coole et al., 2013; Jarvis et al., 2019).

It is reported that one quarter (26%) (Stroke Organisation national statistics, 2015) of adults who experience a stroke in the United Kingdom are under the age of 65 years (Daniel et al., 2009; Coole et al., 2013; Jarvis et al., 2019) and the UK National Clinical Guidelines for Stroke suggest that the needs of young adults may not be met by standard stroke services (Daniel et al., 2009; Rudd et al., 2017). This is because the majority of stroke services are focused towards meeting the requirements of the older stroke population. There is a gap in the literature regarding young stroke, in terms of their needs and requirements from rehabilitation post-stroke.

2.4.3 Incidence of Stroke in Young Adults

In the last decade alone, there has been a global increase by 40% in the incidence of stroke in young adults (Ekker et al., 2018). However, large variations occur between countries, ranging from 7-8 per 100,000 people/year in Europe, to more than 100 per 100,000 people/year in sub-Sarahan Africa. This variation between countries reporting the incidence of young adults who have had a stroke could be due to a myriad of factors, such as differences in the definition of stroke in young adults by age and subtype (Griffiths and Sturm, 2011; Feigin et al., 2016), geographical differences (Béjot et al., 2014), air pollution, socioeconomic circumstances, genetics and ethnicity.

A large number of studies have been published in the last three decades on the incidence of stroke in young adults (Bevan et al., 1990; Marini et al., 2010; Griffiths and Sturm, 2011; Béjot et al., 2014; Maaijwee et al., 2014; Smajlović, 2015; Ekker et al., 2018). The results of these studies have been rather heterogeneous in terms of methodology and ethnicity.

2.4.4 The cost of Stroke in Young Adults

The prevalence of stroke in young adults poses many challenges to societal cost. Compared to the older stroke population, stroke in the young has a disproportionately large economic impact (Smajlović, 2015). The main reasons for this are that young stroke survivors find themselves living longer with potential complex disability at a time in their life when they expected to be supporting themselves and family, through some form of employment (Daniel et al., 2009). Young adults who have had a stroke find it difficult to return to work, often as a result of physical impairments, such as increased fatigue, upper and lower limb weakness, altered walking capabilities and changes in cognition (e.g. unable to concentrate, mental fatigue and in severe cases have difficulty communicating). In the United Kingdom, the cost of treatment, rehabilitation and subsequent loss in productivity from not being able to return to work due to stroke, results in total societal costs of £8.9 billion per year (Saka et al., 2009), and more recently found, loss of productivity from young adults not being able to return to work is £1.04billion per year (Luengo-Fernandez et al., 2020). Separately, the treatment and rehabilitation costs for stroke account for 5.5% of the total UK expenditure healthcare (Evers et al., 2004).

Furthermore, across 32 European countries in 2017, it was estimated the total cost of stroke to be €60 billion per year, of which €27 billion (45%) were incurred by healthcare systems and representing 1.65% of these countries healthcare systems budgets. Within the European countries included in this review by Luengo-Fernandez et al (2020), it was found that 47% (€29 billion) of the economic cost of stroke was in non-health or social care areas, with an estimated €16 billion (27%) in informal care costs and €13 billion in lost productivity as a result of early death or absence from work.

2.4.5 Epidemiology and Aetiology of Stroke in Young Adults

Underlying pathogeneses of stroke, age-related causes in the brain such as atherosclerosis, small-vessel disease and certain high-risk cardiac conditions like atrial fibrillation ultimately cause a small proportion of ischaemic strokes in the younger populations (Ekker et al., 2018). Though it is rarely seen in the older populations, dissection of the carotid artery (15-20%) is the most prevalent cause of ischaemic stroke in young adults. With over a hundred additional rare causes that could result in an ischaemic stroke in the younger population, creates a continual challenge for diagnosis and prevention for young patients. Interestingly, within the plethora of causes of stroke in the young, are the significantly high number of patients that present as having a stroke without an identifiable cause. Between 30% and 40% of ischaemic strokes in those under 50 years of age are classified with experiencing 'cryptogenic strokes' and the highest prevalence seen in the youngest of patients. In neuroimaging, the vast majority of cryptogenic strokes indicate embolic patterns, such as an embolism from elsewhere in the body, most likely the heart. However, despite modern technology in diagnostics, a definitive source of the embolism cannot be distinguished. If the cause of stroke in these instances are not established, it can be problematic for the prevention of a second ischaemic stroke. However, compared with Ischaemic stroke, haemorrhagic stroke results in increased damage to structural conditions like vascular malformations in young stroke survivors, than in the elderly

Large studies (Smajlović, 2015; Ekker et al., 2018) highlight that haemorrhagic stroke (subarachnoid and intracerebral) is the cause for nearly 50% of all strokes in those under 45 years of age. The reported incidence rates in this age category range from 3–6 per 100,000 per year for subarachnoid haemorrhage and 2–7 per 100,000 per year for intracerebral haemorrhage (Marini et al., 2001; Ekker et al., 2018). Generally, the aetiology of intracerebral haemorrhage in young patients is similar to that in those older than 45 years, except for an overrepresentation of arteriovenous malformation, cavernoma, drug abuse, and bleeding disorders such as sickle cell disease and antiphospholipid antibody syndrome early in life. Hypertension remains the most common cause of intracerebral haemorrhage in all ages (Smajlović, 2015; Ekker et al., 2018).

2.4.5.1 Vascular Risk Factors

Vascular (also termed as modifiable of traditional) risk factors are similar for both younger and older stroke populations (Smajlović, 2015), and are seen to be the cause for nearly 90% of all strokes (Aigner et al., 2017). However, over the past decade, there has been an unquestionable increase in the prevalence of hypertension (4-11%), hypercholesterolemia (12-21%), diabetes mellitus (4-7%), smoking (5-16%) and obesity (4-9%) in young adults (George et al., 2017; Ekker et al., 2018). These modifiable risk factors are continually reported in much of the literature investigating stroke in the young (Putaala et al., 2009; Smajlović, 2015; George et al., 2017). A study conducted in Finland by Putaala et al (2009), reported that the most common vascular risk factors included high cholesterol (60%), smoking (44%), and hypertension (39%) among 1,008 young adults. Suggesting the prevalence of modifiable risk factors in young adults as a cause of stroke to be a global issue. A further study (Putaala et al., 2012), aimed to examine the dissemination of vascular risk factors in 3,944 young stroke patients from three geographic regions in Europe and found that the three most common risk factors for stroke were smoking (49%), high cholesterol (46%), and hypertension (36%). However, in a study conducted by Aigner et al (2017), population-attributable risk of most traditional risk factors (e.g. hypertension, diabetes mellitus, coronary heart disease, smoking, heavy episodic alcohol consumption, low physical activity, and high BMI) increased with age.

2.4.5.2 Genetic Risk Factors

Smajlovic (2015) reported that cervicocephalic arterial dissection is a frequent cause of stroke in young adults, ranking first or second alongside other aetiologies of ischaemic stroke in young populations (up to 25% of cases) (Tancredi et al., 2013; Mackey, 2014). The link between migraines and ischaemic stroke has been known for a number of years, however is very much controversial due to the potential differences in the ascertainment of migraine (Ekker et al., 2018). It is most commonly seen in young females who have migraine with aura, with exponential increase among active smokers and those who use oral contraception(Bousser and Welch, 2005). Furthermore, though inherited coagulation disorders do not necessarily play a major role in stroke in young adults, it can have dire consequences with those who also have antiphospholipid antibody syndrome. In one systematic review conducted by Brey (2005), antiphospholipid antibodies, particularly lupus anticoagulant, were found to be an independent risk factor for ischaemic stroke in young adults in five of six studies included.

Some rare genetic and hereditary diseases, need to be taken into consideration when diagnosing young patients for ischaemic strokes, like Fabry disease, cerebral autosomal dominant arteriopathy with subcortical infarcts and leukoencephalopathy (CADASIL), and mitochondrial encephalopathy with lactic acidosis and stroke-like episodes (MELAS).

2.4.6 Covid-19: A Cause of Stroke in Young Adults

Even though the precise incidence is not yet known, stroke in the young is emerging as a potential complication of the COVID-19 pandemic (Hess et al., 2020). A probable cause for the link between COVID-19 and onset of stroke is the hypercoagulability associated with

COVID-19, which is likely a "sepsis-induced coagulopathy" (Ellul et al., 2020), potentially causing thrombotic vascular events including stroke (Fifi and Mocco, 2020). A multicentre study that included 26 patients who were infected with COVID-19, it was reported that those who had a stroke (either ischaemic or haemorrhagic), 27% were under the age of 50 years. Moreover, it was found that out of fifteen patients two presented with large vessel stroke, These patients were younger than 50 years and had no previous stroke risk factors. Consistent with other cases, patients with COVID-19 potentially are worse with regards to clinical outcomes than those patients with stroke who do not have COVID-19 (Fifi and Mocco, 2020).

2.4.7 Summary

This section highlighted the increased prevalence and incidence of stroke in the young and that a stroke can be caused by lifestyle factors such as smoking, poor diet and obesity, hypertension, but also vascular and genetic causes and the newly reported increased risk of stroke as a result of COVID-19. Furthermore, while stroke can affect individuals of all ages, young stroke survivors often face unique challenges related to the etiology of their stroke, life expectancy, recovery potential, emotional impact, and long-term management. Tailored rehabilitation programmes and support services are essential to address the specific needs of young stroke survivors and help them achieve optimal recovery and quality of life. Stroke can affect the individual's ability to return to employment depending on severity, and therefore it is why the traditional definition of "young adult" (18-50 years of age) should also include those who are between the ages of 50 and 65 years. This then encompasses all who are and should still be in employment.

2.5 Walking Performance Post-Stroke

2.5.1 Walking Performance: Definition

The term 'walking performance' is defined and quantified by the physiological effects of walking (metabolic energy expenditure (oxygen uptake) and metabolic cost (efficiency)) (Kramer et al., 2016) and biomechanical function (joint kinematics (how a joint moves), kinetics (the forces that go through joints when walking) and spatiotemporal parameters (step length, step width and walking speed) (Benedetti et al., 1998).

Walking is fundamental to physical independence such as the ability to complete activities of daily living, return to employment and participate in social activities (Jarvis et al., 2019). Regaining the ability to walk is one of the most commonly stated priorities of individuals who have had a stroke (Saunders et al., 2016; Wonsetler and Bowden, 2017). Through stroke rehabilitation, this goal can be achieved by compensating for remedial deficits, promoting recovery of impaired movements, or a combination of these methods (Buurke et al., 2008). However, it has been reported that improvements in clinical outcomes in indoor settings (e.g. hospital environments and gyms) often do not elucidate changes in community walking (Ardestani et al., 2019), giving premise for an alternative form of stroke rehabilitation to be based in outdoor settings (e.g. natural environments and community settings).

Despite 60-70% of stroke survivors recovering the ability to walk post-discharge from hospital, almost one third of individuals are still unable to walk unsupervised in the community (Lord et al., 2004). The inability to walk in the community and outdoor settings are possibly a direct result of physical impairments caused by stroke, such as impairments in motor function, further compromising muscle strength, co-ordination and balance, spasticity and mobility, but also insufficient acute and chronic rehabilitation in the majority of cases. Walking in outdoor environments can be more demanding due to the complexities that this type of environment presents (Kim et al., 2014), such as uneven ground, different terrains and changeable weather (e.g. wind and rain) but also the requirement to step up, down and over obstacles. Outdoor-walking (e.g. community ambulation, walking in urban environments and outdoor natural environments) can therefore become a more arduous task for a young stroke survivor when they complete activities of daily living or community ambulation as a result of previously mentioned motor impairments. Indoor-based rehabilitation programmes are not conducive to the hazards that walking in natural outdoor environments and community walking presents (Lord et al., 2004).

2.5.2 Common Impairments Post-Stroke

The definition of disability under the Equality Act 2010 in the United Kingdom is “if you have a physical or mental impairment that has a ‘substantial’ and ‘long-term’ negative effect on your ability to do normal daily activities” (taken from https://www.gov.uk/definition-of-disability-under-equality-act-2010). Common impairments affecting motor function post-stroke include spasticity, hemiparesis and hemiplegia. Spasticity is the involuntary continuous contraction of muscles of the upper and lower paretic limbs, often characterised by exaggerated tendon reflexes, increased resistance to passive movement and hypertonia resulting from the loss of upper motor neuron inhibitory control (Lance, 1980). Hemiparesis is defined as a weakness or inability to move on one side of the body and can cause difficulty to perform activities of daily living such as eating, dressing and walking. Many previous studies report that patients experience spasticity in muscles and hemiparesis of the paretic lower limb (Serra et al., 2016) due to the damaged descending neural pathways, which can cause abnormal movements, including an altered gait pattern and poor walking efficiency (Cruz et al., 2009).

2.5.3 Efficiency of walking post-stroke

One of the methods in which walking performance post-stroke is defined and quantified is by the physiological effects of walking, such as energy demand (Kramer et al., 2016). Energy demand is an estimate of the cost of physical activity and can be expressed as volume of oxygen uptake in millilitres, which is standardised to bodyweight in kilograms. Oxygen uptake when walking is commonly expressed as VO2/mL/kg/min, also often known as energy expenditure (EE). Energy cost takes walking speed into consideration by dividing oxygen uptake per unit of time by walking speed.

It is well reported that the energetic demands of walking are increased substantially due to the motor impairments caused by stroke (Platts et al., 2006; Kramer et al., 2016; Jarvis et al., 2019), with metabolic cost of walking in young adults ranging between 0.27 – 0.63, compared to controls (0.14) (table 2.1). the differences seen between studies could be the result of a number of factors, such as age of participants, participant sample size, the time since stroke occurred and methods used (e.g. overground versus treadmill walking). Alongside these factors, the increased variability in the measured parameters highlight how stroke affects each individual differently, concluding that no two strokes are the same.

Table 2.2: Literature review of studies investigating walking speed and metabolic cost of young stroke populations

Study	Sample size	Age of participants (mean and range)	Walking speed (m/s) (mean and 95% CI)	Metabolic cost (mean and 95% CI)
Jarvis et al (2019)	6	27.6 (18-40)	0.97 (0.46-1.47)	0.27 (0.07-0.45)
	20	52.8 (41-54)	0.80 (0.47-1.19)	0.27 (0.17-0.31)
	15	59.4 (55-65)	0.79 (0.29-1.25)	0.35 (0.09-0.58)
Platts et al (2006)	13	40.7 (30-54)	0.39 (0.13-0.71)	0.63 (not reported)
Danielsson & Sunnerhagen (2000)	10	52.1 (30-63)	0.27 (not reported)	0.58 (not reported)
Maeda et al (2009)	18	45.0 (32-59)	0.38 (0.13-0.71)	0.41 (not reported)
Awad et al (2015)	42	57.8 (not reported)	0.76 (not reported)	(not reported)
Cunha-Filho et al (2003)		60.0 (27-77))	0.51 (0.23-0.90)	(not reported)
Control (Jarvis et al., 2019)	5	44.8 (41-54)	1.45 (1.31-1.58)	0.14 (0.13-0.16)

Physical inactivity, which is common post-stroke may further contribute to cardiovascular and metabolic deconditioning (Finestone et al., 2003), muscle weakness and associated declines in physical function (Teasell et al., 2001). Compared with healthy controls, the energy expenditure of walking is 1.5-2 times greater post-stroke (Platts et al., 2006). The debilitating consequences of a high energy cost when walking has the potential to limit the individual's activities of daily living.

Many studies investigating the energetic demands of walking have focused on the older stroke patient groups (Kramer et al., 2016). However, recent years have witnessed growing academic interest in examining this field of study specific to young adults who have had a stroke (Danielsson and Sunnerhagen, 2000; da Cunha-Filho et al., 2003; Platts et al., 2006;

Maeda et al., 2009; Awad et al., 2015; Jarvis et al., 2019). This may be due to young stroke survivors typically not being affected by age-related conditions compared the older stroke population (70 years of age and older). Age-related conditions such as arthritis and sarcopenia, can also lead to altered gait patterns and increase sedentary behaviour. The National Clinical Guidelines for Stroke (2016) also reported that some younger adults feel that general stroke services, which the vast majority are older adults, do not meet their needs. Compared to the older stroke population, young stroke survivors are often more motivated to recover due to wanting to return to work, social and leisure activities (Daniel et al., 2009; Morris, 2011) and are therefore it can be hypothesised that young stroke survivors are more likely to respond to rehabilitation differently. Because of these factors it is difficult to rely on research conducted with older stroke patients, to be clinically relevant and be implemented specifically for young stroke survivors.

The study conducted by Jarvis et al (2019) proposed for the first time a critical threshold value for walking speed (0.93m/s). This critical threshold value of 0.93m/s has applications to be used in clinical practice and future research as a predictor for return to work following a stroke. Furthermore, this study was the first of its kind to use age sub-groups to help elucidate age-specific effects when investigating the relationship between walking speed and metabolic cost and its implications for returning to employment.

However, within this study only a small sample was achieved in the youngest age sub-group (18-40yrs, n=6) compared to the larger sample sizes observed in the other age sub-groups (41-54 yrs, n=20, 55-65 yrs, n=15), potentially limiting the clinical applications of this study specifically to young adults. Furthermore, within each age sub-group (18-40 yrs, 41-54 yrs and 55-65 yrs) a wide range in walking performance between stroke patients was observed, giving the means (0.97m/s, 0.80m/s and 0.79m/s) limited value. The 95% confidence intervals (0.46-1.47m/s) highlights that walking speed is highly variable due to the often varied effect a stroke can have on an individual.

Only a small cohort of studies (Danielsson and Sunnerhagen, 2000; da Cunha-Filho et al., 2003; Maeda et al., 2009) have included young adults into their samples, and also having small sample sizes overall. Therefore generalisability of results is limited and is reported as a limitation in many studies (da Cunha-Filho et al., 2003; Maeda et al., 2009) investigating walking speed of both young and old stroke populations. Furthermore, in some studies (da Cunha-Filho et al., 2003), data collected young adult patient groups have been grouped with the older stroke population, so the sensitivity to age is lost.

Different methodologies used could be a confounding variable for comparing studies and therefore why the high variability of walking speed and energy cost may be apparent in previous literature. For instance, when the stroke event occurred, severity of stroke and when data collection took place. The patient group in the study by Platts et al (2006), had experienced a stroke on average 3.6 months prior to testing and were yet to be discharged from inpatient rehabilitation care, compared to Jarvis et al (2019) where inclusion criteria stipulated that the occurrence of stroke took place within the last three years. The patients in the study by Jarvis et al (2019) would have had significantly more outpatient rehabilitation care compared with other previous studies, suggesting one cause for the increased walking speed and lower metabolic cost.

Further methodological differences between studies include measuring oxygen uptake and walking speed during overground walking (Platts et al., 2006; Maeda et al., 2009; Jarvis et al., 2019), treadmill walking (Danielsson and Sunnerhagen, 2000; Awad et al., 2015) or measured during steady-state conditions (Kramer et al., 2016). Overground self-selected walking speed (SSWS) is the most commonly used outcome measure of walking ability in rehabilitation, likely because it is simple, cost effective, reliable, valid, sensitive, and specific (Wonsetler and Bowden, 2017). The use of the treadmill for assessing SSWS and metabolic cost in stroke populations limits the application for data, as walking on the treadmill often increases metabolic cost due to the movement of the belt, as reported by Brouwer et al (2009) and others (Danielsson and Sunnerhagen, 2000). Most patients in the study by Danielsson and Sunnerhagen (2000) had experience of treadmill walking, it could be that some had chosen too low a speed. This correlated with the low heart rate and ratings of perceived exertion, indicating that the work in this study was quite light when compared with overground walking.

2.5.3.1 Gait Classification in Stroke

Though the prediction of functional return and recovery has been noted as difficult by some researchers (Bowden et al., 2008) due to the heterogenous nature of the stroke population, self-selected walking speed is a proven predictor for stroke recovery, due to the simplicity in measurement, is a reflection on both functional and physiological changes and most importantly is a reliable and sensitive measure throughout the recovery process (Perry et al., 1995; Schmid et al., 2007; Bowden et al., 2008). It was Perry et al (1995) who evidenced that using walking speed as a valid predictor for community walking, thus classifying gait post-stroke. Perry's work establishes four classifications ranging from 'severe gait impairments and able to walk indoors only' to being similar to able-bodied individuals, as detailed in table 2.2.

Table 2.3: Gait classifications for stroke, first proposed and established by Perry et al (1995)

Group	Walking Speed	Classification
1	< 0.4m/s	Severe gait impairments and able to walk indoors only
2	0.41-0.79m/s	Moderate gait impairments and able to walk outdoors with limited community ambulation
3	0.8-1.2m/s	Mild gait impairments and able to walk outdoors without assistance

Using Perry's proposed gait classification (table 2.3) has since become a method to understand the rehabilitation needs of stroke survivors on an individual basis, but also to monitor progression and has since become an outcome measure in clinical trials (Plummer et al., 2007; Stanhope et al., 2014). Schmid et al (2007) reported that improving walking performance, and therefore walking speed and the stroke survivors' gait classification, also has the ability to improve self-reported measures of function and quality of life.

2.5.3.2 Walking Performance in Outdoor Environments

Only one study (Kim et al., 2014) has investigated whether a 'community walking training programme' can improve walking function (walking speed and distance), taking place outdoors in community and natural environments over a period of four weeks. It was reported that this form of rehabilitation significantly improved walking speed (pre-intervention 0.51m/s, post-intervention 0.71m/s), assessed using the 10m walk test and walking distance (pre-intervention 162.59m, post-intervention 227.8m), using the 6-minute walk test. However, despite the marked improvements in walking speed and distance, this study does highlight limitations, for instance the small number of participants recruited for this study does not allow for these results to be generalised to all stroke patients. Furthermore, no long-term follow-up of the programme was considered to assess potential behaviour change and the whether the positive improvements observed and reported in this study continue.

2.5.4 Walking Biomechanics Post-Stroke

2.5.4.1 The Gait Cycle

Walking uses a repetitious sequence of limb motions to simultaneously move the body forward, while also maintaining stance stability (Perry, 2010). The term “gait” represents the manner of walking, with a single sequence by one limb termed the “gait cycle”. Each gait cycle can be divided into two phases; the stance phase and the swing phase. In a healthy able-bodied adult, the stance phase accounts for 60% to 62% of the gait cycle, whereas the swing phase accounts for 38% to 40%. and is the entire period during which the foot is on the ground, which commences with “initial contact” (also termed as heel strike). The swing phase accounts for 40% of the gait cycle and applies to the time in which the foot is in the air for limb advancement and commences as the foot is lifted from the floor (toe-off) (figure 2.2) (Kharb et al., 2011).

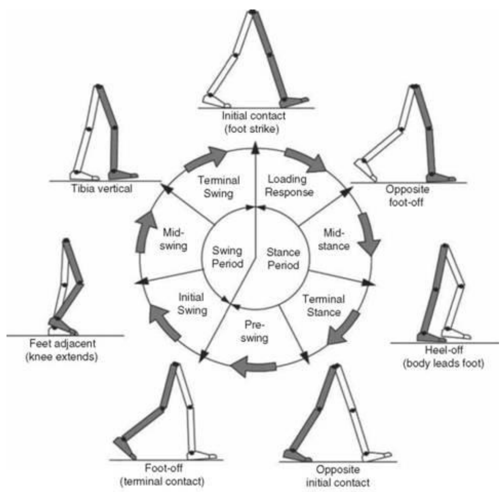


Figure 2.2: Gait cycle from initial contact to the next contact on same side (taken from: https://ebrary.net/7410/health/phases_gait_cycle)

Spatial-temporal parameters and kinetic and kinematic parameters are commonly used to describe gait in research. Spatial-temporal parameters concern the placement of the feet and time aspects of the gait cycle, such as stride length, stride width, step length, step width, single limb support time, double limb support time, stance time, and swing time measurements (Wonsetler and Bowden, 2017). Kinematics describe the angular displacement of joints and kinetics describe forces, joint moments and joint powers (Benedetti et al., 1998).

To measure kinematics and kinetics of walking, researchers regularly utilise embedded force plates, the gold standard method for biomechanics, with data collected to a certain sampling frequency (Renner et al., 2022). However, if the sampling frequency is too low, it is possible to miss important information. For instance, the characteristics of the gait phase will not be able to be determined accurately. Over sampling the data on the other hand, will result in a large quantity of data being collected and therefore require further data processing and reduction. Therefore, recommended sampling frequencies for walking are 50 to 100 Hz for motion capture, walking and running at 100 to 200 Hz, and 1000 Hz for ground reaction force data collection (Gudavalli et al., 2013).

2.5.4.2 Spatial and Temporal Parameters

While self-selected walking speed has been established as the prominent outcome for walking rehabilitation clinical trials, spatiotemporal variables are frequently utilised to quantify gait abnormalities, calculate gait asymmetries and track patient progress (Wonsetler and Bowden, 2017). Researchers consistently report reduced stride length (Nascimento et al., 2015; Zukowski et al., 2019), step length (Allen et al., 2011; Awad et al., 2015), cadence and increased stride width, step width (Chen et al., 2005a; Jarvis et al., 2019) and stance duration in individuals who have had a stroke, compared to control participants and indicate several potential causes for slow walking speeds.

Stride length is often defined as 'the distance that one part of the foot travels between the same instant in two consecutive gait cycles' (Baker and Hart, 2013). Within the first months after experiencing a stroke, cross-sectional studies revealed slower gait speed was a result of reduced stride length and cadence (Brandstater et al., 1983; Chow and Stokic, 2021). Nascimento et al (2015) reported mean stride lengths range between 0.5-0.6m in stroke survivors, compared to healthy able-bodied older adults (1.1 to 1.4m) (Hollman et al., 2011). Stride length variability has further been related to fall risk (Mansfield et al., 2015) and balance confidence (Schinkel-Ivy et al., 2016) post-stroke, perhaps as a result of different lower limb weakness distributions in stroke. It could be theorised that lower extremity distal muscle weakness causes an inability to fully weight-bear over the forefoot and create adequate progression during late stance, resulting in shorter strides, whilst predominantly proximal lower extremity muscle weakness may, or may not, preserve this function (Li et al., 2018).

In a study conducted by (Hak et al., 2015), medio-lateral and backward margins of stability (MoS) were compared between stroke participants and healthy able-bodied controls, during unperturbed walking and more challenging walking conditions, in which fast and accurate adaptations of the gait pattern had to be made. For all conditions, it appeared that stroke participants were able to regulate their medio-lateral MoS to a similar degree as the controls, despite exhibiting larger medio-lateral excursions of the extrapolated centre of mass (XCoM). Stroke participants had to walk with a larger step width and a relatively high stride frequency, compared with the control group. In contrast, the backward MoS was smaller in post-stroke individuals. This smaller backward MoS appeared to be caused by inadequate adjustments in stride frequency and stride length.

Furthermore, the limited increase in stride frequency and stride length in stroke participants could be a result of reduced push-off (Balasubramanian et al., 2007; Roerdink and Beek, 2011) and swing capacity (Campanini et al., 2013) of the paretic lower limb, due to muscle weakness and/or spasticity. However, the study conducted by Hak et al (2015) suggests an alternative, that an increased fear of falling (Maki, 1997) in stroke participants, or conflict between the cognitive demands of the gait adaptability task and walking ability (Plummer-D'Amato et al., 2008).

Jarvis et al (2019), reported that nearly all young stroke participants walked with a wider step compared to healthy able-bodied controls. This is likely adopted as part of a compensation strategy to aid with balance and stability, however this strategy is likely to negatively affect walking speed due to the reduction in distance covered in the forwards direction, in agreement with Chen et al (2005). Adopting a wider stance to promote support in the static standing position may seem to be more stable. However, walking involves the transition from single and double stance and will therefore lead to the body's centre of mass experiencing greater medio-lateral sway, potentially causing greater instability.

Several studies have found step length and step length asymmetry to correlate with paretic lower limb plantarflexor impairment post-stroke (Hsu et al., 2003; Lin et al., 2006). Contrary to traditional results regarding step length asymmetry, one study (Balasubramanian et al., 2007) found that patients who walk asymmetrically with shorter steps, generated a higher total percentage of propulsion from the paretic limb. Though a cause for this occurrence could be due to the paretic plantarflexors being unaffected post-stroke, there is the likelihood that these participants were unable to generate adequate energy during pre-swing of the paretic leg, which would result in the reduction of the paretic leg swing time, hence decreasing paretic step length. Furthermore, in a study by Awad et al (2015), it was found that intervention-induced improvements in step length asymmetry contributed to a reduction in energy cost and causing more efficient walking post-stroke. This demonstrates that a more symmetric walking produced the largest reduction in energy consumption when walking. However, it is not clear which of the three largely different interventions (1. Self-selected overground walking 2. Treadmill walking at the fastest maintainable speed for four minutes or 3. Treadmill walking at the fastest maintainable speed for four minutes with the addition of functional electrical stimulation) facilitated the changes in step length asymmetry.

2.5.4.3 Kinematic and Kinetic Parameters

Many studies (Boudarham et al., 2013; Awad et al., 2015; Jarvis et al., 2019) investigating stroke have utilised a number of combined advanced techniques such as 2D and 3D motion analysis and ground reaction force measurements (use of force plates), to identify gait abnormalities and to evaluate the effectiveness of interventions (Yavuzer et al., 2008). However, there is a paucity of research literature that have exclusively measured walking biomechanics in young adults who have had a stroke. Only one published study by Jarvis et al (2022), with most studies having used samples of older stroke patient groups (e.g. older than 65 years of age) who commonly have pre-existing age-related degenerative conditions not applicable to young adults, like atherosclerosis, cardiovascular disease, arthritis and osteoarthritis, potentially affecting how they walk. Some studies (Chen et al., 2005; Boudarham et al., 2013; Awad et al., 2015) have included young adult patient groups into their sample, but the data has been grouped with the older adults, therefore the sensitivity to how young adults may walk differently is unknown. Therefore, due to the lack of research specific to young adults, the studies discussed in this section only report on gait abnormalities in older stroke patient groups.

As stroke alters the kinematic, kinetic, and muscle activation patterns of individuals, spasticity is a common occurrence at a certain joint and can cause crouch gait, stiff-knee gait and reduced range of motion (RoM) of the lower limb joints (Hicks et al., 2011; Campanini et al., 2013; Boudarham et al., 2013). Between 38-60% (Kim et al., 2016) of individuals who have had a stroke suffer from muscle weakness and spasticity (Fleuren et al., 2009), which can vary according to the severity of stroke. Specifically, those with spasticity are more likely to be functionally impaired than those without, causing key abnormalities such as multi-joint factor asymmetries of the paretic lower limb at all levels (pelvis, hip, knee and ankle) (Cruz et al., 2009).

Table 2.4: Review table of different studies investigating the spatial-temporal, kinematic and kinetic parameters of post-stroke walking

Study	Sample size	Methods	Kinetic variables	Kinematic variables	Strengths	limitations
Hayes Cruz et al (2009)	18	Overground walking SSWS	Not stated	Frontal and sagittal plane hip strength, sagittal plane knee and ankle strength	Multi-joint coupling was associated with increased pelvic movement at toe-off	No demographic information on participants
Stanhope et al (2014)	21	Treadmill walking SSWS	Not stated	Frontal plane pelvic tilt, peak hip abduction, peak knee flexion, peak ankle dorsiflexion during swing phase in sagittal plane	Assessed both slow and fast walkers	No demographic information on participants
Kim et al	10 (5 stroke, 5 control)	Overground walking SSWS	Not stated	Gait phases heel strike and toe off, kinematic profiles of ankle, knee and hip flexion/ extension and pelvic obliquity	Divides results into slow and fast walkers	Only five stroke patients participated and participant groups were not age-matched
Boudarham et al	62 (42 stroke, 20 control)	Overground walking SSWS	Not stated	Sagittal plane hip, knee and ankle	Included young adults who have had a stroke (mean age: 52 yrs)	
Chen et al	12 (6 stroke, 6 control	Treadmill SSWS	Not stated	Sagittal hip, knee, ankle		
Kerrigan et al	40 (20 stroke, 20 control)	Overground SSWS (10m walk test)	Hip, knee and ankle joint motion, torque and power	Sagittal plane hip, knee and ankle	Demonstrated considerable variability in torque and power- varied compensatory mechanisms for reduced knee flexion	

The Pelvis

Pelvic motion plays a crucial role by contributing to the forward progression of the body and trunk vertical support post-stroke. Kim et al (2016) reported an excessive anterior tilt throughout the entire gait cycle, compared to the control group. This could potentially be due to spasticity in the hip flexors as a result of neurological impairment, but also due to prolonged sitting or sedentary behaviour resulting from limited mobility and difficulty walking post-stroke, therefore shortening the hip flexors (Jarvis et al., 2019). The gait performance of the non-paretic limb provided support by the increase in pelvic tilt and pelvic rotation with abnormal excursion of pelvic obliquity in the frontal plane, in order to compensate for reduced range of motion (RoM) of the hip, knee and ankle.

However, the range in pelvic obliquity is varied. A study by Kerrigan et al (2000) suggests it increases with excessive upwards movement during initial to mid-swing, compared to the controls where it is observed that the pelvis on the swing side drops by 3.9 degrees, indicating a hip-hiking pattern to achieve toe clearance due to foot-drop, which may also be related to any impairment in tibialis anterior to lift foot from floor and weakness in gastrocnemius and soleus to generate forward momentum. Similar results were seen in a study by Stanhope et al (2014) as slower walkers were observed in the frontal plane to have greater pelvic tilt. This positive exaggerated work of the pelvis is associated with raising the trunk during pre-swing and swing of the paretic limb contributed to increased mechanical energetic cost of walking (Chen et al., 2005a). While others (Akbas et al., 2019) suggest that pelvic obliquity as a compensatory strategy can be used to facilitate foot clearance with greater energy efficiency, compared to hip abduction. In contrast, Stanhope et al (2014) and others (Chen et al., 2005a) suggest that increased or exaggerated pelvic obliquity (also known as pelvic hiking) to be mechanically inefficient and energetically costly, due to increased upper body lateral sway as a result of greater shifts of the centre of mass. When compared to hip circumduction as a compensatory mechanism, as this deviation in gait is more distal and localised. However, this may be a compensatory strategy that only higher-functioning individuals can employ, who may have better lower limb function. Therefore, the study by Stanhope et al (2014) hypothesised that reducing pelvic obliquity during swing may improve walking efficiency and facilitate faster walking speeds in stroke survivors. While both studies (Chen et al., 2005b; Stanhope et al., 2014) contradict the findings of other regarding increased pelvic obliquity and its potential inefficiency to gait, the methods used for both studies should be scrutinised. The use of a treadmill, rather than overground walking has the potential to generate differences in results between the two, as evidenced by Danielsson and Sunnerhagen (2000). Although overground and treadmill walking are quantitatively similar in healthy able-bodied populations, stroke survivors whose walking ability have been severely affected, may respond differently to treadmill walking, therefore the results can not necessarily be applied to overground gait.

The hip

At the beginning of the gait cycle (initial contact), often the hip joint on the paretic limb prematurely enters into an extended position. During this phase of the gait cycle, peak hip flexion during loading response in the paretic limb is significantly reduced in stroke survivors compared to the control group (Chen et al., 2005a), with the reduction being more evident in the subjects who exhibited shorter step length in the non-paretic limb, as a result of being reluctant to load on the paretic lower limb during single limb support. This therefore reduces the progression in the forward direction of travel and reducing the 'trailing position' of the stance limb, which will likely reduce walking speed. similar to the study by Chen et al (2005a), Boudarham et al (2013) reported that a reduced walking speed was associated with, reduced hip extension during mid and late stance that in the sagittal plane was observed followed by reduced hip flexion at the end of the swing phase.

During the swing phase of the gait cycle, stroke patients exhibited reduced hip flexion in the paretic lower limb, compared to controls (Chen et al., 2005b; Boudarham et al., 2013). This results in the posterior tilt of the pelvis as a compensatory strategy to initiate hip flexion. Another compensatory strategy that is commonly adopted by stroke patients and seen in clinical assessments is excessive hip abduction of the paretic limb. An increase in hip abduction widens the base of support during the stance phase of the gait cycle (Perry et al., 2010). However, in swing phase exaggerations in hip abduction on the paretic limb can be adopted due to lack of hip flexion in order to facilitate toe clearance (Dean et al., 2017; Akbas et al., 2019). As mentioned previously, the lack of hip flexion could be due to spasticity in the hip flexors (Perry et al., 1995) or sedentary behaviours.

The Knee

Sagittal motion of the knee (flexion and extension) is used for progression and maintenance of stability in stance phase and swing phase, to facilitate limb clearance. At the knee joint, Nadeau et al (2013) reported that a decrease in hip extension subsequently brings the knee into hyperextension during stance phase to compensate for lack of heel rise. By hyper-extending the knee, the body can roll forward on the paretic lower limb, compromising step length due to lack of propulsion. The subsequent reduction in knee flexion and the compensatory strategy of knee hyperextension during the swing phase is common in stroke patients with spastic paretic gait as a result of upper-motor neuron injury (Kerrigan et al., 1999). However, during toe-off in the non-paretic limb, it was found that knee flexion tended to be greater than normal, potentially due to the exaggerated propulsion of the limb during pre-swing phase of the gait cycle (Chen et al., 2005a).

The Ankle

Generating the forces required to propel the body forward during walking has been defined as an essential requirement of gait (Shumway-Cook and Woollacott, 1995), and greater propulsive ground reaction forces (GRFs) are required to achieve faster walking speeds (Nilsson and Thorstensson, 1989). These propulsive forces are predominantly produced by the ankle plantarflexors (Neptune et al., 2001), which play a critical role in gait as primary providers of both Stability of the tibia and forward propulsion during the terminal stance phase (Neptune et al., 2001). However, plantarflexor weakness is a common impairment post-stroke, limiting power generation at the ankle joint during propulsion, gait speed and causing insufficient push-off due to lack of heel rise. Many studies report decreased ankle dorsiflexion during swing phase (Olney et al., 1994; Danielsson and Sunnerhagen, 2000; Chen et al., 2005a; Roelker et al., 2019).

2.5.4.4 The Role of Assistive Devices to improve walking Performance Post-Stroke

Assistive devices (also known as walking aids), were designed to increase gait efficiency, reduce residual disability and lower the burden of care during early intensive rehabilitation and gait training for stroke survivors in clinical settings (Karakkattil et al., 2020; Huizenga et al., 2021). However, assistive devices are also often used by stroke survivors long after rehabilitation has ended, as they offer increased safety through reducing both the fear and risk of falling, due to increasing the support surface, improving postural stability, improving functional independence, and improving distance and pace (Caro et al., 2018; Morris et al., 2022).

It should be noted that there are a range of assistive devices, such as walking sticks and crutches to support dynamic balance and often used to unload weight from the affected side, ankle–foot orthoses (AFOs) are designed to support and stabilise the ankle and foot. They help to prevent foot drop, correct gait abnormalities, and improve overall walking mechanics. Functional Electric Stimulation (FES) devices use electrical impulses to stimulate weakened muscles and enhance their function. They can be applied to the lower limbs to improve muscle strength, reduce spasticity, and promote a more natural walking pattern (Jutai et al., 2007; Hwang and Song, 2023).

Studies on the use of assistive devices by hemiparetic stroke patients report that 32% to 76% of patients use at least one device after a stroke (Laufer, 2004; Allet et al., 2009). Allet et al (2009) examined the effects of three different walking canes (1. Nordic stick, 2. 4-point cane, 3. simple cane with ergonomic handgrip) that are widely used in clinical practice. Although differences in spatiotemporal parameters between the three walking aids were discrete, participants walked significantly longer distance during the 6-minute walk test using the simple cane with the ergonomic handgrip. Furthermore, reduction in weight-bearing on the non-paretic lower limb and step time symmetry was significantly improved with the simple cane with the ergonomic handgrip than with the 4-point cane. On the other hand, Laufer et al (2004) observed that the 4-point cane significantly reduced mediolateral sway during stance, it could be assumed that stroke survivors with increased balance issues would prefer the 4-point cane.

Findings from previous studies have evidenced that AFO improves spatiotemporal parameters such as stride length, walking speed and cadence (Abe et al., 2009; Tyson et al., 2013; Daryabor et al., 2022). A systematic review by Tyson et al (2013) further suggests that

AFO can improve knee and ankle kinematics by preventing plantarflexion in early stance, swing phase and toe-off, but also facilitating weight-bearing on the paretic lower limb by increasing the centre of pressure forwards over the stance foot, enhancing knee movements during stance phase, compared to walking without the AFO. However, the studies selected in this review were predominantly cross-over trials that assess the immediate effects of AFOs in small samples, with trials conducted over a single day. Although this is an effect way to examine the use of AFOs on stroke biomechanics, the effects of long-term use are not explored. Therefore the long-term impacts of AFO is not known.

The selection of an assistive device depends on the stroke survivor's specific needs, level of impairment, and rehabilitation goals. A comprehensive assessment by healthcare professionals, such as physical therapists or occupational therapists, is essential to determine the most suitable assistive device and to tailor a rehabilitation plan that addresses the stroke survivor's unique challenges and strengths.

2.5.4.4 Walking biomechanics on uneven ground

Community ambulation often requires to have the capabilities to adapt to the environment when walking, which can also be termed as the ability to adjust the basic stepping pattern in order to meet environmental demands and task goals (Hawkins et al., 2017). Walking on terrain that one would encounter when walking in natural outdoor environments are often unpredictable, non-linear and yielding underfoot (e.g. soft ground). Therefore, inaccessibility, the characteristics of uneven terrain, alongside the various transitions between different surfaces, make many tasks challenging for the stroke survivor, however these factors are often forgotten in traditional indoor stroke rehabilitation and offers a rationale for the development of a novel programme that is based in outdoor settings. In much of the literature investigating walking performance on uneven terrain, healthy able-bodied individuals modify both spatial and temporal parameters and lower limb kinematics in order to alter walking strategies on uneven terrain (Rogers, Cromwell, & Grady, 2008; Schulz, 2011; Thies, Richardson, & Ashton-Miller, 2005).

2.5.5 Summary

Walking performance is one of the main physical functions negatively affected by stroke and regaining independent walking capability is a key priority in stroke rehabilitation. This section highlights that walking performance is multifaceted, incorporating walking speed and metabolic cost, spatial and temporal parameters and biomechanical function of walking. Poor walking performance can lead to lack of independence and increase inactivity, promoting sedentary behaviour, which ultimately causes many young stroke survivors to be confined to indoor settings. This reduces social participation and interaction with others and the inability to partake in community and outdoor ambulation. Therefore, new approaches to stroke rehabilitation to improve walking performance post-stroke are being developed, which uses outdoor environments, as evidenced within this thesis.

2.6 Quality of Life and Confidence

2.6.1 The Impact of Stroke on Young Stroke Survivors

Often the full impact of having a stroke is not recognised until young stroke survivors have been discharged from the hospital and attempt to recommence previously known physical and social practices and activities of daily living. Despite clinical progression in the treatment of stroke, many young stroke survivors are continually discharged home with limited walking ability and unidentified perceptual and cognitive disorders. These can restrict participation in outdoor physical activity (e.g. recreational activities), activities of daily living (e.g. washing or dressing), return to work, education or participate in social activities.

The severe change in lifestyle as a result of having a stroke, leads to loss in independence, mood alterations such as depression and anxiety, decreased life satisfaction (defined here as 'quality of life' (King, 1996)) and disruption to and cessation of social interaction with others have all been reported (Kim et al., 1999). Overall resulting in a more sedentary lifestyle (Billinger et al., 2014). Moreover, pain and fatigue commonly associated as consequences of having a stroke, may lead to limited activity. Despite these difficulties, young adults are often more motivated, but also have different functional and personal aims (Rudd et al., 2017) and have a strong desire return to employment and enjoy sport or recreational activities.

2.6.2 The Definition of Quality of Life

Quality of life has been defined in a multitude of ways, such as the need of satisfaction, health-related subjective experiences, or psychosocial and physical wellbeing (de Haan et al., 1993). In the context of health and illness, health-related quality of life (QoL) according to World Health Organisation and others (Cella, 1995; Carlozzi and Tulsky, 2013) is defined as "the extent to which ones usual or expected physical, emotional and social wellbeing are affected by a medical condition or it's treatments". Therefore, a multi-dimensional concept has since been adopted by researchers (de Haan et al., 1993; Carod-Artal et al., 2000) that is often defined by a broad range of life domains such as physical (e.g. mobility and performance of activities of daily living) (Carod-Artal and Egido, 2009), psychological (e.g. depression, anxiety and fatigue) (de Bruijn et al., 2015) and social (e.g. employment, social network and social role) (Kim et al., 1999; Carod-Artal and Egido, 2009; Daniel et al., 2009).

2.6.2.1 Physical Domain of Quality of Life After Stroke

For many young stroke survivors, the physical attributes of health-related quality of life include the difficulties in performing physical activities such as walking ability and activities of daily living (Chen and Rimmer, 2011). Research studies investigating quality of life of stroke survivors in the past twenty years, have focused on the physical elements of stroke recovery in isolation from the psychological effects of experiencing a stroke (Kim et al., 1999). This has since been viewed as a more narrow approach toward stroke rehabilitation and despite increased emphasis to improve quality of life, only functional status or health status were regularly used as the only criteria to measure quality of life (Renwick et al., 1996; Kim et al., 1999). In a meta-analysis conducted by Chen et al (Chen and Rimmer, 2011), it was found that exercise to improve health-related quality of life outcomes had a small positive effect post-intervention (physical domain p=0.02), but not at follow-up after the respective studies had ended (physical domain p=0.98). Despite the improvements made in stroke recovery in recent years, this raises the issue of how sustainable exercise interventions and interventions that solely place emphasis on physical function are, in order to maintain adherence in stroke survivors. Therefore it could be hypothesised that the end of structured supervised support may reduce access or motivation to continue with the exercise. Potentially the environment may play an important role in maintaining motivation and creating a more sustainable programme, as many post-stroke interventions for rehabilitation purposes take place in indoor clinical (McCluskey and Middleton, 2010) . The notion of 'green exercise', involving physical activity in green spaces (in the presence of nature) (previously discussed in section 2.1 *Exercising in Outdoor Environments*) has the strong potential to generate positive health outcomes and influence behavioural choices (Barton and Pretty, 2010). Though the majority of literature discussing the influential factors of 'green exercise' has been focused on healthy populations, the premise is there to use this alternative environment to improve physical aspects of quality of life of stroke survivors.

2.6.2.2 Psychological Domain of Quality of Life after Stroke

The impact of psychological factors (e.g. mental health) young adults face after having a stroke as they endeavour to navigate through managing newly acquired physical and functional impairments is reported frequently to be undeniably challenging (Desrosiers et al., 2006). Fatigue, depression and anxiety are reported to be prominent symptoms years after having a stroke at a young age, adversely affecting quality of life. Post-stroke fatigue affects activities of daily living through lack of energy, weariness and aversion to effort and is often reported in approximately 40% of stroke patients compared to 18.4% in healthy able-bodied controls (Christensen et al., 2008).

In a study conducted by Maaijwee et al (2016), symptoms of depression and anxiety were found to be nearly three times higher when compared with healthy age-matched controls. These findings could be interpreted that these symptoms are attributable to having stroke at a young age, potentially due to the profound changes experienced and the inability to return to how life was prior to having a stroke. Thus resulting in lower motivation and isolation from daily and social activities.

It should be interesting to note that in this study, having a more severe stroke or recurrent stroke, were not necessarily affiliated with increased risk of depression and anxiety, though comparatively some studies reported recurrent strokes to be linked with increased depression (de Groot et al., 2000; Tiemeier et al., 2004). One explanation for the contradictory findings may not be as a result of severity of brain damage, but more the location of the lesion and damage caused to neural pathways (Terroni et al., 2011). However, no differences in prevalence of depressive symptoms or anxiety were found between different lesion locations. However, the study conducted by Maaijwee et al (2016) may have suffered from selection bias as a result of using the Hospital Anxiety and Depression Scale (HADS) (Snaith, 2003) in the assessment and prevalence of depressive symptoms and anxiety. Patients in this study cohort may not have been able to complete the questionnaire due to severe aphasia or cognitive difficulties, which could have also have been the patients with the highest prevalence of depressive symptoms and anxiety.

Though many stroke recovery interventions and rehabilitation programmes often place particular emphasis on physical activity in order to improve functional outcomes, such as regaining the ability to walk, complete activities of daily living and increase independence (Saunders et al., 2020), it is also important to develop interventions that promote positive psychological outcomes, as part of improving overall quality of life of young stroke survivors. Literature within both ‘health geography’ and ‘environmental psychology’ brings to light the positive and restorative attributes of being in, or engaging with the natural environment, which have been shown to reduce symptoms of stress and anxiety (Korpela et al., 2008; Thompson Coon et al., 2011; Meijering et al., 2017) and therefore give premise for this to be applied as a part of stroke rehabilitation services.

2.6.2.3 Social Domain of Quality of Life After Stroke

Many young adults report decreased social interaction with others one-year post-stroke, negatively affecting health-related quality of life. This can be due to reduced mobility, a lack of confidence, unemployment or change in family relationships. In a systematic review by Daniel et al (2009), studies reported that up to 54% of stroke patients expressed that stroke was the cause for family problems, by deterioration of spousal relationships and change of role from spouse to caregiver. Blake et al (2003) reported that carers of stroke patients experience significant strain. Levels of strain were high with 39% under strain at 3 months and 40% under strain at 6 months. Supporting the view that strain remains relatively high over time due to patient dependence on family.

Shipley et al (2018) found that many participants described stroke to be the cause of 'profound loss'. These 'life losses' were reflections on what the participants had lost due to stroke, such as the elements of their life before stroke like leisure and social activities and their established work and family roles. Also, for the majority of participants, the losses manifested when they returned home, or seeing previous social circles 'doing things that you can't do' on social media or other forms of communication. In many cases this created barriers to the environments that leisure and social activities take place in, such as outdoor and community settings (McCluskey and Middleton, 2010). However, outdoor settings and outdoor adaptive activities provide opportunities to overcome social and attitudinal barriers and promote social interaction (James et al., 2018; Louise S Madsen et al., 2021).

In addition to the aforementioned losses, a number of participants reported the breakdown of relationships and social isolation after stroke, similar to findings in other studies (Daniel et al., 2009). However, what was most prominent in terms of loss was losing friendships as a result of stroke and thus became a barrier when re-building social connections, such as friends not knowing how to broach the subject of stroke, socialising required more effort than before having a stroke and the inability to connect through shared interests and activities like running, therefore losing the balance required to maintain reciprocal friendships. However, this study was performed within a region in Australia and therefore the insights detailed in the study by Shipley et al (2018) might not necessarily be transferable for other countries. Moreover, the use of telephone and online methods to interview participants living at greater distances could have swayed disclosure of participants. Though it was reported that researchers were assured with the depth of participant reflections during interviews.

2.6.3 Confidence Post-Stroke

Reduced confidence post-stroke is common regardless of level of impairment and is present in all three domains of quality of life (e.g. physical, psychological and social). Low confidence is associated with thinking pessimistically, which is believed to limit rehabilitation potential after a stroke (Robinson-Smith and Pizzi, 2003). A lack of confidence has also been associated with reduced social interactions, not getting out of the house and a loss of self-identity. The impact of such factors are likely to lead to increased dependence and poor health-related quality of life in the long-term, with many young stroke survivors having identified that finding ways to improve confidence is one of the main priorities of rehabilitation post-stroke. Whereas people who think optimistically are reported to have higher levels of self-confidence and have increased chances of recovering pre-stroke functional capabilities (Lenzi et al., 2008; Broomfield et al., 2011). Though confidence, self-esteem and self-efficacy are not as frequently measured as quality of life, the outdoor environments can play a role in not only a stroke survivors recovery, but also for other conditions such as dementia (Whear et al., 2014), providing a place of healing as well as consolidation of self-esteem (Rappe and Topo, 2007).

Horne et al (2017) reported the importance of capturing perceived levels of confidence quantitatively in stroke patients, to facilitate and target appropriate rehabilitation. The Confidence after Stroke Measure (Horne et al., 2017) (CaSM) has been developed to assess confidence defined as a broader term than previous measures (Maujean et al., 2014). Three subcomponents of confidence are evaluated in the CaSM; self-confidence, positive attitude and social confidence, which are key difficulties for many individuals post-stroke. Though the CaSM is the first measure to evaluate overall confidence post-stroke, there are limiting factors needing to be addressed. Only ten participants were recruited and all had experienced having a stroke over twelve months and therefore in the chronic phase of stroke recovery, before taking part in the study. As a result of this, participants may have been happier to discuss their post-stroke experience, unlike the stroke survivors who are three or six months post-stroke. This population of stroke survivors may have felt differently about their experiences. Collating experiences from stroke survivors who are at different points in their stroke recovery would have given a spectrum of perspectives.

2.6.4 Summary

Quality of life is an important factor to consider regarding recovery post-stroke. Despite improvements in stroke rehabilitation services, many young stroke survivors are still heavily dependent on the support of their spouse, families and community healthcare clinicians, with some not being able to return to work and become confined to indoor settings. Social isolation and the loss of friendships/ relationships are commonly seen after stroke. Current literature suggests that promoting engagement in natural outdoor settings to improve physical and psychological wellbeing, but also increasing social interactions, could be a key mechanism to improve stroke recovery in young adults. Because of this, the rationale for why a new and alternative rehabilitation programme based in outdoor environments continues to strengthen.

2.7 Rehabilitation Post-Stroke

2.7.1 What is the Role of Rehabilitation and How Important is it?

Rehabilitation has a prominent role in recovery to regain independence, improve quality of life and restoration of walking ability (Dickstein, 2008) is a key aim of many individuals post-stroke (Saunders et al., 2016). However, no specific rehabilitation guidelines exist for young adults who have had a stroke, despite increased prevalence of stroke in young adults who have different functional requirements and capabilities (Rudd et al., 2017).

Most literature investigating stroke evidence-based rehabilitation programmes involve combined aerobic and resistance exercises, which have reported significant improvements in cardiovascular fitness, walking ability and muscle strength gains in the upper and lower limbs (Brogårdh and Lexell, 2012). Although exercise has primarily been used to improve physical function post-stroke, new research suggests that exercise interventions may further improve some aspects of neurological function such as memory and health-related quality of life domains such as physical, psychological and social wellbeing after stroke and post-stroke fatigue (Billinger et al., 2012).

2.7.2 Aerobic Exercise and Stroke

Aerobic exercise (Billinger et al., 2012) is commonly defined as a form of physical exercise of low to high intensity for an extended period, which depends primarily on the transportation and use of oxygen. Following a stroke, the decrease in aerobic capacity continues over the ensuing six months, often remaining decreased thereafter (Sandberg et al., 2016). Reduced aerobic capacity impedes participation in everyday physical and social activities (Stoller et al., 2012), negatively impacting quality of life. Aerobic exercises have the potential to enhance motor unit recruitment and favour the development of high oxidative muscle fibres (Teixeira-

Salmela et al., 1999), enhancing functional mobility and enabling activities of daily living to be performed at lower percentages of maximal aerobic capacity. Most literature support the application of physical activity to improve aerobic capacity, walking performance and health-related quality of life outcomes of stroke patients from seven days to six months post-stroke (Macko et al., 2005; Brogårdh and Lexell, 2012; Gordon et al., 2013; Kim et al., 2014; Sandberg et al., 2016). However specific exercise programmes are often not mentioned, making many studies difficult to replicate or produce results (Pang et al., 2013). It is further difficult to compare results across different studies due to the different measures used to assess quality of life.

In the vast majority of research literature investigating the role of aerobic exercise interventions on walking performance and health-related quality of life, often utilise treadmills or cycling ergometers based in indoor clinical settings like hospitals or leisure centre gyms. with mixed findings on improvements in walking speed (Saunders et al., 2016). Therefore, walking endurance assessed by the 6-minute walk test (6-MWT) is commonly reported with positive results after participation in a 12-week aerobic exercise programme (Billinger et al., 2014).

The study by Sandberg et al (2016) reported multiple improvements in aerobic capacity measuring peak work rate ((watts), pre 113.9 ± 27.6, post 130.4 ± 33.7), walking speed during the 10m walk test (10MWT) ((seconds) pre 8.2 ± 3.0, post 6.0 ± 1.5) and walking distance during the 6-minute walk test ((metres) pre 394.7 ± 114.7, post 499.8 ± 93.1), compared to control group after completion of a twelve week, twice-weekly aerobic exercise sessions, involving exercises on the cycle ergometer and walking. Despite the improvements in aerobic capacity, walking speed and distance noted in the study by Sandberg et al (2016), these results cannot be generalised to the younger stroke population, due to the mean age of stroke survivors in this study (71.3±7.0 (range, 61-84)). It furthermore cannot be generalised to the wider stroke population as only individuals whose impairments corresponded to mild stroke (using the National Institute of Health Stroke Scale) were recruited, thus excluding a large proportion of stroke survivors who may have more severe impairments and could have benefitted from such exercise intervention.

Studies (Taylor et al., 2006; Langhammer and Stanghelle, 2010) using community overground walking have also reported improvements in walking endurance at a similar rate to treadmill and cycling ergometer protocols (Pang et al., 2013), with no differences seen in the 6-MWT three months post-intervention between indoor and outdoor interventions. These studies indicate that exercise rehabilitation for stroke need to include community overground walking to improve not only walking endurance but also functional ability, such as management of uneven and different terrains, and ascending and descending curbs and slopes when walking in a community setting, which cannot be done in a clinical setting (Billinger et al., 2014). The study conducted by Kim et al (2014), chronic stroke survivors were prescribed a supervised four-week intensive community walking rehabilitation programme to improve walking performance (e.g. walking speed and distance), but also social participation (measured using the Stroke Impact Scale) and was composed of various real community environments, including walking near the hospital setting, walking outside the hospital setting, walking outside of the hospital setting on uneven ground (e.g. unpaved road with obstacles). Whilst improvements in walking parameters were observed, this study should be compared against another outdoor-walking programme, to identify and assess the effectiveness of the community walking training programme. However, due to the paucity of studies investigating outdoor programmes, this could not be done. Therefore, the study by

Kim et al (Eng et al., 2003) also emphasised that most stroke rehabilitation programmes focused on improving walking performance are conducted in indoor clinical settings such as hospitals and leisure centre gyms, stating that these indoor settings would not suffice for providing different outdoor environmental situations that a stroke survivor would experience when back in the community (Lord and Rochester, 2005).

2.7.3 Resistance Exercise and Stroke

Resistance exercise refers to exercises improving muscular strength and power by making repeated muscle contractions resisted by body weight, free weights and other isokinetic devices (Billinger et al., 2014; Winstein et al., 2016). A meta-analysis conducted by Mehta et al (2012), demonstrated that lower-limb resistance exercise 6-month post-stroke has the capacity to improve self-selected walking speed and total distance walked in community settings. Despite some literature (Billinger et al., 2014) investigating the role of resistance training in stroke recovery and walking ability, stating that lower limb muscle strength has been found to positively correlate with walking endurance (6-MWT), no correlation was found post-intervention between resistance exercise and walking speed. With the majority of literature (Flansbjer et al., 2008; Saunders et al., 2016, 2020; Gambassi et al., 2017) agreeing with this correlation, by reporting that resistance exercise has little or no effect in improving gait performance, unlike aerobic exercise, leading to the question whether resistance exercise alone is a key component of stroke rehabilitation.

After stroke, time spent being inactive is greater than 50%, this increase of inactivity can cause a decline in muscle mass of the paretic limbs, having detrimental effects on health-related quality of life and functional ability. An efficient method to increase muscle strength is to include progressive resistance training into stroke rehabilitation programmes, involving loads of 70% or more of the maximum strength to be utilised (Kraemer and Ratamess, 2004; Flansbjer et al., 2008). Previous literature has reported that resistance exercise can also decrease cardiac demands of activities of daily living (e.g. carrying groceries or lifting moderate weighted objects) and therefore subsequently improves health-related quality of life (Billinger et al., 2014; Winstein et al., 2016). In a study by Flansbjer et al (2008), reported that ten weeks of twice weekly leg extension and curl exercises resulted in multiple improvements, including significant improvements in dynamic knee muscle strength (41-75% increase in improvement), increase in walking distance using the 6-MWT (mean change of 22m) and quality of life, using the Stroke Impact Scale (mean change of 4.6) from baseline to post intervention, with gains through the programme being maintained at follow-up, pertaining that resistance training does play a role in stroke recovery in the long-term. Though a limiting factor from this study is that it does not state a time point when follow-up testing occurred, reducing the chances of replicating the study.

A systematic review by Gambassi et al (2017), evaluated the role structured resistance exercise programmes play in stroke recovery. Out of the twelve studies included in the review, it was highlighted that only five studies explicitly detailed the main variables (e.g. rest intervals between sets and exercises) used for resistance exercise programmes. Detailing the rest intervals between sets and exercises have been found by some researchers (Ahtiainen et al., 2005; Comstock et al., 2013) to be an important factor for an effective resistance exercise programme. In what would benefit stroke recovery, Robinson et al (Robinson et al., 1995) details that rest intervals play a key role in neuromuscular adaptations, with greater rest intervals were associated with greater strength gains. However inadequate rest intervals may have a negative effect on expected results (Gambassi et al., 2017) by exacerbating fatigue and muscle weakness caused by stroke.

2.7.4 Combined Aerobic and Resistance Exercise and Stroke

There is strong evidence to suggest that combined aerobic and resistance exercise rehabilitation programmes post-stroke address and improve multiple impairments, such as functional ability, cardiovascular fitness and walking performance, compared to stand-alone aerobic or resistance exercise programmes. Meta-analysis conducted in the Cochrane Review (Saunders et al., 2016, 2020) reported mixed methods programmes significantly increase walking speed and endurance in 6-MWT compared to aerobic or resistance exercise alone. A scientific statement by Billinger et al (2014) also highlights the need for combined exercise programmes specific to stroke, to also include flexibility training in order to increase range of movement and prevent deformities, alongside neuromuscular training to enhance balance and co-ordination.

Table 2.5: Exercise recommendations developed by Billinger et al (2014)

Mode of exercise	Goals/Objectives	Prescriptive Guidelines Frequency/Intensity/Time
Aerobic • Large-muscle activities (e.g. walking, stationary cycle ergometry, functional activities)	• Increase walking speed and efficiency • Improve exercise tolerance • Increase independence and activities of daily living • Reduce motor impairment and improve cognition • Improve vascular health	• 55-80% of maximum heart rate • 3-5 days per week • 20-60 minutes per session
Resistance • Resistance training of upper and lower limbs, trunk using free weights, weight-bearing activities • Circuit training • Functional mobility	• Increase muscle strength and endurance • Increase ability to perform leisure time activities and activities of daily living • Reduce cardiac demands	• 1-3 sets of 10-15 repetitions of 8-10 exercises involving major muscle groups • 2-3 days per week • Resistance to increase over time as tolerance permits
Flexibility • Stretching (e.g. trunk, upper and lower limbs)	• Increase range of movement • Prevent contractures • Decrease risk of injury	• Static stretches (hold for 10-30 seconds) • 2-3 days per week (before or after aerobic or resistance training)
Neuromuscular • Balance and co-ordination activities • Yoga • Recreational activities using paddles/balls to challenge hand-eye co-ordination	• Improve balance, skill acquisition, quality of life and mobility • Decrease fear of falling • Improve level of safety during activities of daily living	• Use as a complement to aerobic, resistance and stretching activities • 2-3 days per week

Many studies (Pang et al., 2005; Eng, 2010) have used various mixed methods exercise programmes with success, one being the 'Fitness and Mobility Exercise Programme' (FAME), involving combined aerobic and resistance exercises, in community settings for older adults with stroke, finding it beneficial for improving walking endurance as assessed through the 6-MWT (distance). The 6-MWT improved significantly from baseline (328.1m) to post-intervention (392.7m), meaning a marked improvement of 64.6m, suggesting that after completion of the programme, participants were able to walk further, thus improving walking endurance and could have positive implications for completing activities of daily living (Billinger et al., 2014). However, the results from these studies are generalisable to a select group of community dwelling individuals with chronic stroke only.

A randomised clinical trial conducted by Duncan et al (2003) designed an exercise programme to improve strength, balance, and endurance, similar to the guidelines set out more recently by Billinger et al (2014) and detailed in table 2.4. This study observed gains in balance, endurance and mobility, with overall benefits seen in participants who were beyond the thirty day post-stroke recovery period. However, as this study solely recruited those who were in the sub-acute phase of stroke and therefore may not be generalisable to the wider stroke population. The researchers themselves expressed that this study was resource intensive, with each subject receiving 54 hours of 1-to-1 rehabilitation over the duration of three months. It could be stated that similar gains found in balance, endurance and mobility, can be achieved in group sessions where the programme is less time and resource intensive, but also has the potential to offer the positive effects of group support and group motivation. Furthermore, though this study was intended as a comprehensive, progressive intervention, it cannot be determined what component of the programme contributed to the success of the study.

2.7.5 Limitations of Established Stroke Rehabilitation Programmes

Nearly all research investigating the effects of aerobic, resistance and combined exercise programmes for stroke have been found on the older stroke population that may have pre-existing age-related degenerative conditions, like atherosclerosis, cardiovascular disease, arthritis and osteoarthritis (Saunders et al., 2016). Furthermore, older adults are at risk of age-related sarcopenia, due to being more inactive than that of the average young adult. Many exercise programmes may not be beneficial to the young stroke survivor, due to dosage, intensity and frequency of the prescribed exercise being tailored to older stroke patients. Young stroke survivors may be able to cope better with increased intensity, frequency and difficulty of exercises, depending on stroke severity (Rudd et al., 2017).

Furthermore, young adults need to have a rehabilitation programme that focuses on and supports their needs and requirements, such as return to employment, enjoy social/ leisure activities and participate in activities that take place in outdoor environments. Aerobic exercise that specifically takes place in natural outdoor settings are found to increase social participation and adherence to exercise compared to indoor settings (Focht, 2009; Fraser et al., 2019). As there are no established comprehensive exercise rehabilitation programmes for the younger stroke population, the potential to develop a rehabilitation programme that takes into account the young stroke survivor's requirements and uses a more stimulating environment such as outdoor settings is needed.

2.7.6 Summary

Combined aerobic and resistance exercise programmes for stroke rehabilitation have been proven to improve cardiovascular fitness, certain walking performance parameters and quality of life. However, as highlighted in this section, the majority of research has been conducted with the older stroke population as participants, who may have age-related degenerative conditions, which are not applicable to the typical young stroke survivor. Developing a combined aerobic and resistance exercise programme that emphasises the priorities of the young stroke survivor is much needed. There is a true opportunity to use natural outdoor environments an alternative setting for stroke rehabilitation programme and elicit potential increased improvements in walking performance and quality of life.

2.8 Thesis Aims and Objectives

The overarching aim of this research project is to design, develop and deliver a rehabilitation programme, using the outdoor natural environment as an alternative setting, specific to the needs and requirements of young stroke survivors with mild to moderate physical impairments. Furthermore this research project is to investigate whether an outdoor-walking rehabilitation programme can improve walking performance (walking biomechanics, speed and efficiency) and quality of life of young adults who have had a stroke. The results from this project will be used as benchmark data to provide evidence to support the role of outdoor rehabilitation in natural outdoor environments and green spaces (Tzoulas et al., 2007) for promoting health and wellbeing of young adults who have had a stroke.

The research project objectives are:

1. To investigate whether a ten week outdoor-walking rehabilitation programme can increase walking speed and decrease energy demands of young adults who have had a stroke
2. To investigate whether a ten week outdoor-walking rehabilitation programme can improve walking biomechanics (kinetics and kinematics) of young adults who have had a stroke
3. To investigate whether a ten week outdoor-walking rehabilitation programme can improve quality of life of young adults who have had a stroke

The research hypotheses are:

1. The outdoor-walking rehabilitation programme will increase walking speed and improve walking performance (reduce energy cost and improve biomechanical function when walking)

2. The outdoor-walking rehabilitation programme will improve quality of life and confidence for young adults who have had a stroke

Chapter Three

3. Study One: Assessing the Feasibility of an Outdoor-Based Rehabilitation Programme For Young Stroke Survivors

This chapter has been submitted as a two part research paper to the journal, Disability and Rehabilitation, for publication. Furthermore, the findings from this feasibility study has been accepted in the form of an abstract to the European Stroke Organisation Conference (May 2022) and has been presented at the Stroke Hub Wales Symposium in March 2022.

3.1 Rationale for the Feasibility Study

Study 1: Due to the paucity of research studies investigating the role of outdoor activities for health and wellbeing in clinical populations, it was decided that a feasibility study was a necessary part of this research project. Conducting a feasibility study allowed us as researchers, to understand and assess what activities were appropriate for young stroke survivors (with mild to moderate physical impairments) to engage in, as part of the development of an outdoor-based rehabilitation programme, specific to young stroke survivors.

3.2 Background

In the United Kingdom, twenty-six percent of adults who experience a stroke are younger than sixty-five years of age and therefore defined as a young adult (Mallick and O'Callaghan, 2009; Ekker et al., 2018). Most are unable to complete activities of daily living, return to work, education, participate in social activities (Daniel et al., 2009), or take part in outdoor physical activity (Winstein et al., 2016; Leung et al., 2017). This can result in a loss of independence, social isolation, depression and poor quality of life (de Bruijn et al., 2015). Despite the increased prevalence of young adults experiencing a stroke due to unhealthy lifestyle choices (e.g. eating unhealthily, smoking, alcohol consumption) (Putaala et al., 2009; George et al., 2017; Ekker et al., 2018), obesity and sedentary behaviour and the cause for nearly 90% of all strokes (Aigner et al., 2017), there is very little research and only limited clinical guidelines to support their care (Aigner et al., 2017).

Rehabilitation has a prominent role in recovery to regain independence, improve quality of life and walking performance (Dickstein, 2008), which are often key aims of many individuals who have experienced a stroke (Saunders et al., 2016). Recent research (Billinger et al., 2014; Winstein et al., 2016) supports the use of combined exercise (aerobic and resistance) for rehabilitation programmes to improve functional capabilities and quality of life. However, all rehabilitation programmes currently in use have been developed for older stroke populations (Eng, 2010; Billinger et al., 2014; Rudd et al., 2017), who may also have pre-existing age-related degenerative conditions (Jaul and Barron, 2017), with no established comprehensive exercise rehabilitation programmes for the younger stroke population. The cause of the stroke in the young often differs (e.g. rare genetic conditions, arteriovenous malformation) to the older population which can impact on the design and delivery of the rehabilitation programme.

Exercise rehabilitation conducted in natural outdoor environments, termed “green exercise”, has been associated with better physical and mental health compared to indoor exercise, in terms of wellbeing, longevity with decreased anxiety and depression for both healthy individuals (Thompson Coon et al., 2011) and individuals with dementia(Tzoulas et al., 2007; Whear et al., 2014) and diabetes (Fritz et al., 2011). Kim et al (2014) investigated the effect of an outdoor community walking training programme for young stroke survivors that used different outdoor environments over a period of four weeks and they reported significant improvements in walking speed assessed using the 10m walk test (pre-intervention 0.51m/s, post-intervention 0.71m/s), and walking distance using the 6-minute walk test (pre-intervention 162.59m, post-intervention 227.8m). In the same study, social participation scores using the Stroke Impact Scale significantly increased, indicating the participants benefited from the group based activity.

Thompson-Coon et al (2011) and others (Hartig et al., 1991; Hug et al., 2009) found that physical exposure to views of nature can improve health and wellbeing by providing relaxation from stress and mental fatigue in healthy populations, compared to windowless indoor environments. As most rehabilitation provided post-stroke is delivered in indoor clinical settings such as leisure centre gyms and hospitals (McCluskey and Middleton, 2010), utilising an outdoor-based rehabilitation programme may facilitate better physical and psychological health due to additional factors associated with the outdoor environment.

There are no intervention studies evaluating the role of a structured outdoor-based rehabilitation programme to date for young stroke survivors and no studies exist that take into account of other outdoor activities, such as canoeing and archery, as previous studies investigating outdoor and community rehabilitation programmes include only walking as its main activity (Kim et al., 2014) and therefore the feasibility of delivering a rehabilitation programme utilising the outdoor environment and different outdoor activities needs to be determined.

3.2.1 Aims

The aims of this study were to determine, 1. The delivery and adherence of an outdoor-based rehabilitation programme for young stroke survivors and 2. The participant capability of an outdoor-based rehabilitation programme for young stroke survivors.

3.3 Materials and Methods

3.3.1 Recruitment

This study was approved by the Manchester Metropolitan University Research Ethics Committee (EthOS- 11718). Informed verbal and written consent to take part in this study was obtained from each participant.

Four young adults aged between 33 and 52 years, who have had an infarct or haemorrhage stroke in the last three years and are able to walk continuously for five minutes, were recruited via word of mouth and letters sent via post from a sample of young stroke survivors already known to the research team through previous involvement in outreach activities, public engagement events and community groups from Swansea Bay University Health Board, Wales, UK.

3.3.2 Focus Group: Understanding what the Young Stroke Survivor want in an outdoor-based rehabilitation programme

Prior to commencing the feasibility study, a focus group with three of the participants were invited as part of patient and public involvement in engagement (PPIE), to discuss and aid with the development of an outdoor-based rehabilitation programme. The following questions were asked as part of a semi-structured group interview format:

1. What activities would you like to take part in, as part of a rehabilitation programme specific to young stroke survivors?
2. What do you feel is important to focus and investigate for an outdoor-based rehabilitation programme?
3. Do you enjoy taking part in outdoor activities? If so, why?
4. If there was opportunity, would you want to have your family involved in the programme?

3.3.2 Intervention

This study involved an outdoor-based rehabilitation programme, for a duration of three weeks period in the Brecon Beacons National Park, Wales, UK. It included outdoor activities such as walking, archery, canoeing. Each session was conducted by a qualified and experienced outdoor activity instructor (KL), once-per-week for a duration of two hours.

Table 3.1: Planning of outdoor-based rehabilitation programme using the Consensus for Exercise Reporting Template (CERT) as a guide

Materials	1.	*Type of exercise equipment*
	-	Minimal (no specialist gym equipment required)
	-	Walking clothing and equipment recommended
Provider	2.	*Qualifications, teaching/supervising expertise and/or training of the exercise instructor*
	-	Outdoor activity instructor with over thirty years of experience in outdoor instruction. Holds all appropriate qualifications for leading outdoor-activities. Has in-depth local knowledge of the area where the outdoor-walking rehabilitation programme is planned to take place
	-	Rebecca Clarke (researcher of study) - outdoor activity instructor with four years of experience in outdoor instruction. Holds all appropriate qualifications for leading outdoor-activities
Delivery	3.	*Whether exercises are performed individually or in a group*
	-	3-week outdoor-based rehabilitation programme: group
	4.	*Whether exercises are supervised or unsupervised*
	-	3-week outdoor-based rehabilitation programme: supervised
	5.	*Measurement and reporting of adherence to exercise*
	-	Exercise Diary
	6.	*Details of motivation strategies*
	-	Researcher to call participant once-per-week
	7.	*Decision rules for progressing the intensity of the exercise programme*
	-	This will be dependent on walking speed
	8.	*Each exercise is described so that it can be replicated (e.g. illustrations, photographs)*
	-	3-week outdoor-based rehabilitation programme sessions are described in the exercise diary using word descriptions and illustrations
	9.	*Content of any home programme component*
	-	
	10.	*Non-exercise components*
	-	No non-exercise components are included in this study
	11.	*How adverse events that occur during exercise are documented and managed*
	-	In the unlikely situation of any adverse events, participants will be treated accordingly and reported appropriately. We will adhere to institutional procedures for recording and reporting adverse events and their follow-up
Location	12.	*Setting in which the exercises are performed*
	-	Outdoor-based rehabilitation programme: Talybont-on-Usk, Brecon Beacons National Park, Wales
Dosage	13.	*Detailed description of the exercises (e.g. sets, repetitions, duration, intensity)*
	-	Detailed description of the 3-week outdoor-based rehabilitation programme are included in the exercise diary
Tailoring	14.	*Whether exercises are generic ("one size fits all") or tailored to the individual*
	-	Exercises will be tailored to the individual
	15.	*Decision rule that determines the starting level for exercise*
	-	Walking speed will determine the starting level of exercise

3.3.3 Data Collection

3.2.3.1 Participant Demographics

Demographic data included age, time since stroke, type of stroke and walking speed.

3.3.3.2 Delivery and adherence to the outdoor-based rehabilitation programme

End of week and end of study questionnaires. Delivery and adherence to the outdoor-based rehabilitation programme was measured through the use of structured questionnaires adapted from the Consensus for Exercise Reporting Template (CERT) (Slade et al., 2016). End of week and end of study questionnaires were contained within the participant exercise diary, provided at the start of the study and were completed at the end of each week and at the end of the study. Both end of week and end of study questionnaires used a Likert scale response format with a range from 1-5 (1-completely disagree, 5-completely agree) for assessing level of enjoyment, delivery, tailoring and support for the outdoor-based rehabilitation programme, the end of study questionnaire additionally assessed re-participation to the outdoor-based rehabilitation programme. A Likert scale response format has been found to be a valid, reliable and responsive measure of attitudes, beliefs and opinion (DeVellis, 2016) in health related research. Participants could also provide feedback in a separate comments section. Exercise diaries were returned to the researcher (RC) at the end of the study.

Table 3.2: End of week and end of study questionnaires provided to participants in the exercise diary, using the CERT and likert scale response format

CERT Domains	End of Week Questionnaire
Enjoyment	Did you enjoy this week's outdoor activity session? 1 2 3 4 5
Support	Was the outdoor activity instructor helpful and supportive during this session? 1 2 3 4 5
Delivery	Did you like how this week's outdoor activity session was delivered? 1 2 3 4 5
Tailoring	Was this week's outdoor activity tailored to you? 1 2 3 4 5
CERT Domains	**End of Study Questionnaire**
Enjoyment	Did you enjoy the outdoor activity sessions provided? 1 2 3 4 5
Delivery	Did you like how the outdoor activity sessions were delivered? 1 2 3 4 5
Support	Was the outdoor activity instructor helpful and supportive during all sessions? 1 2 3 4 5
Tailoring	Were the outdoor-based instructor-led sessions tailored to you? 1 2 3 4 5
Re-participation	Would you take part in a rehabilitation programme that uses outdoor activity again? 1 2 3 4 5

Quality of life. As part of the small-scale pilot, participants were asked to complete the EuroQoL EQ-5D-5L Quality of Life scale pre and post-intervention to identify any changes in self-reported quality of life. The EQ-5D-5L is split into two components, the first, classed as the descriptive system, comprising five domains (mobility, self-care, usual activities, pain/discomfort, anxiety/depression). The second, classed as the EQ-VAS (visual analogue scale), recorded the participant's self-rated health from 0-100 (0- worst health you can be, 100- best health you can be).

3.3.3.3 Assessment of participant capability to take part in the outdoor-based rehabilitation programme

Measurement of walking speed. Walking speed was captured pre-intervention in a community centre in the Brecon Beacons National Park, Wales, UK, to provide an indication of whether self-selected walking speed can be used to guide suitability and capability of taking part in outdoor activity and the outdoor environment. Previous research by this research team[24] has identified that walking speed can predict walking performance (efficiency) and ability to return to employment suggesting it could be used to guide capability of participation in an outdoor-based rehabilitation programme. At the start of the outdoor-based rehabilitation programme, participants were asked to walk at their self-selected walking speed for three minutes up and down a 15m long indoor walkway following guidelines used in a previous study conducted by Jarvis et al[24]. Brower timing gates (Brower TCi System, Brower Timing Systems, Draper, USA) were situated 2.5m from either end of the walkway to measure walking speed.

Instructor and researcher reflections. At the end of each outdoor-based programme session, the instructor and researcher completed qualitative reflections using a questionnaire developed from four CERT domains; enjoyment, support, delivery and tailoring.

Table 3.3: End of week open-ended questionnaire for instructor and researcher using CERT domains

CERT Domains	Instructor and Researcher Questionnaire
Enjoyment	Do you think the participants enjoyed that week's activity?
Delivery	Was this week's activity able to be delivered safely and as planned?
Support	Were you able to give support to all participants during the activity?
Tailoring	Were you able to give each participant different objectives to improve during the activity?

3.4 Results

3.4.1 Participant Demographics

The mean age of participants was 46 years (8.83). Mean time since stroke was 24.5 months (9.74). All data is presented mean (standard deviation).

Table 3.4: Mean ± standard deviation for participant demographics, EQ-5D-5L Quality of Life scale for domains mobility, self-care, usual activities, pain/ discomfort and anxiety and EQ VAS for young adults who have had a stroke

Participant Demographics (n=4) Mean ± SD		
Age (years)		46 ± 8.83
Time since stroke (months)		24.5 ± 9.74
Type of stroke	Infarct	3
	Haemorrhage	1
Gender	Male	4
	Female	0
Walking speed (m/s)		1.1 ± 0.41

EQ-5D-5L Quality of Life Questionnaire		
Descriptive system	**Pre-intervention**	**Post-intervention**
Mobility	2 ± 1.41	2 ± 1.5
Self-care	2 ± 0.57	1 ± 0.57
Usual activities	2 ± 0.81	2 ± 0.5
Pain/ discomfort	3 ± 1.70	2 ± 1.29
Anxiety	1 ± 0.5	1 ± 0.5
EQ-VAS	70 ± 14.14	87.5 ± 9.57

3.4.2 Assessment of delivery and adherence to the outdoor-based rehabilitation programme

3.4.2.1 End of week questionnaires

Results from "End of Week" questionnaires suggest that the outdoor-based rehabilitation programme was very well received by participants. Consistent feedback (on a scale of 0 = completely disagree and 5 = completely agree) by participants in each of the CERT domains, which included enjoyment (week 1; 5±0, week 2; 5±0, week 3; 5±0), support (week 1; 5±0, week 2; 5±0, week 3; 5±0), delivery (week 1; 5±0, week 2; 5±0, week 3; 5±0) and tailoring (week 1; 5±0, week 2; 5±0, week 3; 5±0).

3.4.2.2 End of study questionnaires

As similar to the end of week questionnaire, for each CERT domain the feedback was 5±0 from all participants. Key themes from participant's feedback for the outdoor-based rehabilitation programme were "enjoyment" as reported by all participants (n=4/4), with one participant preferring the outdoor-based rehabilitation programme to exercising indoors and "motivation" (n=4/4). Sub-themes for the key theme of "motivation" included "increased confidence to exercise outdoors", as participants were more willing to push themselves more due to the outdoor-based element of the rehabilitation programme and "socialise with other young stroke survivors". Participant feedback for the additional domain "Re-participation" (i.e. whether participants would like to take part in an outdoor-based programme again), reported that all participants are keen to participate in an outdoor-based programme again in the future (mean score of 5±0).

Table 3.5: Mean ± standard deviation for end of week and end of study questionnaires for outdoor-based programme

Outdoor-based Rehabilitation Programme				
	End of Week Mean ± SD			**End of Study Mean ± SD**
CERT Domains	**Week 1**	**Week 2**	**Week 3**	
Enjoyment (How well)	5 ± 0	5 ± 0	5 ± 0	5 ± 0
Support	5 ± 0	5 ± 0	5 ± 0	5 ± 0
Delivery	5 ± 0	5 ± 0	5 ± 0	5 ± 0
Tailoring	5 ± 0	5 ± 0	5 ± 0	5 ± 0
Re-participation				5 ± 0

Table 3.6: Key themes from participant feedback for the end of study questionnaire

Intervention	Key Theme	Sub-Theme	Example
Outdoor-based	Enjoyment	Enjoyment	*"I really enjoyed all of the activities"* *"The outdoor activities were really enjoyable"* *"Exercising outdoors is much more enjoyable than being inside"*
	Motivation	Increased confidence to exercise outdoors	*"made me want to push myself more"* *"I feel more confident walking in the outdoors and on different trails"* *"I never thought I would be confident enough to try different activities, even canoeing"*
		Socialise with other stroke survivors	*"Being on a rehabilitation programme, as a group with similar problems even though no two strokes are the same has helped me so much"*

3.4.2.3 EuroQoL EQ-5D-5L Quality of Life

Results from the EQ-5D-5L quality of life at baseline to post-intervention, indicated self-reported quality of life improved in self-care pre-intervention from 2 (0.57) to 1 (0.57) post-intervention and pain/discomfort pre-intervention from 3 (1.70) to 2 (1.29) post-intervention. No changes were observed in other quality of life domains of the EQ-5D-5L; mobility, pre 2 (1.41), post 2 (1.50), usual activities, pre 2 (0.81), post 2 (0.5) and anxiety, pre 1 (0.5), post 1 (0.5). Overall, the mean EQ VAS for all participants suggest a significant improvement from 70 (14.14) pre-intervention to 87.5 (9.57) post-intervention suggesting participants rated their health-related quality of life to be the 'best that it can be'.

3.4.3 Assessment of participant capability to take part in the outdoor-based rehabilitation programme

3.4.3.1 Walking speed

Mean walking speed for all participants was 1.1m/s (0.41), but there was a considerable range in walking speed across all participants which was from 0.6m/s to 1.5m/s. On reflection by instructor and researcher, walking less than 0.6m/s could incur difficulties in the outdoor-walking programme due to the different hazards commonly presented in natural outdoor environments (e.g. uneven ground, varying terrain).

3.4.3.2 Instructor and researcher reflections

At the end of each outdoor-based rehabilitation programme sessions, both instructor (KL) and researcher (RC) reflected on the activity provided through the use of end of week open-ended questionnaires, developed from CERT. One key theme that emerged was "support", both instructor and researcher reported that archery and canoeing activities required one-to-one support to participate due to the physical limitations of some participants (e.g. reduced function of one arm) compared to walking activities. For the key theme of "delivery", the walking activities were easy to deliver and manageable, in comparison to the archery and canoeing activities, as these activities were time-consuming to prepare for. Archery and canoeing also posed difficulties for participants who had upper limb impairments, requiring more one to one support from the instructor, and therefore more difficult to deliver to a larger cohort. For the key theme of "tailoring", the walking activities were tailored to the individuals in distance and route choice, however due to the range in walking speed between individuals the group would often become divided.

Table 3.7: Instructor and researcher reflections of the outdoor-based rehabilitation programme, using the CERT and including additional comments

CERT Domains	Example quotes		
	Week 1	**Week 2**	**Week 3**
Enjoyment (How well)	*"All participants expressed enjoyment for both the walking and archery session"*	*"Canoeing was very well received by all participants"*	*"Participants and their families enjoyed the walk around Tor-Y-Foel and the reservoir"*
Support (Provider)	*"We were able to offer one-to-one support during walking as we were able to move quickly between participants"*	*"All participants were well supported when climbing into the canoes. However this was time consuming as two participants had more severe impairments, causing issues climbing into the canoes"* *"The two participants that had more severe impairments were in the same canoes as the instructor and researcher"*	*"We were able to communicate well with all participants and their families and offer support on step ground sections, when participants were unsure of their footing"*
Delivery	*"Walking was easy to deliver, the route was checked before the start of the session"* *"Participants were all able to take part"* *"Only two participants at any one time could take part. Other participants had no activity to do"*	*"Once participants were on the water with us, it was an easy and manageable activity"* *"Setting up for this activity was time consuming"*	*"Walking was really easy to deliver and will also be an easy activity to do with a larger group of participants"*
Tailoring	*"During the walking activity, the route was able to be shortened for anyone finding difficulty with the distance. However the group split between fast and slow walkers"*	*"One participant began to get pins and needles in their legs, therefore we were able to help him climb on to trail next to the canal and walk with one of the researchers"*	*"Able to give each participant different skills to work on, like how to use walking poles and how to walk safely on steep ground"*
Additional comments	*"For the larger-scale study, participants will be divided into two groups: fast walking group and slow walking group"* *"Archery will not be feasible for larger group as only two participants can take part at any one time"*	*"Although participants enjoyed the activity, if we had more participants it would not be a manageable activity for stroke participants, due to too many people on the water and different levels of physical impairments"*	*"An outdoor-walking rehabilitation programme will be a better programme to deliver. We can increase the difficulty of the walk each week through distance, terrain or gradient and not need as much equipment"*

3.5 Discussion

In this feasibility and small-scale pilot study, which aimed to assess the delivery, adherence and participant capability and effect of quality of life to an outdoor-based rehabilitation programme for young stroke survivors. All participants responded very positively to the programme, enjoying and adhering to it. Overall, the programme was deliverable, but the walking-based activities were much more manageable than canoeing or archery activities.

The mean walking speed of participants collected pre-intervention was 1.1m/s, with large variability in walking speeds between participants. The slowest walking speed reported was 0.6m/s. The instructor (KL) and researcher (RC) deemed that 0.6m/s would be the minimum walking speed required for participants to be able to cope with the demands of the natural outdoor environment based upon a subjective assessment of the capabilities of the participants on different terrain and gradients.

Instructor and researcher reflections for the outdoor-based rehabilitation programme suggest that archery and canoeing would not be feasible to run as part of an outdoor-based rehabilitation programme for a larger cohort of young stroke survivors. Both activities require additional resources (e.g. equipment and outdoor activity instructors) and the need for one to one supervision, which is potentially time-consuming and could cause participants to lose interest in the activity. Therefore, an outdoor-walking rehabilitation programme could be developed and be delivered in a safe manner, without the need for excessive, specialist equipment and facilitate social interaction between participants.

Despite the study taking place over three-weeks with a limited number of participants, improvements in self-reported health-related quality of life using the EuroQol EQ-5D-5L scale, are potentially important findings for young stroke survivors and one that is likely to only be enhanced with a long-term study. Post-intervention, significant improvements in two quality of life domains (self-care and pain/discomfort) were reported, with the EQ VAS conveying significant improvement from 70 pre-intervention to 87.5 post-intervention, with no changes observed from pre-intervention to post-intervention in other quality of life domains; mobility, usual activities and anxiety. These results may be due to participants being higher functioning compared to other studies, with Duncan et al (2003) reporting significant improvements in both emotional and physical role functioning components of the SF-36. Similarly, Kim et al (2014) reported increased social participation post intervention using the Stroke Impact Scale (SIS), suggesting that use of mixed methods and community rehabilitation programmes can improve quality of life outcomes.

A number of limitations emerged during the current study. Firstly, the study had a small sample size (n=4), which may limit the broader delivery of the programme if the sample was much greater. Within the small sample there was a wide range in participant ability, highlighted by the difference in self-selected walking speed. However, this enabled assessment of capability across these different ability levels. Also, there was agreement between participants on all aspects of the CERT domains of enjoyment, support, delivery and tailoring. A further limitation is that this study only had a duration of three weeks, and therefore we can only predict whether participants will adhere to this type of programme delivered over ten weeks or more. In order to facilitate muscular strength and aerobic adaptations, programmes need to run over the course of a minimum of eight weeks (Saunders et al., 2020) so further research will look to explore these adaptations with a longer duration study.

3.6 Conclusions

In summary, an outdoor-based rehabilitation programme with outdoor-walking as the sole form of activity, which we predict is feasible to develop into a larger scale intervention for young stroke survivors. This feasibility and small-scale pilot study highlights that exercising in natural outdoor environments for young stroke survivors can increase motivation, confidence, improve health-related quality of life and has the potential to be used in rehabilitation for stroke survivors.

Chapter Four

4. General Methodology

The experimental design for this thesis follows guidelines from the Medical Research Council (MRC) Complex Interventions Framework (Skivington et al., 2021).

Study two: Originally planned as a randomised clinical trial (ClinicalTrials.gov ID-NCT04314388) but now a mixed-methods case controlled study, investigating the effects of an outdoor-walking rehabilitation programme on walking performance (walking speed, metabolic cost and biomechanical function) and quality of life outcomes, in young adults who have had a stroke.

4.1 Ethical Approval

This study was approved by the NHS Ethics Committee (Greater Manchester South Committee), Health Research Authority (United Kingdom) (IRAS study number 271699) and Manchester Metropolitan University Research Ethics Committee.

4.2 Study Design

Before the COVID-19 pandemic, this study was planned to be phase 1 randomised controlled clinical trial. However, the COVID-19 pandemic hampered the original design of the study, for a plethora of reasons. The uncertainty of the pandemic and ensuing nationwide lockdowns, led to alterations of when we were able to conduct research activities (e.g. participant recruitment, commencement of data collection and the rehabilitation programme). We also had to be aware of the differing COVID-19 guidelines set by the government and NHS of each respective nation (e.g. Wales and England). We also witnessed low participant recruitment rates from each participating NHS health boards (those acting as participant identification centres (PIC) for this study), through prioritisation of the pandemic and the redeployment of principal investigators at each PIC to other areas in the NHS. This did not allow for full efforts to be made in increasing participant recruitment. But also there was a reluctance by potential eligible participants to take part in the study due to increased risk of COVID-19 transmission. This was reported by site principal investigators (e.g. physiotherapists at NHS health boards acting as participant identification centres) that many young stroke survivors did not wish to leave their homes as a result. The COVID-19 pandemic also caused alterations with the proposed equipment used in this study, which would have potentially further increased risk of COVID-19 to participants and the research team (detailed in section 4.3.2.2.1 of this chapter).

Therefore, the study design of this research project is now a case controlled study to assess the effectiveness of an outdoor-walking rehabilitation programme. This chapter will present in detail two methodologies; 1. The case-controlled study that was physically conducted for this research project and 2. The previously planned randomised control clinical trial and the changes that were put in place.

4.3 The Case-Controlled Study

Table 4.1: Overview of methods used to investigate the influence of an outdoor-walking rehabilitation programme.

Recruitment	- Multi-centre case-controlled study involving three health board sites in Wales - Twelve participants
Assessment of walking speed & energy cost *Pg. 95*	*Walking Speed (see figure 4.3)* - Participant to sit quietly for 5-minutes to measure resting heart rate. - Participant to walk at their self-selected walking speed for 3-minutes up and down a 15m walkway. - This was conducted both indoors and outdoors. *Energy Cost* - Physiological Cost Index (Section 4.3.2.2.1) was used to calculate energy cost of walking during indoor and outdoor protocols. These assessments were conducted at baseline and post rehabilitation for comparison.
Biomechanical Function *Pg. 99*	- *Camera system:* Qualisys Motion Capture with eight optoelectronic cameras around the capture volume to assess the foot, trunk, lower and upper limbs. Capturing at 120 Hz. - *Force Plates:* Four Kistler force plates were located 2x2 in a square formation, at the centre of the capture volume (15m portable walkway). All force data collected were then sampled at 1000 Hz *(see figure 4.4 for schematic of remote laboratory set-up)* - Participants completed seven walking trials to ensure full collection of data. Walking trials were conducted at baseline and post rehabilitation for comparison.
Assessment of Quality of Life *Pg. 106*	Quality of Life was assessed using six questionnaires, which were completed at baseline and post rehabilitation for comparison. - Stroke and Aphasia Quality of Life Scale - Confidence after Stroke Measure - Nature-Relatedness Scale - Three Aims and Three Difficulties Questionnaire - Intervention Questionnaires - Three-month Follow-up Questionnaire
Interventions *Pg. 111*	*Outdoor-walking Rehabilitation Programme* - Consisted of four 2.5 day residentials, which were delivered over a period of 10 weeks, based in Brecon Beacons National Park (see table 4.4) *Home Exercise Programme* - This was included to ensure participants had a mixed methods training programme to follow. - consisted of two unsupervised training sessions per week for 10-weeks - involved resistance, balance and stretching exercises
Statistical Analysis *Pg. 124*	*Quantitative Data* - All statistical analysis for quantitative variables was conducted using SPSS Version 27. If data was parametric: Dependent samples T-test, with Bonferroni correction If the data was non-parametric: Wilcoxon signed rank test *Qualitative Data* - Survey Research using mixed methods - Thematic analysis

4.3.1 Recruitment

This was a multi-centre study, involving three health board sites in Wales, United Kingdom: Aneurin Bevan University Health Board, Swansea Bay University Health Board and Cwm Taf Morgannwg University Health Board. The health board sites mentioned were used as PICs for participant identification and recruitment. These health board sites were also specifically chosen due to having established working relationships through previous studies and their geography in relation to the Brecon Beacons National Park, the location setting for the outdoor-walking rehabilitation programme.

4.3.1.1 Participant Randomisation

Fear of transmission of COVID-19 in a vulnerable patient group such as stroke, increased reluctance to take part in research activities and reduced support from PICs and principal investigators resulted in low participant recruitment rates for this study. Therefore, we were unable to conduct block randomisation as the sample size would have been too small in each patient group (group 1: intervention, group 2: control) to result in significant analysis. Ultimately, all participants were selected to have the intervention and the study design changed from a randomised clinical trial (detailed in section 4.4 of this chapter), to a case-controlled study (figure 4.1).

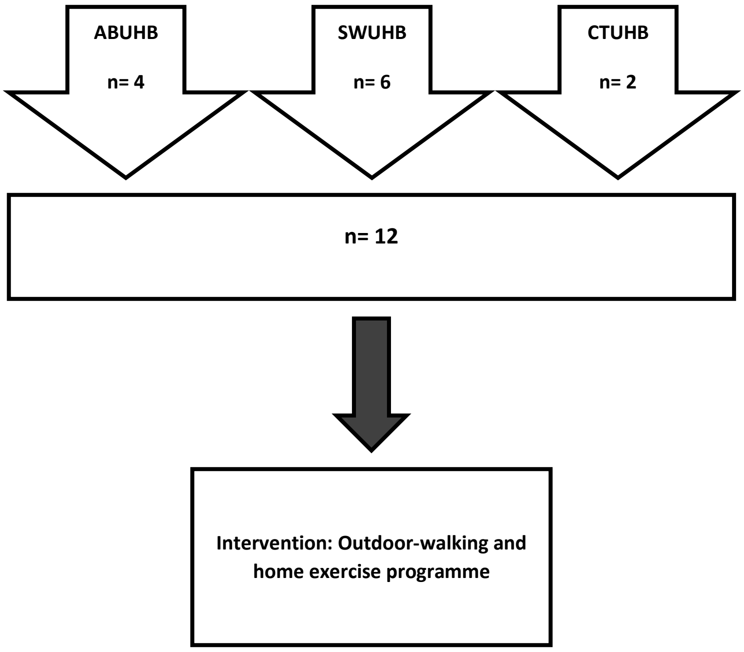


Figure 4.1: Actual study design as a case controlled study post COVID-19, with participating health boards Aneurin Bevan University Health Board (ABUHB), Swansea Bay University Health Board (SWUHB) and Cwm Taf Morgannwg Health Board (CTUHB)

4.3.1.2 Participants

Twelve individuals who have had a stroke were recruited to take part in this study (participant characteristics in *Chapter Five*). Despite conducting a feasibility study (detailed in chapter three of this thesis) to assess whether a rehabilitation programme (based in outdoor natural environments) is a suitable and safe form of rehabilitation for young stroke survivors (with mild to moderate impairments), recruitment via health boards used as participant identification centres (PICs) for participant identification and recruitment was unsuccessful. This was firstly due to aforementioned reasons relating to COVID-19 (detailed in section 4.2 Study Design, of this chapter), but also as a result of further reasons, such as supposed lack of potential participants who fitted the inclusion and exclusion criteria within the health boards and the perceived increased risk of walking in outdoor environments by young stroke survivors, as reported by physiotherapists and Principal Investigators resulting in the small sample size for this case controlled study.

Table 4.2: Inclusion and exclusion criteria for the outdoor-walking rehabilitation programme

Inclusion Criteria
- Young adults who have had a stroke and capable of giving informed consent[#]
- Aged 18-65years
- Male or Female
- Stroke within the last 3years
- Cause of stroke from cerebral infarct or haemorrhage that is clinically evident or from a Computerised Tomography Scan (CT Scan) or Magnetic Resonance Imaging (MRI) Scan
- Able to walk continuously for 5minutes and have a walking speed between 0.3 and 0.9m/s.
- Participants are permitted to use a walking cane or assistive devices (not wheelchair). Some participants may have been prescribed orthoses, ankle-foot orthoses, or Functional Electrical Stimulation (FES), participants will be tested wearing these devices if applicable
[#] If a participant has cognitive impairment we will rely on the expertise of the clinical team as to whether they have an adequate cognitive function to provide informed consent.

Exclusion Criteria
- A patient diagnosed with a respiratory disease, musculoskeletal disease or injury or an auto-immune disease will be excluded from this study if this comorbidity is the predominant health concern or the major factor that limits their ability to walk.
- A patient is currently participating in another rehabilitation programme or study
- Amputation of more than one digit
- Unable to speak or comprehend English*
- Unable to or unwilling to comprehend informed consent
*Welsh translated versions of the participant information sheet, consent form and contact form will be provided to all participants. However, the participant must be able to understand spoken English as the data collection protocols will be explained in English by the researcher.

To be included in this study, all participants were required to report that they are able to walk continuously for a minimum of five minutes. Walking speed criteria of 0.3 and 0.9m/s was ascertained by physiotherapists during face to face participant identification (if possible due to COVID-19 NHS guidelines) using the 10-metre walk test (10MWT) or telephone consultations.

The inclusion and exclusion criteria for this case controlled study were largely based on the recent work of the research team, investigating walking performance in young stroke survivors (Jarvis et al., 2019). Through this study, it was determined that individuals able to walk faster than 0.93m/s were significantly more likely to return to work post-stroke than those who walked slower than 0.93m/s (Jarvis et al., 2019). With returning to employment being a priority to many young stroke survivors, it was important to have walking speed of 0.93m/s as the upper threshold for the inclusion criteria. The lower threshold for walking speed of 0.6m/s, was established via the feasibility study, previously conducted as part of this research project. Through this study, the slowest walking speed reported was 0.6m/s. both the outdoor instructor and research team deemed that 0.6m/s would be the minimum walking speed required for participants with mild to moderate physical impairments, and would be able to safely cope with the demands of the natural outdoor environment, based upon a subjective assessment of the capabilities of the participants on different terrain and gradients.

However, during recruitment phase of this study, the decision was made to increase the range of walking speed from 0.6-0.93m/s, to 0.3-1.0m/s, in response to improve participant recruitment. Although this change could be seen as a limiting factor for this study, as potential participants who learnt about the study but walked slower than 0.6m/s or faster than 0.93m/s were interested in taking part. In a study by Platts et al (2006), it was noted that in many rehabilitation programmes individuals who walk slower, are more likely to be excluded from studies than those who walk at a faster pace. This may be due to many potential participants not fitting the inclusion and exclusion criteria stipulated for research studies. However, it is important for studies to include young stroke survivors who simply walk at a slower pace, to gain a true sample of the young stroke population, this would therefore reduce bias and allow for clinical initiatives and rehabilitation programmes to be developed that can give the same opportunities for recovery to all.

4.3.2 Procedures

4.3.2.1 Participant preparation for data collection

For all data collection procedures (walking speed, metabolic cost and biomechanical function), participants were instructed to wear minimal non-reflective and non-restrictive clothing and footwear. This included shorts (e.g. running shorts or cycling shorts) and the option of wearing a tight fitting sleeveless top for both male and female participants. Regarding participants footwear to be worn for data collection procedures, instructions stipulated that footwear should be comfortable to walk in and reflect the typical footwear the participant wears on a regular basis to complete activities of daily living (e.g. walking to the shops). Participants footwear were deemed suitable by the investigator if they were non-slip, suitable to be worn outside and have a flat sole (e.g. without a substantial heel rise). As per the inclusion criteria for this study, participants were permitted to complete all data collection procedures with or without personal assistive devices (e.g. walking cane or ankle foot orthoses), again this is to reflect what the participant uses on a regular basis to complete activities of daily living.

4.3.2.2 Assessment of walking speed and energy cost

4.3.2.2.1 Justification to use the Physiological Cost Index as a proxy measure for energy cost of walking

The methodology to measure metabolic cost of walking of young adults who have had a stroke was to utilise the Cortex Metamax 3B (portable breath by breath analysis). However, as a result of the pandemic affecting the years 2020 and 2021, utilising this piece of equipment could have the potential to be detrimental to the health of both the researcher and potential participants through the potential increased transmission of Covid-19. The method of using the Cortex Metamax 3B includes using face masks and the collection and analysis of participants' expelled breath. The face mask and turbine (connects to the face mask and analysis unit) can be cleaned and sterilised after each and every use, however there is the potential that these pieces of equipment may not be cleaned properly and therefore leave remnants of participants bodily fluids (saliva from expelled breath and sweat). Participants may also not be aware that they are carrying the virus, therefore risking future participants and the researcher. Furthermore, risk of infection and transmission can be increased when handling the used face masks, turbine and unit needed to be carefully considered.

The physiological cost index (PCI) was developed by MacGregor (1981), to consider heart rate as an indicator of energy expenditure, and therefore can be used as an indirect method to measure oxygen consumption. The PCI is a simple and inexpensive tool that can be used clinically to estimate energy expenditure during overground walking. For much of the literature (Danielsson et al., 2007; Fredrickson et al., 2007; Delussu et al., 2014), the PCI has been used as an outcome for rehabilitation for many conditions (e.g. lower limb amputees, stroke, elderly subjects), with good test-retest reproducibility, good validity and reliability (interrater) in these conditions. Fredrickson et al (2007) concluded that the PCI can be used as a proxy index for oxygen cost of walking as it was found to correlate with oxygen cost and to distinguish between healthy able-bodied individuals and individuals with stroke. However, previous studies (refs may dispute this and may argue that the PCI is better used as a clinical tool for individuals with conditions and a slower walking speed.

As stated by Fredickson et al (2007) and others (Danielsson et al., 2007; Delussu et al., 2014), the PCI calculation by MacGregor (1981) can easily be used by clinical teams to document participant progress during their rehabilitation. The PCI does not require specialist training or a dedicated technician to standardise the unit, conduct testing and analyse the data. It was reported that some participants in the aforementioned study, the portable gas analysis unit was found to be uncomfortable and cumbersome, with further dissatisfaction expressed with the face mask and the weight of the equipment that is necessary to measure oxygen consumption.

$$\text{PCI (beats/m)} = \frac{\text{Walking heart rate (beats/min)} - \text{Resting heart rate (beats/min)}}{\text{Walking speed (m/min)}}$$

Figure 4.2: Physiological Cost Index (PCI) calculation for energy cost of walking (MacGregor, 1981)

4.3.2.3 Protocol

To capture walking speed and energy cost of walking, all participants were fitted with a Polar Heart Rate monitor (Polar Beat heart rate monitor (Polar, Electro Oy, Kempele, Finland) and were instructed to sit quietly for five minutes to measure resting heart rate. Participants were then instructed to walk at their self-selected walking speed (SSWS) for three minutes up and down a 15m walkway, similar to our previous research (Jarvis et al., 2019). Participants heart rate during exertion was recorded every thirty seconds by the researcher as proposed by Danielsson et al (2007). Timing gates were positioned at 2.5m from either end of the walkway, giving a measured distance of 10m. Within the 2.5m areas at either end of the walkway situated a chair, which was used for the participant to walk around and give support if needed (Figure 4.3). Chairs were used as they were a larger object for the participants to see and focus on to walk towards compared to using cones. Utilising a larger object also eliminated the need for participants to stop at each end of the course and turn at 180 degrees, this encouraged them to therefore walk at a more consistent walking speed (Platts et al., 2006).

After participants were given adequate rest, the protocol was repeated and took place outdoors on a flat, tarmac path to measure walking speed. This protocol was repeated to be completed outdoors, as most walking tests (e.g. 6minute walk test or 10m walk test) tend to take place in laboratory and hospital settings, which do not reflect the different environments (e.g. in the community) that post-stroke individuals are in on a daily basis. Therefore, conducting a walking protocol both indoors and outdoors provided better representation of activities of daily living (e.g. outdoor errands, walking to and from shops). Participants may also adopt different compensatory walking strategies when walking outdoors compared to indoors during testing procedures.

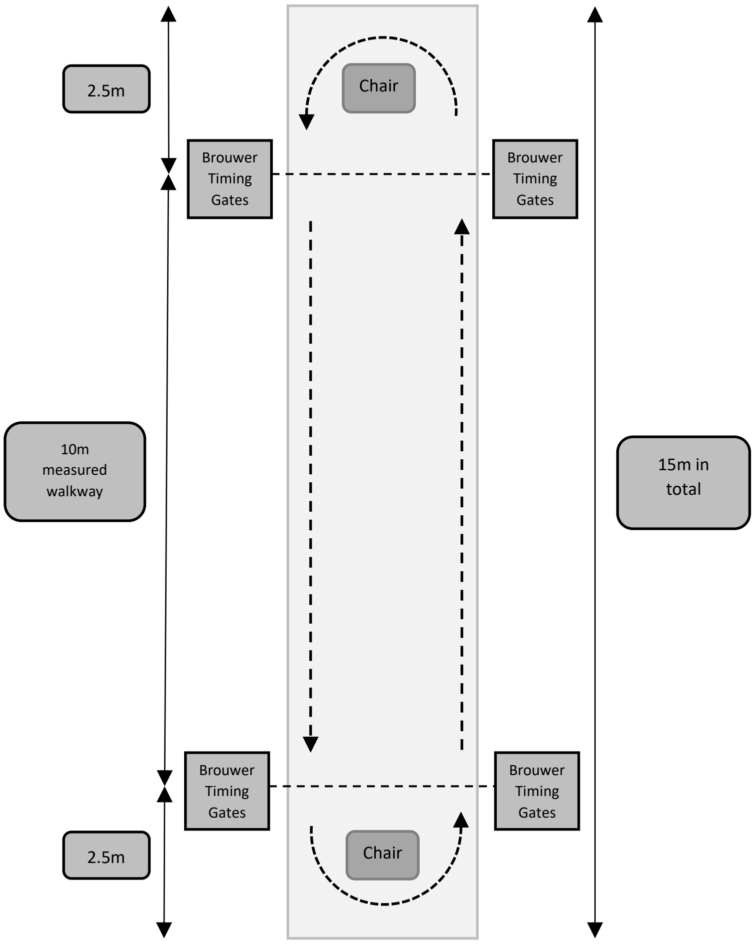


Figure 4.3: Schematic of equipment set-up of walking speed and energy cost protocols- indoors and outdoors

4.3.3 Biomechanical Function

4.3.3.1 Equipment

A Qualisys motion capture system (Miqus, Qualysis motion capture system, Qualysis, Sweden) was used to collect motion analysis of the foot, trunk, lower and upper limbs. The system consisted of eight optoelectronic Qualisys cameras (Miqus Series), with four ground embedded Kistler force plates in a portable 15m walkway, a Lenovo ThinkPad Laptop with Qualisys Track Manager (QTM version 2.0) was used to capture and process data.

Similar to the methods of setting up equipment, used previously by the research team (Jarvis et al., 2019), eight optoelectronic cameras were positioned on portable tri-pods around the edge of the capture volume (e.g. portable 15m walkway), set at a height of 1.8m from the ground. The Qualisys cameras were connected by an ethernet cable to a Lenovo ThinkPad Laptop that used Qualisys Track Manager software to attain kinematic data at a sampling frequency of 120 Hz similar to previous studies (Jarvis et al., 2019). Four Kistler force plates were located 2x2 in a square formation, at the centre of the capture volume. Each force plate measured 30cm by 50cm and was mounted flush into the 15m portable walkway. Each force plate was connected by a 25-pin connector cable to an amplifier. This amplifier was then connected to a Qualisys Miqus Sync unit by the output cable (Figure 4.4). All force data collected were then sampled at 1000 Hz through the analogue-digital converter, which was connected to a Lenovo ThinkPad Laptop that used Qualisys Track Manager software to obtain kinetic data.

The Qualisys Miqus Motion capture system was used for this study in comparison to the industry "gold standard" Vicon Motion capture system for a number of reasons. Firstly, as this is a multicentre study with data collection taking place remotely at Gilwern Outdoor Education Centre (Ty Mawr Road, Gilwern, Abergavenny), it was therefore necessary to have a motion capture system that was easily transportable, and easy to set-up for data collection, in comparison to the Vicon motion capture system. Furthermore, the Qualisys system can be utilitised in multiple settings, as the cameras automatically adjust to bright or low light settings, but also due to the easy compatibility with other equipment such as Kistler force platforms.

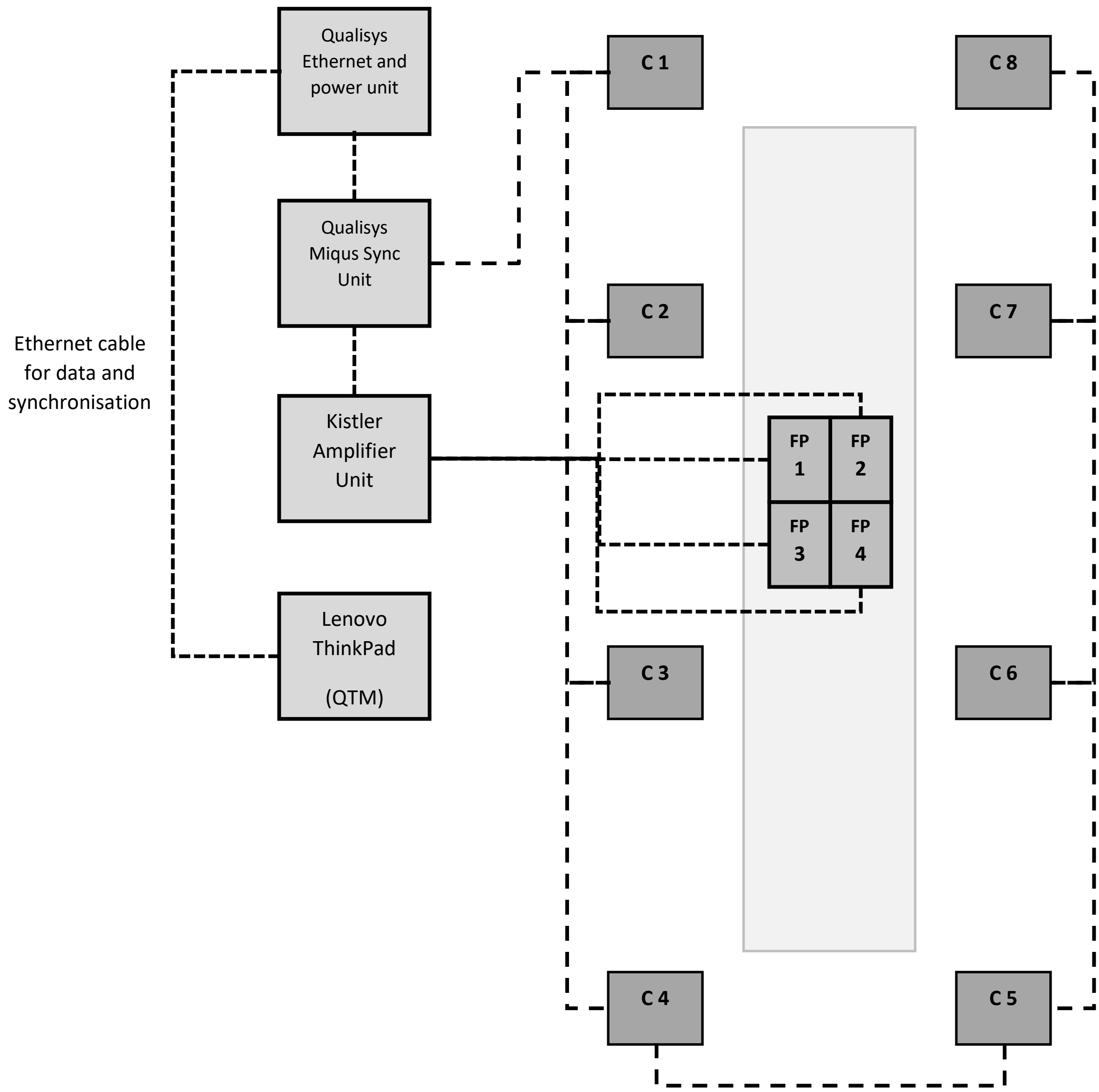


Figure 4.4: Schematic of remote laboratory set-up for motion capture of walking biomechanics

4.3.3.2 System Calibration

Prior to collecting data from participants, the Qualisys motion capture system was calibrated and a residual of less than 1mm for each camera was accepted. An L frame with four retroreflective markers and 600mm calibration wand with two retroreflective markers were used according to the manufacturer's guidelines (Miqus, Qualysis motion capture system, Qualysis, Sweden). As data collection was conducted remotely at Gilwern Outdoor Education Centre, set up and positioning of the camera system in relation to the force platforms took place. This involved placing the L frame in the bottom left-hand corner of force platform 1 and to ensure all cameras were able to see all four retroreflective markers on the L frame. Once all camera positions were correct, a dynamic calibration was undertaken, which involved the investigator to wave the calibration wand within the capture volume in a variety of positions and orientations for a recorded time of 30 seconds. Following this, calibration of force platforms commenced to define the laboratory origin. The lab coordinate system was defined as Y-axis: anterior-posterior, X-axis: medial-lateral and Z-axis: superior-inferior. Force platform signals were zeroed using the 'automatic zero function' in Qualysis Track Manager.

4.3.3.3 Marker Placement

Qualisys cameras are optoelectronic, emitting invisible infrared light (102 NIR light emitting diodes LEDs at 850nm), which is reflected back by retroreflective markers on the participants body to track motions. Seventy-one markers in total were used and positioned on specific landmarks on the participant's body following the 'Calibrated Anatomical Systems Technique' (CAST) developed by Cappozzo et al (1996, 1997).

Upper body markers were placed first, and when participants were seated to avoid fatigue in participants with limited mobility. Four markers were secured onto a fabric headband

and positioned over the left and right temple at the front of the head and on the left and right side of the back of the head. Lower body markers were placed as participants were standing, and were encouraged to use support, such as holding onto a walking aid, edge of a table or member of the research team, where required. Due to stroke participants reporting low walking confidence and reduction in stability when walking barefoot, gait analysis was completed shod. Participants were instructed to wear shoes that were comfortable, suitable to be worn outdoors and what they would typically wear on a daily basis to complete activities of daily living.

Figure 4.5: Example of marker placement from anterior (left), posterior (centre) and side (right) view

Table 4.3: Checklist used for marker placement during data collection

Marker	Marker Placement: Lower Body Location	Marker	Marker Placement: Upper Body Location
ASIS	ASIS right and left side each	Clavicle	Mid-point between the right and left clavicle
PSIS	PSIS right and left side each	Xiphoid	End point of sternum, onto the xiphoid process
Thigh (1, 2, 3)	Midpoint of the anterior aspect of the thigh overlaying rectus femoris. Placed in a triangle formation	T2	Project 2 spinal processes down from C7
Thigh 4	Midpoint of the posterior aspect of the thigh between semitendinosus and biceps femoris	Right Back	Anywhere on the scapula (right side only- this acts as a reference marker)
Lateral Knee	Lateral condyle of femur	T10	From iliac crest, go across to spine and count 6 spinal processes upwards
Medial Knee	Medial condyle of femur	Acronium	Distal end point of acronium
Tibia (1, 2, 3, 4)	Lower third of the lateral aspect of the shank in a individual marker cluster (square formation)	Upper Arm (1, 2, 3)	Mid-point of the upper arm in a triangle formation
Lateral Malleolus	Lateral head of ankle	Lateral Elbow	End point of ulna nearest elbow- flex elbow to locate
Medial Malleolus	Medial head of ankle	Medial Elbow	Placed onto radial head. Flex elbow joint to locate centre of radial head (right and left side each)
Posterior Calcaneus	Mid-point of the most posterior aspect of the calcaneus or the heel of the shoe	Lower Arm (1, 2, 3)	Mid-point of the lower arm in a triangle formation
Lateral Calcaneus	Mid-point of the lateral aspect of the calcaneus or the heel of the shoe.	Lateral Wrist	Distal end point of ulna. Flex wrist to locate
Metatarsal 1	Head of metatarsal 1	Medial Wrist	Styloid process of radius on the medial side. Ensure lateral and medial wrist are in line with each other
Metatarsal 2	Head of metatarsal 2	2nd Finger/ metacarpal	Midpoint of 2nd metacarpal
Metatarsal 5	Head of metatarsal 5	Head (1, 2)	1 and 2 placed above canthus of eye on right and left side.
		Head (3, 4)	3 and 4 placed onto occipital section of the cranial near where it joins with the temporal section. These are placed on right and left side at the same height as head 1 and 2

4.3.3.4 Protocol

An initial a static calibration was conducted and saved. Participants were instructed to stand facing forward with their arms raised slightly away from their body, if possible, with each foot on force platform 1 and 2 within the capture volume. Once static marker data were collected and used together with anatomical measurements were used to define each body segment and establish the location of each joint centre, relative to the coordinate system. If participants were able and not fatigued, they were asked to complete a minimum of three practice trials, enabling them to become familiar with their surroundings and to establish a starting position that allowed a clean foot strike on the force platform with their dominant leg. Following familiarisation, participants then completed seven successful walking trials. It is important to note that participants were instructed to walk at their self-selected walking speed (e.g. typical walking speed used to complete activities of daily living). Participants walked along a 5m level, purpose-built walkway, however the starting position for teach participant was modified to ensure a clean foot strike on the force platform. To offset fatigue, participants were allowed and offered as much time to rest as necessary between walking trials, in particular those who presented with more severe physical impairments that affected walking performance. Motion analysis data was collected at 120Hz and ground reaction forces at 1200Hz.

4.3.3.5 Data Processing

Digitisation of the data in Qualisys Track Manager and Visual3D (C-Motion)

Digitisation of data were completed using Qualisys Motion Capture software called Qualisys Track Manager (Qualisys, Sweden). For both static and dynamic trials, markers and their trajectories were labelled using a loaded label marker list (71 trajectories). On dynamic trials, gait events (heel strike/ initial contact and toe-off) were determined via frame by frame visual inspection. The AiM Model (Qualisys, Sweden) was then applied to each walking trial to calculate marker trajectories, spatial and temporal parameters and joint kinematics and kinetics. Walking trials were then exported as C3D files for modelling and analysis with Visual 3D (C-motion, Rochelle, USA).

Within Visual 3D, a model specific to the height and body mass of each participant was generated and inertial parameters were calculated for the pelvis, hip, knee and ankle, using inverse kinematics. This allowed specific constraints to be applied at the joints of the virtual model, so to limit rotation and/ or translation. The pelvis permitted six degrees of freedom, but only sagittal, coronal, and transverse plane rotation was permitted at all other joints (Jarvis et al., 2022). Gait events such as initial contact and toe off were defined from contact with the force plates. Visual 3D was further used to calculate and extract specific range of motion, moment and power parameters previously used by Jarvis et al (2020) for clinical gait analysis and specific to stroke. Once specific gait events were determined, data was normalised to 101 data points (translating to 0 to 100% of the gait cycles) kinematic parameters (pelvis, hip, knee and ankle joints) were exported in the sagittal, coronal and transverse planes. Both kinematic and kinetic parameters (hip, knee and ankle joints and joint powers) were exported from Visual3D as ASCII files. Data from each participant was subsequently presented in one Microsoft EXCEL spreadsheet to determine mean and standard deviation for each % of the gait cycle.

Alongside kinematic and kinetic parameters, spatial and temporal parameters such as, stride width (m), stride length (m), step length (m), stance time (% gait cycle), swing time (% gait cycle) and initial double support (% gait cycle) of the paretic and non-paretic lower limbs were exported from Visual 3D for each participant, similar to parameters used by Jarvis et al (2019).

Data extraction using MATLAB

Following data extraction from Visual3D and transfer of all data into one Microsoft EXCEL spreadsheet, all data (kinematic, kinetic and powers for the pelvis, hip, knee and ankle) were imported into MATLAB version R2020b (MathWorks Inc, USA) in order to generate highly detailed gait graphs of joint kinematics (pelvis, hip, knee and ankle) and joint moments (hip, knee and ankle) in the sagittal, coronal and transverse plane, and joint absolute powers of the hip, knee and ankle. Each graph presents the paretic and non-paretic lower limb 0% to 100% of the gait cycle and compared pre and post intervention. These graphs are presented in *Chapter Five* as part of the results and discussion of this thesis.

4.3.4 Assessment of Quality of Life

For this research project, survey research was adopted as the preferred approach to assess quality of life in young stroke survivors. Survey research is defined as "the collection and analysis of information from a sample of individuals through their responses to questions" (Ponto, 2015; Schutt, 2019). Survey research is ideal to be used for this project, as it encompasses three research strategies: quantitative (e.g., using questionnaires with numerically rated items), qualitative (e.g., using open-ended questions), or both strategies (e.g., mixed methods). Surveys are frequently used in social and psychological research to describe and explore human behaviour (Singleton et al., 1988).

For the purpose of this project and clarity of survey research strategies used, all data assessing quality of life was collected using questionnaires, administered individually by paper copy and in an electronic format, by the researcher. Table 4.4 offers an overview of each questionnaire.

Table 4.4: Overview of questionnaires for Survey Research

Measure	Type
Stroke Aphasia Quality of Life Scale	Self-Report Scale (Quantitative)
Confidence after Stroke Measure	Self-Report Scale (Quantitative)
Nature-relatedness Scale	Self-Report Scale (Quantitative)
Three Aims and Three Difficulties	Qualitative questionnaire with open-ended questions
Pre/ post intervention Questionnaires	Qualitative questionnaire with open-ended questions
Three-month Follow-up Assessment	Qualitative questionnaire with open-ended questions

Participants were given a total five questionnaires to complete before participation of the outdoor-walking rehabilitation programme and five questionnaires post completion of the outdoor-walking rehabilitation programme, to report whether changes occurred in quality of life (using the Stroke and Aphasia Quality of Life scale (Hilari et al., 2003)), confidence (using the Confidence after Stroke measure (Horne et al., 2017)) and nature-relatedness (using the Nature-relatedness scale (Nisbet et al., 2009)) as a result of taking part in the outdoor-walking rehabilitation programme. At three months, a follow-up assessment was sent out to all participants to report whether participants had continued to exercise in natural outdoor environments and whether they felt the outdoor-walking rehabilitation programme had improved their quality of life.

4.3.4.1 Stroke and Aphasia Quality of Life Scale

The Stroke and Aphasia Quality of Life Scale (SAQOL) (Hilari et al., 2003) was chosen to be used in this study, as it has been used previously by the research team (Jarvis et al., 2019). This questionnaire also represents a measure of quality of life in the stroke population and clearly depicts in what areas quality of life is most affected post-stroke, through four domains: physical (17 items), psychosocial (11 items), communication (7 items) and energy (4 items). The SAQOL has been proven to have good Internal consistency ($\alpha = 0.74$ to 0.94) and test-retest reliability ($r=0.89$ to 0.98) (Hilari et al., 2003). The timeframe for all questions is the past week. Scores for each question are marked on the scoring sheet. The overall Stroke and Aphasia Quality Of Life-39 score is a mean score and is calculated by adding up all the items and dividing by the number of items. Domain scores are calculated in the same way. Overall mean and domain scores can vary from 1 to 5 and are rounded to two decimal points (e.g., 3.46). Higher scores are indicative of better quality of life.

4.3.4.2 Confidence after Stroke Measure

The Confidence after Stroke Measure (CaSM) (Horne et al., 2017) was chosen to be used in this research study to evaluate confidence and is developed to assess confidence after stroke as there are currently no other specific measures available (Horne et al., 2019).

Confidence, seen as a component of emotional impact, is important to many stroke survivors to regain during their recovery and is necessary to measure in assessing a rehabilitation programme, which takes place in an environment where stroke survivors seem to lack the most confidence (McCluskey and Middleton, 2010). The CaSM has been proven to have good internal consistency ($\alpha = 0.94$), test re-test Reliability ($r = 0.85$) (Horne et al., 2017, 2019). This measure consisted of 27 questions that cover three domains: self-confidence (9 items), positive attitude (8 items) and social confidence (10 items). The timeframe for all questions is the past week. Scores for each question are marked on the scoring sheet. Each scale in the Confidence after Stroke Measure have separate scorings, adding the total of each domain to equal a total score. The total score will range from 0-81, with 0 indicating low confidence and 81 indicating the highest level of confidence. A change of four points on the total scale has been assessed as being clinically meaningful.

4.3.4.3 Nature-relatedness Scale

The Nature-Relatedness Scale (NR) (Nisbet et al., 2009) assesses the affective, cognitive and experiential aspects of the individual's connection with the natural outdoor environment, however is not stroke specific. This questionnaire was used in this study in order to assess the role that the outdoor natural environment plays as part of the outdoor-walking rehabilitation programme and understanding the emotional or personal aspect of how individuals' feel about actually being in nature (Nisbet et al., 2009; Zelenski and Nisbet, 2012). This questionnaire has good internal consistency ($\alpha=0.87$) and test re-test reliability ($r = 0.85$). This scale consists of 21 questions that covers three dimensions: Self (8 items), Perspective (7 items) and Experience (6 items). Overall Nature-Relatedness score is calculated by averaging all 21 items after reverse scoring appropriate items.

Scores on the three dimensions are calculated by averaging appropriate items after reverse scoring each dimension. The timeframe for all questions is the past week. Scores for each question are marked on the scoring sheet.

4.3.4.4 Three Aims and Three Difficulties

Participants were asked to provide three key difficulties of day to day living and three aims they have at the moment as first proposed and used by Jarvis et al (2019). This provided a personalised insight into how to best adapt rehabilitation guidelines for young adults who have had a stroke. These were completed prior to participating in the outdoor-walking rehabilitation programme and repeated post-completion of the outdoor-walking rehabilitation programme.

4.3.4.5 Pre-intervention and Post-Intervention Questionnaires

Participants were asked four questions to understand what outdoor physical activities they take part in and how they feel towards outdoor physical activity. These questions were developed from previous patient and public involvement and engagement (PPIE) work and the feasibility study (detailed in *Chapter Three* of this thesis) that took place prior. As part of this research project, understanding whether the participants take part in outdoor physical activity allowed the research team to ensure the outdoor-walking rehabilitation programme was suitable for the young stroke survivor. Alongside the CaSM as a measure of confidence, it was important to gain a personal perspective from the young stroke survivor in what way and why they make lack confidence to walk outdoors, as this was previously mentioned during the feasibility study as a priority to improve. Regarding question three of this questionnaire, it was necessary to see how this outdoor-walking rehabilitation programme can have the potential to improve activities of daily living, further giving the rehabilitation programme premise to be included in stroke recovery initiatives. Lastly, question four is understanding what barriers are experienced by the young stroke survivor, when walking outdoors. These were completed prior to participating in the outdoor-walking rehabilitation programme and repeated post-completion of the outdoor-walking rehabilitation programme to report if any changes in behaviour and attitudes towards outdoor physical activity. Participants were asked to explain their answers.

Questions asked on the pre and post rehabilitation questionnaire:

1. Do you participate in outdoor physical activity?
2. How confident do you feel to walk outdoors
3. How do activities of daily living (e.g. walking to the shops, completing daily errands) affect you?
4. Do you experience any difficulties walking outdoors?

4.3.4.6 Three-month Follow-up assessment

Participants were contacted by the researcher at 3-months post rehabilitation to report whether they have continued to walk in natural outdoor spaces and if there has been any long-lasting effects on quality of life and confidence as a result of taking part in the outdoor-walking rehabilitation programme. Gaining the personal perspectives and opinions of the participants who took part in the outdoor-walking rehabilitation programme, is necessary to understand where the programme can be improved and what aspects of the programme was seen as important (e.g. group-based design) and how this form of rehabilitation can be implemented in the future. For example, the benefits of group-based design programme was observed during the feasibility study, when assessing delivery and adherence to an outdoor-based rehabilitation programme. Furthermore, as confidence is one of the main themes of this research study, understanding whether this programme had a long-term effect on the individual and promoting behaviour change gives further evidence to suggest this alternative form of rehabilitation has a place in stroke recovery.

Questions asked for the 3-month follow-up assessment:

1. Would you be able to write down what you thought was good about your time in the research study and how you feel you have progressed?
2. Discuss how it has allowed you to improve your confidence
3. Whether you enjoyed the group-based side of the outdoor-walking rehabilitation programme
4. If you want to see more outdoor rehabilitation opportunities in the future

4.3.5 Interventions

4.3.5.1 Outdoor-walking Rehabilitation Programme

The outdoor-walking rehabilitation programme consisted of four 2.5 day residentials, which were delivered over a period of 10 weeks. These residentials took place at Gilwern Outdoor Education Centre, in the Brecon Beacons National Park, Wales, UK. A residential programme that focused on improving young stroke survivors walking ability and confidence to walk in the natural outdoor environment was chosen in order to offer a more intense rehabilitation and immersive walking programme, to allow participants to spend more time in the natural outdoor environment and build connections with other young stoke survivors. Alongside the outdoor-walking rehabilitation residential programme, participants were also given a home exercise and light stretches programme to follow and to self-report daily on any physical activity when they were not on the residential.

To develop the outdoor-walking rehabilitation programme, the Consensus for Exercise Reporting Template (CERT) was utilised (table 4.5).

Table 4.5: Development of the outdoor-walking rehabilitation programme using the CERT

Materials	1. *Type of exercise equipment* - Minimal (no specialist gym equipment required) - Walking clothing and equipment recommended
Provider	2. *Qualifications, teaching/supervising expertise and/or training of the exercise instructor* - Gilwern Outdoor Education Centre with trained and experienced outdoor activity instructors in outdoor instruction. Hold all appropriate qualifications for leading outdoor-activities. Have in-depth local knowledge of the area where the outdoor-walking rehabilitation programme is planned to take place - Rebecca Clarke (researcher of study) - outdoor activity instructor with four years of experience in outdoor instruction. Holds all appropriate qualifications for leading outdoor-activities
Delivery	3. *Whether exercises are performed individually or in a group* - 10-week outdoor-walking rehabilitation programme: group 4. *Whether exercises are supervised or unsupervised* - 10-week outdoor-walking rehabilitation programme: supervised 5. *Measurement and reporting of adherence to exercise* - Exercise Diary 6. *Details of motivation strategies* - Researcher to call participant once-per-week 7. *Decision rules for progressing the intensity of the exercise programme* - This will be dependent on walking speed 8. *Each exercise is described so that it can be replicated (e.g. illustrations, photographs)* - 10-week outdoor-walking rehabilitation programme sessions are described in the exercise diary using word descriptions and illustrations 9. *Content of any home programme component* - 10. *Non-exercise components* - No non-exercise components are included in this study 11. *How adverse events that occur during exercise are documented and managed* - In the unlikely situation of any adverse events, participants will be treated accordingly and reported appropriately. We will adhere to institutional procedures for recording and reporting adverse events and their follow-up
Location	12. *Setting in which the exercises are performed* - Outdoor-walking rehabilitation programme: Gilwern Outdoor Education Centre, Brecon Beacons National Park, Wales
Dosage	13. *Detailed description of the exercises (e.g. sets, repetitions, duration, intensity)* - Detailed description of the 10-week outdoor-walking rehabilitation programme are included in the exercise diary
Tailoring	14. *Whether exercises are generic ("one size fits all") or tailored to the individual* - Exercises will be tailored to the individual 15. *Decision rule that determines the starting level for exercise* - Walking speed will determine the starting level of exercise

Table 4.6: Information of what each residential includes and how the residentials increase in difficulty

Residential One	an introductory residential, which will ease the participants into the walking activities due to take place in the following residentials. This residential will include short and easy walking routes 3-5km in length, with no steep gradients or difficult terrain. Other activities when walking will be introduced and include navigation skills training (during the first week, this is to stay relatively simple dependent on the capabilities of the participants). Introducing other activities when walking or when taking a rest will enable participants to regain their energy and to focus their concentration on other tasks.
Residential Two	will build and develop on the walking and navigation skills that were introduced in residential 1. During residential 2, we will keep the walks at the same length (3-5km). However, to increase the difficulty of the walk through steeper gradients (introduction of steep groundwork. Both ascent and descent) and harder terrain (e.g. looser ground, more hazards like tree roots). Navigation will also increase slightly in difficulty, include the teaching of pacings and compass and bearing work.
Residential Three	will aim to increase the difficulty of the walks by the length/ duration of walking activities (4-6km walks) and continuing the increased difficulty of gradient and terrain by consolidating the skills learnt during residential 2.
Residential Four	This is the last residential of the outdoor walking rehabilitation programme. Walks will be 4-6km in length and include more difficult terrain that was introduced in residentials 2 and 3. Navigation and map reading skills will have also increased in difficulty (e.g. compass bearings, pacings) all skills will be brought together for this residential.

An exercise diary (Appendix 9) was provided to participants, which included information on the walking routes planned for each outdoor residential. Information on the routes included an image of the route using Ordnance Survey mapping computer software (OS Maps Online, Ordnance Survey, Southampton, UK) distance measured in metres (m) and kilometres (km), terrain (e.g gravel, tarmac, grass), environment (e.g woodland, lowland, moorland), gradient (e.g uphill to downhill ratio, how steep/ flat) and perceived level of difficulty.

4.3.5.2 Home Exercise Programme

Alongside the outdoor-walking rehabilitation programme, which involved aerobic exercise, a home exercise and light stretches programme was included to ensure participants had a mixed methods training programme to follow. The home exercise programme consisted of two unsupervised training sessions that involved resistance, balance and stretching exercises, taking place in the participants home each week, for a duration of 10 weeks (table 4.5). According to stroke exercise recommendations (Billinger et al., 2014; Saunders et al., 2016; Winstein et al., 2016), a frequency of two resistance training sessions per week focusing on the upper and lower limbs, can reduce cardiac demands during lifting or carrying (e.g. grocery shopping), increase the ability to perform in leisure activities and activities of daily living and induce some muscular adaptations in novices, while also requiring little time commitment, therefore promoting adherence to the programme. Furthermore, implementing a resistance training programme can facilitate increased limb strength, thus improve limb function compared to conventional therapies that emphasise spasticity reduction (Bütefisch et al., 1995).

Participants received a progressive training plan specific to improving common motor impairments caused by stroke (e.g. increase knee flexion during loading response phase of the gait cycle) and included four consistent resistance exercises across all participants. Each resistance exercise had options for progression (e.g. to increase difficulty) dependent on the capabilities of the participant. Each training session was complemented by eight active stretching exercises to be used as warm-up for the subsequent resistance exercises. These included four active stretches for the upper body and four active stretches for the lower body adapted to be used safely by less-able individuals.

Descriptions and examples of exercises for the upper body and lower body are presented in tables 4.8 and 4.9.

Table 4.7: Structure of the outdoor-walking rehabilitation programme and home exercise programme

Week	Monday	Tuesday	Wednesday	Thursday	Friday
1			**Week 1: Intervention (Introduction)**		
2	Home-based exercise programme				
3	Home-based exercise programme				
4			**Week 2: Intervention (Milestone week)**		
5	Home-based exercise programme				
6	Home-based exercise programme				
7			**Week 3: Intervention (Group discussion)**		
8	Home-based exercise programme				
9	Home-based exercise programme				
10			**Week 4: Intervention (Milestone week)**		

4.6.1.2.1 Exercise Selection

All resistance exercises selected as part of the home exercise programme involved a set amount of repetitions consisting of eccentric and concentric muscle movements, with single-joint exercises for most of the home exercise programme. This was to isolate specific muscle groups easily and for the participants to learn techniques safely and easily. Compared with single joint exercises, multi-joint exercises are more demanding on coordination for those affected by stroke and other conditions. As a result, two multi joint exercises were included in the programme; bodyweight squat and sit to stand. The bodyweight squat and sit to stand were chosen specifically as there exercises involve simple techniques, which was a necessary requirement for a cohort of novices with potential muscle contracture and weakness and are used routinely in rehabilitation programmes.

All at home exercise sessions started with a short 5-minute warm-up that included eight stretches (four upper body, four lower body). Following the warm-up, participants then completed four resistance/ bodyweight exercises. The muscle groups that are to be targeted within the resistance exercises selected for the home exercise programme include four muscle groups of the upper body, such as; biceps triceps, rhomboids and deltoids, along with the abdominals and/or lower back muscles. The eight muscle groups of the lower body targeted include the following; hip flexors, hip extensors, hip adductors, hip abductors, hip internal rotators, hip external rotators, dorsi-flexors and plantar-flexors.

As part of the home exercise programme and to accommodate different levels of capability of each participant, variations of each exercise to work the same muscle group were developed to enable exercises to be completed in alternative positions (e.g. seated and/ or standing). Descriptions and examples of exercises for the upper body and lower body are presented in tables 4.10, 4.11, 4.12 and 4.13, descriptions and examples of balance exercises are presented in table 4.14.

Table 4.8: Upper body stretches as part of the light stretches programme, with description and image demonstration on how to perform stretch correctly

Exercise	How to perform exercise correctly	
Inner arm and wrist stretch	Standing or sitting tall. Extend your arm in front with palm down. Bend wrist, pointing hand toward the floor. With your other hand, gently bend your wrist until you feel a mild to moderate stretch in your forearm.	
Shoulder cross-body stretch	standing or sitting tall. Hold one arm above your elbow with your opposite hand, and pull it across your body toward your chest until you feel a stretch in your shoulder. Make sure to keep your elbow below shoulder height.	
Chest stretch	Sitting tall. Place hands behind yourself, holding on to the chair. Gently squeeze shoulders together and hold as tolerated. Stretch felt in chest.	
Seated torso twist stretch	Sitting tall, with both feet flat on ground, begin to rotate upper body left or right, holding the stretch for a comfortable period.	

Table 4.9: Lower body stretches as part of the light stretches programme, with description and image demonstration on how to perform stretch correctly

Exercise	How to perform exercise correctly	
Ankle rotation	sitting tall or standing with heel on floor, rotate foot clockwise and anti-clockwise, feeling a stretch in the ankle and calf muscle.	
Seated hamstring stretch	Sitting tall on floor or edge of chair. Sit with one leg extended with other leg at 90degree bend at knee (so that the foot is flat on the floor) and reach toward your ankle of the straight leg without feeling uncomfortable. Repeat on other leg	
Seated quadriceps stretch	Sitting tall on chair, sit facing the side and you are able to hold the back of the chair for support. If possible, holding your foot in your hand, slowly bring the foot furthest away from the back of the chair upwards towards your bottom and hold stretch	
Seated long adductor stretch	Sit with both legs straight in front of you, with your back straight. Slowly work your legs apart without feeling uncomfortable. Hold this position as you slowly bend forward at your hips until you feel more resistance, keeping back straight.	

Table 4.10: Push-up and lateral raise exercises with progressions in difficulty and justifications

Exercise	Progressions				Justification
	1	2	3	4	
Push-up (progress to a kneeling prone press-up)	Sitting position, both hands flat on wall/ counter- bring chest to hands, push to extend and straighten arms	Standing, both hands on wall, bring chest to hands, push to extend and straighten arms	Kneeling incline position, using edge of sofa to push away from (cushioning for knees)	Kneeling prone press-up	Activates deltoids, pectorals, triceps, core, simultaneous use of both arms and sides of upper body
					
Lateral-raise	Sitting position, single straight arm raise to side	Sitting position, both arms raise at same time	Sitting position, single straight arm raise to side using resistance bands	Standing position, single or both arms raise to the side	Activates deltoids, trapezius, core, simultaneous use of both arms and sides of upper body
					

Table 4.11: Tricep kickback and bicep curl exercises with progressions in difficulty and justifications

Exercises	Progressions				Justification
	1	2	3	4	
Tricep kickback	Sitting position, single arm at 90degree bend, push back to extend arm	Sitting position, both arms at 90degree bend, push back and extend both arms	Sitting position, single arm at 90degree bend, pull with resistance bands	Standing position, single or both arms with use of resistance bands	Activates triceps, simultaneous use of both arms and sides of upper body
					
Bicep curl	Sitting position, single arm at 90degree bend, curl forearm towards shoulder (weight of arm only)	Sitting position, both arms at 90degree bend, curl both forearms towards shoulder	Sitting position, single arm at 90degree bend, pull with resistance bands	Standing position, single or both arms with use of resistance bands	Activates biceps, simultaneous use of both arms and sides of upper body
					

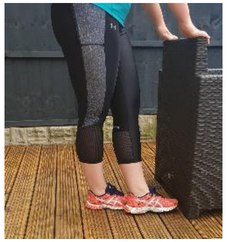
Table 4.12: Sit to stand and calf raise exercises with progressions in difficulty and justifications

Exercise	**Progressions**				**Justification**
	1	**2**	**3**	**4**	
Sit to stand (progress to bodyweight squat)	Chair to standing- use both arms to push up from chair	Chair to standing- use one arm to push up from chair	Chair to standing- no use of upper body	Bodyweight squat- use counter or back of chair to hold for support	Will help to improve initiation of movement in the direction of travel- this exercise will strengthen quadriceps, gluteal and calf muscles and stretch plantarflexor muscles
					
Calf-raise (raise heels of feet off floor)	Sitting position- bring both heels off floor	Standing position- use counter for balance	Standing position	Standing position- use stairs for greater range of movement, have heels hang over edge	Will help Improve the initiation of movement in the direction of travel to increase walking speed- this exercise will help to strengthen triceps surae and soleus
					

Table 4.13: Frontal single leg raise and lateral single leg raise exercises with progressions in difficulty and justifications

Exercise	Progressions				Justification
	1	2	3	4	
Frontal single leg-raise (progress to standing)	Sitting position- bring one foot off the floor and straighten leg	Sitting position- use of resistance bands for single leg raise	Standing position- use counter for balance, flex at knee (heel towards glutes), extend knee, bring foot back down to floor	Standing, hands on hips, flex knee	Increase loading onto the paretic limb- Strengthen hip abductors and core musculature
					
Lateral single leg-raise (keep leg straight, raise leg to the side)	Standing position, use counter or wall for balance and support	Standing position, use counter or wall for balance, use resistance bands	Standing, hands on hips, bring leg to side	Use of resistance bands for protocol	Increase loading onto the paretic limb- Strengthen hip abductors and core musculature
					

Table 4.14: Balance exercises with progressions in difficulty and justifications

Exercise	Progressions				Justification
	1	2	3	4	
Heel to toe walk	Standing stationary, with both hands on wall for support, cross foot over to the other, repeat with other foot	Standing position, use counter or wall for support, walk heel to toe	Standing position, without support, walk heel to toe		Strengthen gluteals and hamstrings and stretch hip flexors and plantarflexor muscles
Simple side walk	Standing stationary, with both hands on wall for support, cross foot over to the other, repeat with other foot	Standing position, both hands on wall or counter, side step	Standing position, without support, side step		Increase step length and improve the initiation of movement in the direction of travel to increase walking speed
					
Single leg stand	Standing stationary, with both hands on wall or counter for support, raise one leg (bend at knee)	Standing stationary, with one hand on wall for support, raise one leg (bend at knee)	Standing stationary, raise one leg (bend at knee)	Standing stationary, use stairs, have heels hang over edge, raise one leg (bend at knee)	Increase loading onto the paretic limb Strengthen hip abductors and core musculature
					

4.3.6 Statistical Analysis

Statistical analysis was conducted using SPSS Version 27. All statistical analysis for quantitative variables (spatial and temporal parameters, joint kinematics, joint kinetics and standardised quantitative questionnaires). Mean, standard deviation, range (min-max) and 95% Confidence intervals were calculated, with the critical level of significance set at $p \leq 0.05$. Both range and 95% confidence intervals were reported.

All data were checked for normality using the Shapiro Wilk test and measures of skewness and kurtosis prior to analysis. Once data had been checked for normality, to compare between pre and post intervention and assuming the data was parametric, a dependent samples T-test was used, with Bonferroni correction. If the data was non-parametric, Wilcoxon signed rank test would be used. Dependent samples T-test was chosen to statistically analyse data in this study, as only two time points (pre-intervention and post-intervention) were collected.

4.3.6.1 Spatial and Temporal parameters

Key spatial and temporal parameters were extracted for analysis as identified previously in research (Chen et al., 2005b; Awad et al., 2015) and the research team (Jarvis et al., 2019), these parameters include; stride width measured in metres (m) measuring the distance between right and left leg, stride length measured in metres (m) measuring the distance between initial contact of right leg to initial contact of that same leg, step length measured in metres (m) and measuring the distance between initial contact of right leg to initial contact of left leg, Stance time is measured in percentage of the gait cycle (%) during which the left or right foot is in contact with the ground, swing time is measured in percentage of the gait cycle (%) during which the left or right foot is not in contact with the ground, initial double limb support is measured in percentage of the gait cycle (%) during which both feet are in contact with the ground.

These parameters were extracted from analysis of biomechanical function, indoors, pre and post-intervention. With the assumption that the data will meet the criteria for parametric testing, we expect to use a dependent samples T-test. For non-parametric data, a Wilcoxon signed-rank test will be used instead.

4.3.6.2 Walking Speed and Energy Cost

Walking speed and energy cost (PCI) from both indoor and outdoor walking protocols and pre and post-intervention will be extracted and tested for normality using a Shapiro-Wilk test. Walking speed will be measured in metres per second (m/s) and energy cost data will be measured in beats per metre (beats/m). With the assumption that the data will meet the criteria for parametric testing, we expect to use a dependent samples T-test. For non-parametric data, a Wilcoxon signed-rank test will be used instead. Furthermore, Walking speed and energy cost will be presented together in a correlation graph for pre and post intervention, for the indoor and outdoor walking protocols. Prior to plotting the results for walking speed and energy cost of each participant, a Pearson's *r* correlation (or for non-parametric data a Spearman correlation) coefficient will be calculated to measure the relationship between these two variables.

4.3.6.3 Joint Kinematics, Kinetics and Power

Key joint range of motion rotational forces and power parameters identified by Benedetti et al (1998), Winter et al (2009), in total twenty joint kinematic and eighteen joint kinetic parameters of the paretic and non-paretic lower limb were extracted for further analysis. For kinematic parameters, these were peak anterior and peak posterior tilt and range of sagittal plane motion of the pelvis (pelvic tilt), peak upward movement and peak down movement and range of frontal plane motion of the pelvis (pelvic obliquity), peak interior and peak exterior and range of transverse plane motion of the pelvis (pelvic rotation), peak hip flexion during loading response and peak hip extension during mid-stance and range of sagittal plane motion of the hip, peak adduction and abduction and range of frontal plane motion at the hip, peak knee flexion during loading response, peak knee extension during stance and peak knee flexion during swing phase, peak ankle dorsiflexion at initial contact and peak plantarflexion during late stance phase. For kinetic parameters, these were peak hip extension during weight acceptance and peak hip flexion during midstance, peak power generation during propulsion (H3) and midstance (H2) at the hip joint, peak knee extension during weight acceptance, peak knee flexion, peak power generation at the knee joint, peak ankle plantarflexion, peak ankle dorsiflexion and peak power generation during A2 at the ankle joint.

With the assumption that the data will meet the criteria for parametric testing, we expect to use a dependent samples T-test. For non-parametric data, a Wilcoxon signed-rank test will be used instead. Furthermore, gait graphs will be produced for all joint kinematic and kinetic parameters of interest for both the paretic and non-paretic lower limb, which will include the mean and standard deviation, pre and post intervention. These will be normalised to 100 data points and can be attributed 0-100% of the gait cycle. Comparisons will be made between pre-intervention and post-intervention.

4.3.7 Qualitative Data Analysis

Data collected from the 'Three aims and three difficulties' (Jarvis et al., 2019), pre and post post-rehabilitation open-ended questionnaires and 3-month follow-up assessments (detailed in section 4.3.4 of this chapter) will be analysed via Thematic Analysis, taking an inductive approach to coding (e.g. themes that are identified are strongly linked to the data)(Boyatzis, 1998). This is an analytical technique to identify themes, which focuses on examining themes or patterns of meaning within the qualitative data and is often used in mixed-method designs. Braun and Clarke's (2006) six-phase method for thematic analysis was used, these included familiarising yourself with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes and producing the report.

4.4 The Original Proposed Study: Randomised Clinical Trial

This section details the randomised clinical trial, which was originally planned and submitted for HRA and NHS ethical approval before the COVID-19 pandemic, as part of the research project investigating the effects of an outdoor-walking rehabilitation programme on walking performance and quality of life of young stroke survivors.

4.4.1 Recruitment

This was to be a multi-centre study, involving three health board sites in Wales, United Kingdom: Aneurin Bevan University Health Board, Swansea Bay University Health Board and Cwm Taf Morgannwg University Health Board. The health board sites mentioned were used as participant identification centres (PICs) for participant identification and recruitment. These health board sites were also specifically chosen due to having established working relationships through previous studies and their geography in relation to the Brecon Beacons National Park, the location setting for the outdoor-walking rehabilitation programme.

4.4.1.1 Sample Size and Participant Randomisation

To estimate the required sample size, a power analysis (Kadam and Bhalerao, 2010) was performed using values for one of the key variables of interest, which was determined to be walking speed, in reference to recently published work (Jarvis et al., 2019) with the assumption of using two-sided effect of 1.96 and population standard deviations of 0.3 (Duncan et al., 2003). Forty participants were to be required to take part in this study. However, this study will aim to recruit forty-six participants (twenty-three participants for intervention and twenty-three participants for control group) in total, to account for 14% dropout rate and any instances of participants unable to complete the 12-week outdoor-walking rehabilitation programme as per reported in similar studies (Saunders et al., 2020).

It can be hypothesised that this study would have recruited to target, if it were not for the challenges posed by the COVID-19 pandemic such as:

- The uncertainty of the pandemic and ensuing nationwide lockdowns
- Differing COVID-19 guidelines set by the government and NHS of each respective nation (e.g. Wales and England)
- Prioritisation of the pandemic and the redeployment of principal investigators at each PIC to other areas in the NHS
- Reluctance by potential eligible participants to take part in the study due to increased risk of COVID-19 transmission

After participants were screened for eligibility and recruited by the PICs, and as part of the randomised controlled trial design blocked randomisation was to be used to assign participants to either the 12-week outdoor-walking and home exercise rehabilitation programme (intervention) or the 12-week home exercise programme (control). Allocation sequence was to be randomised using a computer generated online algorithm, which implemented stratified (by site) randomisation. As the interventions were to be inherently different, both participants and the research team were not blinded to the allocation.

Blocked randomisation was to be utilised as the main method of randomisation, as it is designed to randomise participants into groups that result in equal sample sizes (Suresh, 2011) and are more often uniformly distributed by key outcome-related characteristics (Efird, 2011) into comparable intervention groups, which are alike in all aspects except for the intervention each group receives, thus reducing bias and increasing efficacy of the intervention. See figure 3 for study design and randomisation of participants from PICs.

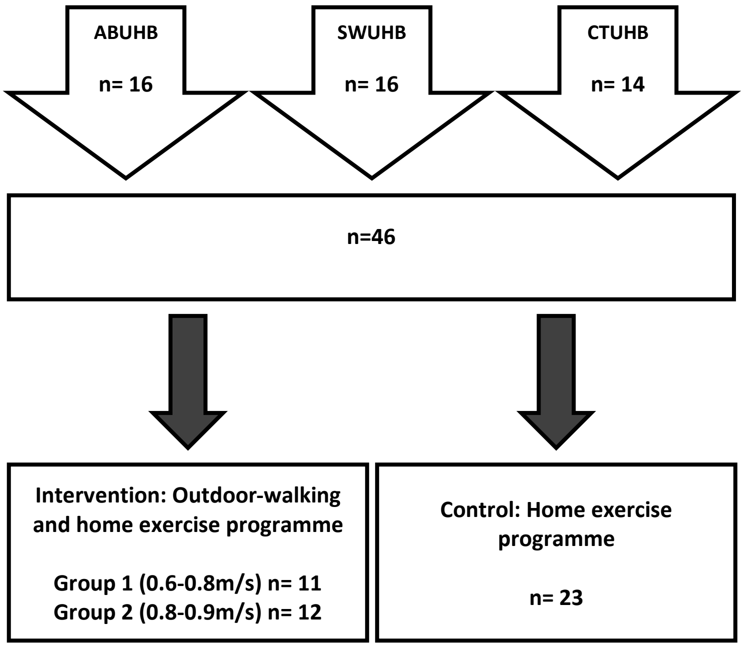


Figure 4.6: Proposed study design for the randomised clinical trial

4.4.1.2 Participants

Forty-six individuals who have had a stroke were to be recruited to take part in this study.

4.4.2 Procedures

4.4.2.1 Assessment of walking speed and metabolic cost

To capture walking speed and metabolic cost of walking, all participants were to be fitted with a small mask, covering the nose and mouth. This would then be connected to a portable gas analyser (Cortex Metalyser) which measures oxygen consumption. Participants were also to be fitted with a Polar Heart Rate monitor (Polar Beat heart rate monitor (Polar, Electro Oy, Kempele, Finland) to measure heart rate and they will be asked to grade their rating of perceived exertion (Borg, 1982). Participants were asked to stand quietly for three minutes to capture resting heart rate and oxygen consumption during quiet standing. Capturing oxygen consumption during quiet standing would provide an indication of the oxygen required for basal metabolism and support a resting posture (Schwartz et al., 2006). Participants were then instructed to walk at their self-selected walking speed (SSWS) for three minutes up and down a 15m walkway, similar to our previous research (Jarvis et al., 2019). Timing gates were positioned at 2.5m from either end of the walkway, giving a measured distance of 10m. Within the 2.5m areas at either end of the walkway situated a chair, which was used for the participant to walk around and give support if needed. Chairs were used as they were a larger object for the participants to see and focus on to walk towards compared to using cones. Utilising a larger object also eliminated the need for participants to stop at each end of the course and turn at 180degrees, this encouraged them to therefore walk at a more consistent walking speed (Platts et al., 2006).

After participants were given adequate rest, the protocol was repeated and took place outdoors on a flat, tarmac path to measure walking speed. This protocol was repeated to be completed outdoors, as most walking tests (e.g. 6minute walk test or 10m walk test) tend to take place in laboratory and hospital settings, which do not reflect the different environments (e.g. in the community) that post-stroke individuals are in on a daily basis. Therefore, conducting a walking protocol both indoors and outdoors provided better representation of activities of daily living (e.g. outdoor errands, walking to and from shops). Participants may also adopt different compensatory walking strategies when walking outdoors compared to indoors during testing procedures.

4.4.2.2 Biomechanical Function

Procedures used for collecting data at baseline and post-intervention on all biomechanical function parameters (joint kinematics, moments, powers and spatial-temporal parameters) were not altered and can be found in section 4.3.3 of this methods chapter.

4.4.2.3 Assessment of Quality of Life

Procedures used for collecting data from standardised questionnaires at baseline and post-intervention for quality of life (using the Stroke and Aphasia Quality of Life scale), confidence (using the Confidence after Stroke Measure) and nature-relatedness (using the Nature-relatedness Scale) and open-ended questionnaires (Three Aims and Three Difficulties and pre and post rehabilitation questionnaires) were not altered and can be found in 4.3.4 of this methods chapter.

4.4.3 Interventions

4.4.3.1 Outdoor-walking Rehabilitation programme

Originally, the outdoor-walking rehabilitation programme would have been delivered over a period of 3-months (or 12-weeks), taking place in Talybont-on-Usk, in the Brecon Beacons National Park, Wales, UK. The programme was designed to include 2-hour, once weekly outdoor-walking instructor-led sessions. An outdoor-walking programme that took place once-weekly, which focused on improving young stroke survivors walking ability and confidence to walk in the natural outdoor environment was originally chosen in order to offer a more regular walking programme, in line with previous community rehabilitation programmes specific to stroke (Eng et al., 2003; Kim et al., 2014). This design would allow participants weekly exposure to uneven terrain, environment, changing gradients and potential changing weather conditions.

Breakdown of the originally proposed programme design can be seen in table 4.15, using the Consensus for Exercise Reporting Template.

Table 4.15: Development of the originally proposed outdoor-walking rehabilitation programme using the CERT

Materials	1. *Type of exercise equipment* - Minimal (no specialist gym equipment required) - Walking clothing and equipment recommended
Provider	2. *Qualifications, teaching/supervising expertise and/or training of the exercise instructor* - Outdoor activity instructor with over thirty years of experience in outdoor instruction. Holds all appropriate qualifications for leading outdoor-walking. Has in-depth local knowledge of the area where the outdoor-walking rehabilitation programme is planned to take place - Rebecca Clarke (researcher of study) - outdoor activity instructor with four years of experience in outdoor instruction. Has appropriate experience for leading outdoor-walking
Delivery	3. *Whether exercises are performed individually or in a group* - 3-month outdoor-walking rehabilitation programme: group - Home exercise and light stretches programme: individually 4. *Whether exercises are supervised or unsupervised* - 3-month outdoor-walking rehabilitation programme: supervised - Home exercise and light stretches programme: unsupervised 5. *Measurement and reporting of adherence to exercise* - SIYA Exercise Diary 6. *Details of motivation strategies* - Researcher to call participant once-per-week 7. *Decision rules for progressing the intensity of the exercise programme* - This will be dependent on walking speed 8. *Each exercise is described so that it can be replicated (e.g. illustrations, photographs)* - 3-month outdoor-walking rehabilitation programme sessions are described in the exercise diary using word descriptions and illustrations 9. *Content of any home programme component* - Home exercise and light stretches programme is detailed in the exercise diary 10. *Non-exercise components* - No non-exercise components are included in this study 11. *How adverse events that occur during exercise are documented and managed* - In the unlikely situation of any adverse events, participants will be treated accordingly and reported appropriately. We will adhere to institutional procedures for recording and reporting adverse events and their follow-up
Location	12. *Setting in which the exercises are performed* - Outdoor-walking rehabilitation programme: Talybont-on-Usk, Brecon Beacons National Park, Wales - Home exercise programme: in the participant's home
Dosage	13. *Detailed description of the exercises (e.g. sets, repetitions, duration, intensity)* - Detailed description of exercises are included in the exercise diary and 3-month outdoor-walking rehabilitation programme
Tailoring	14. *Whether exercises are generic ("one size fits all") or tailored to the individual* - Exercises will be tailored to the individual 15. *Decision rule that determines the starting level for exercise* - Walking speed will determine the starting level of exercise

4.4.3.2 Home Exercise Programme

Alongside the outdoor-walking rehabilitation residential programme, participants were to be given a twice-weekly home exercise and light stretches programme, that focus on the major muscle groups of the upper and lower body (table 4.9), following stroke rehabilitation guidelines (Billinger et al., 2014; Winstein et al., 2016). The exercises have been utilised in a number of previous studies and designed with less able individuals in mind. For further information on this, refer to section 4.3.5.2 as this did not alter from the study.

4.4.3.3 The Control Group

As part of the originally proposed randomised controlled trial, a control group would be included into the design of this study. During the twelve week outdoor-walking rehabilitation programme, the control group intervention were to be given the same home exercise programme as the intervention group. Therefore, the control group will be asked to keep to their normal activities of daily living and given eight exercises for the upper and lower body two times per week at home, similar to previous studies (Ivey et al., 2010). For further information on this, refer to section 4.3.5.2 as this did not alter from the study. Participants in the control group will each be provided a booklet for the given exercises (in appendices). Each exercise will be detailed in the booklet, in the form of photographs, and information on how best to perform the stretch and how long the stretch should be performed for. Once the 12-week outdoor-walking rehabilitation programme had finished, and post-rehabilitation data collection concluded, the control group were to be given the opportunity to participate in one 2.5 day outdoor-walking residential.

Each participant in the control group would have been contacted by the researcher (Miss Rebecca Clarke) by telephone once-a-week, to ensure the control group have the same amount of contact time as the intervention group for attention effects (Abbott et al., 2019). Furthermore, during this telephone call, the researcher would check for adherence to the light stretches programme by asking the participant a series of questions such as, have they had any changes to medication, were they able to complete that week's planned stretches, did they have any difficulties performing the planned stretches and whether they enjoyed performing the stretches.

4.4.4 Statistical Analysis

Statistical analysis was conducted using SPSS Version 27. Mean and standard deviation and 95% Confidence intervals were extracted and reported. The critical level of significance was set at $p \leq 0.05$.

Data were compared between the time points (pre and post intervention). All data were checked for normality using the Shapiro Wilk test and measures of skewness and kurtosis prior to analysis. Data that satisfied the assumptions were assessed using a dependent samples t-test.

4.4.4.1 Walking Speed, Energy Expenditure and Metabolic cost of Walking

Walking speed, Energy expenditure and metabolic cost data collected during indoor and outdoor over-ground walking protocols, from intervention group and control group will be tested for normality using a Shapiro-Wilk test. Walking speed will be measured in metres per second (m/s) to assess how fast or slow a young stroke survivors walks. Energy expenditure is a measure of energy consumption (per unit time), which is normalised to the participant's body mass and is reported in millilitres per kilogram per minute (mL/kg/min). Metabolic cost, when in conjunction with walking speed, measures efficiency of walking (per unit distance). The calculation for metabolic cost is energy expenditure divided by walking speed and is reported in millilitres per kilogram per metre. With the assumption that the data will meet the criteria for parametric testing, it is expected that a dependent samples T-test would be used to compare the intervention group at pre and post completion of the rehabilitation programme, in order to observe a change in the aforementioned parameters. A dependent samples T-test would similarly be used for the control group. To compare between the intervention and control groups at pre and post intervention, an independent samples T-test would be utilised to determine whether there is a statistically significant difference in parameters. For non-parametric data, Mann-Whitney test will be used if required. For further analysis, an ANCOVA (analysis of covariance), which is a blend of analysis of variance and linear regression, can be used.

4.4.4.2 Biomechanical Function

Biomechanical function data collected from intervention group and control group will be checked for normality using a Shapiro-Wilk test. Spatial and temporal parameters and key joint kinematic, moment and power parameters of the paretic and non-paretic lower limbs of young adults who have had a stroke will be compared to the control during walking, similar to previous work by the research team (Almurdhi et al., 2016; Jarvis et al., 2019) in different clinical populations. With the assumption that the data will meet the criteria for parametric testing, it is expected that a dependent samples T-test would be used to compare the intervention group at pre and post completion of the rehabilitation programme, in order to observe a change in the aforementioned parameters. A dependent samples T-test would similarly be used for the control group. To compare between the intervention and control groups at pre and post intervention, an independent samples T-test would be utilised to determine whether there is a statistically significant difference in parameters. For non-parametric data, Mann-Whitney test will be used if required. For further analysis, an ANCOVA (analysis of covariance), which is a blend of analysis of variance and linear regression, can be used.

4.4.5 Qualitative Data Analysis

Procedures used for analysing qualitative data pre and post-intervention on pre and post intervention questionnaires and three-month follow-up assessment were not altered and can be found in section 4.3.7 of this methods chapter.

4.5 Summary

This chapter describes in detail, the methods used for the research project investigating the effects of an outdoor-walking rehabilitation programme on walking performance and quality of life. This chapter further highlights the difficulties experienced when developing a research study during a time of uncertainty, which COVID-19 caused. For this project, a randomised clinical trial, involving an intervention group and a control group, was originally planned that had previously been successful in attaining HRA NHS ethical approval

Chapter Five

5. The influence of an outdoor-walking rehabilitation programme on gait kinematics and kinetics of young adults who have had a stroke

5.2 Results

5.2.1 Participant Characteristics

Mean age of participants at the time of study was 59.1 (44 – 65) years. Mean body mass of participants at the time of study was 87.91kg (62.6 - 117) . Mean height of participants was 173cm. Eleven out of twelve participants were male (male=11, female=1). Eleven out of the twelve participants had experienced an infarct stroke, with one participant who experienced a haemorrhagic stroke. Nine out of the twelve participants had left side hemiparesis, and three participants with right side hemiparesis. Mean time since having a stroke was 27.75 (4 - 66) months. Five out of the twelve participants used ankle foot orthoses to aid with walking. Two participants out of the five participants that required assistive devices, used a walking cane to further aid with walking. Three participants from the cohort smoked pre-stroke, with two participants continuing to smoke post-stroke.

Table 5.1: Individual participant characteristics, type of stroke, time since stroke, side affected, use of walking aids and smoking habits prior to and post-stroke are reported. Mean ± standard deviation and range for age, body mass, height and time since stroke are also reported

	Sex	Age (years)	Body mass (kg)	Height (cm)	Type of stroke	Paretic side	Time since stroke (months)	walking aids	Smoking	
									Pre	Post
P1	M	60	84.2	168	Infarct	Left	43	No	No	No
P2	M	60	103	181	Infarct	Right	60	No	Yes	No
P3	M	54	65.3	164	Infarct	Left	66	No	No	No
P4	M	60	62.6	163	Infarct	Left	25	Yes- Ankle Foot Orthoses and walking cane	Yes	Yes
P5	M	60	79	183	Infarct	Left	13	Yes- Ankle Foot Orthoses	No	No
P6	M	63	117	176	Infarct	Left	14	Yes- Ankle Foot Orthoses	No	No
P7	M	44	92	183	Infarct	Right	5	No	No	No
P8	M	64	91.4	168	Infarct	Left	30	No	No	No
P9	M	62	94.4	175	Infarct	Left	22	No	No	No
P10	F	55	116	172	Infarct	Left	38	Yes- Ankle Foot Orthoses and walking cane	Yes	Yes
P11	M	65	63.4	164	Haemorrhage	Right	6	Yes- Ankle Foot Orthoses	No	No
P12	M	63	86.7	179	Infarct	Left	4	No	No	No
		59.17 ± 5.81 (44 – 65)	87.91 ± 18.54 (62.6 – 117)	173 ± 7.54 (163 – 183)			27.75 ± 21.55 (4 – 66)			

5.2.2 Walking Speed, Energy Cost and Spatial Temporal Parameters

Due to the large variability of participant capabilities as a result of experiencing a stroke, it was decided to firstly present data as a full sample. Following this, data for walking speed, energy cost and spatial temporal parameters will be presented by excluding the two slower walkers for walking speed, walking distance and energy cost. This is because ten out of twelve participants walking speeds during the indoor walking protocol ranged between 0.47-1.45m/s pre intervention and 0.52-1.42m/s post intervention. On the other hand, the two slowest walkers in the sample during indoor walking protocol walked between 0.07-0.15m/s pre intervention and 0.17-0.18m/s post intervention causing them to be outliers in this sample. The walking speeds recorded by the two slowest walkers in this sample for both indoor and outdoor walking protocols lie an abnormal distance away from the main set of data from other participants in the sample, creating difficulty to draw general conclusions.

5.2.2.1 Full Sample (Unadjusted)

The following variables were non-parametric: energy cost (PCI), walking speed, walking distance, in these cases, Wilcoxon Signed Rank tests were conducted. For correlation analysis, to determine the relationship between walking speed and energy cost, a Spearman's Correlation was used due to data being non-parametric.

Walking speed during indoor walking protocols increased from 0.82m/s (0.52-1.12) pre-intervention to 0.91m/s (p=0.01) post-intervention and walking speed during outdoor walking protocol increased from 0.79m/s to 0.89m/s (p=0.005). Walking distance over a time frame of three-minutes for indoor walking protocol increased from 97.5m (63.43 – 131.57) pre-intervention, to 111.66m (77.95 – 145.37) post-intervention (p=0.058) and walking distance over a time frame of three-minutes during the outdoor walking protocol increased from 98m (64.62 – 132.04) pre-intervention, to 114.16m (77.27 – 151.06) (p=0.058). Energy cost during indoor walking protocol decreased from 0.75 beats/m (0.15 – 1.33) pre-intervention, to 0.57 beats/m (0.22 – 0.91) post-intervention (*p*=0.56) and energy cost during outdoor walking protocol decreased from 0.83 beats/m (0.24 – 1.41) pre-intervention, to 0.60 beats/m (0.23 – 0.98) (*p*=0.168) post intervention.

A strong negative relationship was found between energy cost and walking speed, pre (ρ = -0.84) and post intervention (ρ = -0.83) for the indoor walking protocol, and for the outdoor walking protocol pre (ρ = -0.8) and post-intervention (ρ = -0.82) (Figures 5.1 and 5.2). In comparison, A strong positive relationship was found between walking speed and walking distance, pre (ρ = 0.96) and post intervention (ρ = 0.99) for indoor walking protocol and pre and post-intervention for the outdoor walking protocol.

Table 5.2: Mean ± standard deviation, range and 95% CI for energy cost, walking speed and walking distance for indoor and outdoor 3-minute walking test (3-MWT) protocols pre and post intervention. *represents a significant difference between pre and post interventions.

	Indoor					**Outdoor**				
	PRE		**POST**			**PRE**		**POST**		
	Mean ± SD (Range)	**95% CI**	**Mean ± SD (Range)**	**95% CI**	***P***	**Mean ± SD (Range)**	**95% CI**	**Mean ± SD (Range)**	**95% CI**	***P***
Walking Speed (m/s)	0.82 ± 0.47 (0.07 – 1.45)	0.52 – 1.12	0.91 ± 0.45 (0.17 – 1.42)	0.61 – 1.19	0.01*	0.79 ± 0.45 (0.1 – 1.4)	0.24 – 1.07	0.89 ± 0.46 (0.14 – 1.49)	0.59 – 1.18	0.005*
Energy Cost (beats/m)	0.75 ± 0.93 (0.12 – 3.2)	0.15 – 1.33	0.57 ± 0.53 (0.17 – 1.81)	0.22 – 0.91	0.56	0.83 ± 0.92 (0.15 – 3.26)	0.24 – 1.41	0.60 ± 0.58 (0.15 -2.12)	0.23 – 0.98	0.168
Walking Distance (m)	97.5 ± 53.61 (20 – 180)	63.43 – 131.57	111.66 ± 53.05 (20 – 180)	77.95 – 145.37	0.058	98 ± 53.05 (20 – 170)	64.62 – 132.04	114.16 ± 58.06 (20 – 190)	77.27 – 151.06	0.014*

Table 5.3: Correlation analysis using Spearman's Rank (ρ) between energy cost and walking speed and walking speed and walking distance.

	Indoor		**Outdoor**	
	PRE	POST	PRE	POST
Energy cost and walking speed	ρ = -0.84 (0.001)	ρ = -0.83 (0.001)	ρ = -0.8 (0.002)	ρ = -0.82 (0.001)
Walking speed and walking distance	ρ = 0.98 (0.001)	ρ = 0.99 (0.001)	ρ = 0.96 (0.001)	ρ = 0.99 (0.001)

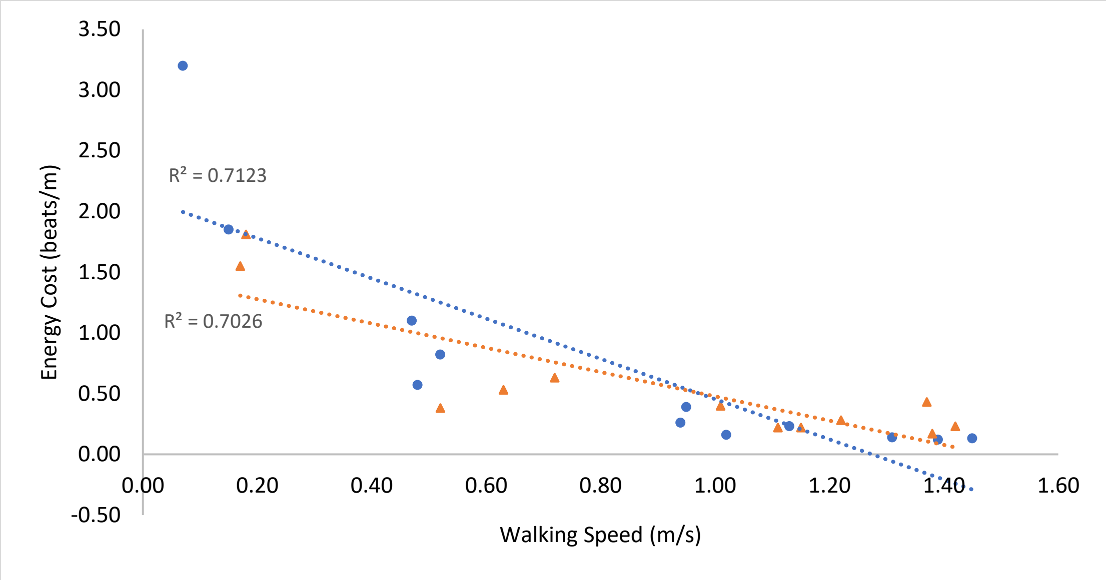


Figure 5.1: Scatter graph showing correlation between walking speed and energy cost, pre and post intervention for indoor walking protocols. Blue circular data plots with blue dashed linear trendline represents pre-intervention, orange triangular plots with orange dashed trendline represents post-intervention. R^2 values for linear trendlines are reported.

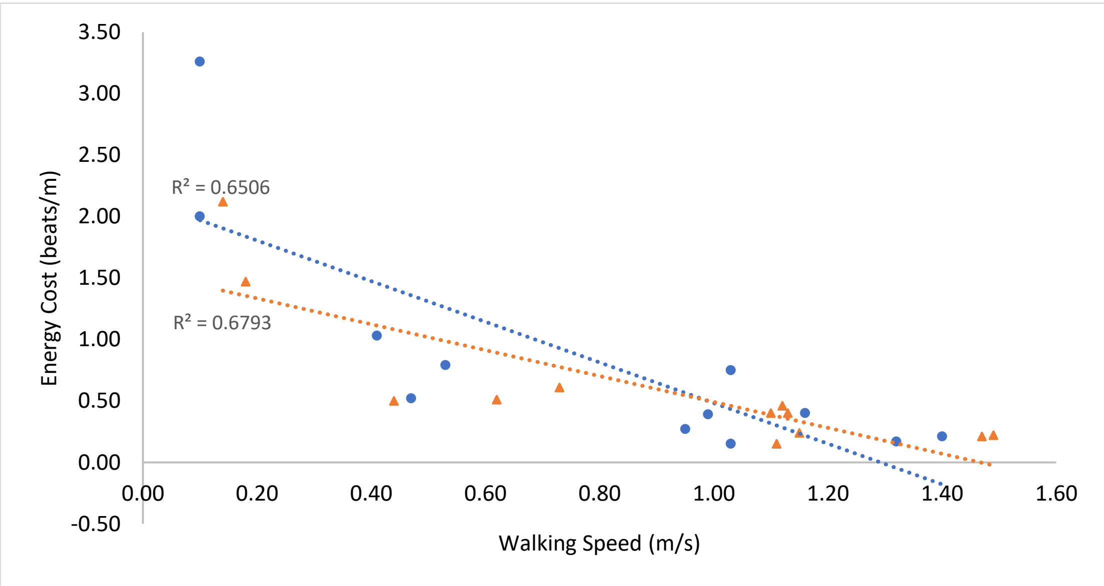


Figure 5.2: Scatter graph showing correlation between walking speed and energy cost, pre and post intervention for outdoor walking protocols. Blue circular plots with blue dashed linear trendline represents pre-intervention, orange triangular plots with orange dashed trendline represents post-intervention. R^2 values for linear trendlines are reported.

5.2.2.2 Partial Sample (adjusted)

Subtracting the two slowest walkers in the sample, walking speed during indoor walking protocols increased from 0.96m/s pre-intervention to 1.05m/s (*p*=0.019) post-intervention and walking speed during outdoor walking protocol increased from 0.92m/s to 1.03m/s (*p*=0.009). Walking distance for indoor walking protocol increased from 113m (81.72 – 144.28) pre-intervention, to 129m (101.92 – 156.07) post-intervention (*p*=0.065) and walking distance during the outdoor walking protocol increased from 114m (83.61 – 144.4) pre-intervention, to 133m (103.01 – 162.98) (*p*=0.014). Energy cost during indoor walking protocol decreased from 0.39 beats/m (0.15 – 0.63) pre-intervention, to 0.34 beats/m (0.24 – 0.45) post-intervention (*p*=0.76) and energy cost during outdoor walking protocol decreased from 0.46 beats/m (0.25 – 0.68) pre-intervention, to 0.37 beats/m (0.25 – 0.48) (*p*=0.183) post intervention.

Table 5.4: Mean ± standard deviation, range and 95% CI for energy cost, walking speed and walking distance for indoor and outdoor 3-minute walking test (3-MWT) protocols pre and post intervention excluding the two slowest walkers. *represents a significant difference between pre and post interventions.

	Indoor					**Outdoor**				
	PRE		**POST**			**PRE**		**POST**		
	Mean ± SD (Range)	**95% CI**	**Mean ± SD (Range)**	**95% CI**	***P***	**Mean ± SD (Range)**	**95% CI**	**Mean ± SD (Range)**	**95% CI**	***P***
Walking Speed (m/s)	0.96 ± 0.37 (0.47 – 1.45)	0.7 – 1.23	1.05 ± 0.32 (0.52 – 1.42)	0.81 – 1.28	0.019*	0.92 ± 0.34 (0.41 – 1.40)	0.67 – 1.17	1.03 ± 0.34 (0.44 – 1.49)	0.79 – 1.28	0.009*
Energy Cost (beats/m)	0.39 ± 0.33 (0.12 – 1.1)	0.15 – 0.63	0.34 ± 0.15 (0.17 – 0.63)	0.24 – 0.45	0.76	0.46 ± 0.29 (0.15 – 1.03)	0.25 – 0.68	0.37 ± 0.15 (0.15 – 0.61)	0.25 – 0.48	0.183
Walking Distance (m)	113.0 ± 43.72 (60 – 180)	81.72 – 144.28	129.0 ± 37.84 (60 – 180)	101.92 – 156.07	0.065	114.0 ± 42.47 (50 – 170)	83.61 – 144.4	133.0 ± 41.91 (60 – 190)	103.01 – 162.98	0.014*

5.2.3 Spatial and Temporal Parameters

The following variables were non-parametric: paretic swing time percentage, non-paretic swing time percentage, paretic stance time percentage, non-paretic stance time percentage, paretic initial double support percentage and non-paretic initial double support percentage. In these cases, Wilcoxon Signed Rank tests were conducted. Data were sampled at 120Hz.

Stride length during assessment of biomechanical function of walking increased from 0.86m (0.59 – 1.13) pre-intervention to 0.97m (0.71 – 1.24)) (*p*=0.005) post-intervention, increasing by 11%. Step length of the paretic lower limb increased from 0.43m (0.31 – 0.56) pre-intervention, to 0.50m (0.38 – 0.62)) (*p*=0.006) post-intervention. Step length of the non-paretic lower limb increased from 0.42m (0.29 – 0.56) pre-intervention, to 0.48m (0.34 – 0.61)) (*p*=0.005) post-intervention. Stride width was similar before and after the outdoor-walking rehabilitation programme (pre-intervention 0.19m (0.15 – 0.22), post-intervention 0.18m (0.15 – 0.22)) (*p*=0.880). Symmetry ratio decreased (therefore symmetry between limbs increased) from 2.18 (0.49 – 3.87) pre-intervention to 1.86 (1.08 – 2.64) (*p*=.497) post-intervention.

Stance time increased from 58.19% (47.13 – 69.25) to 61.69% (56.94 – 66.43) (*p*=0.721) post-intervention for the paretic lower-limb. In the non-paretic lower limb, stance time increased from 66.55% (58.35 – 74.75) to 70.52% (55.92 – 71.56) (*p*=0.583) post-intervention. Swing time for the paretic lower limb increased from 35.53% (30.62 – 40.44) (*p*=0.203), to 37.92% (33.27 – 42.58) (*p*=0.814) post-intervention. Initial double support for the paretic lower limb increased from 16.27% (10.36 – 22.17) to 37.92% (33.27 – 42.58) (*p*=0.388) post-intervention. Initial double support for the non-paretic lower limb decreased from 19.4% (11.66 – 27.14) to 17.93% (11.68 – 24.18) (*p*=0.347) post-intervention.

Table 5.5: Mean ± standard deviation, range and 95% CI of spatial and temporal parameters of self-selecting walking pre and post interventions. *represents a significant difference between pre and post interventions.

	PRE		POST		*P*
	Mean ± SD (Range)	95% CI	Mean ± SD (Range)	95% CI	
Stride width (m)	0.19 ± 0.05 (0.09 – 0.29)	0.15 – 0.22	0.18 ± 0.05 0.9 – 0.3	0.15 – 0.22	0.880
Stride length (m)	0.86 ± 0.42 (0.22 – 1.62)	0.59 – 1.13	0.97 ± 0.41 0.22 – 1.62	0.71 – 1.24	0.005*
Symmetry Ratio	2.18 ± 2.66 (0.38 – 4.24)	0.49 – 3.87	1.86 ± 1.22 0.99 – 2.82	1.08 – 2.64	0.497

	Paretic					Non-paretic				
	PRE		POST		*P*	PRE		POST		*P*
Step length (m)	0.43 ± 0.19 (0.16 – 0.81)	0.31 – 0.56	0.5 ± 0.18 (0.16 – 0.81)	0.38 – 0.62	0.006*	0.42 ± 0.24 (0.08 – 0.79)	0.29 – 0.56	0.48 ± 0.21 (0.08 – 0.79)	0.34 – 0.61	0.005*
Stance time (% gait cycle)	58.19 ± 17.40 (13.74 – 82.26)	47.13 – 69.25	61.69 ± 7.46 (52.82 – 82.26)	56.94 – 66.43	0.721	66.55 ± 12.90 (37.24 – 89.62)	58.35 – 74.75	70.52 ± 11.26 (55.83 – 91.9)	55.92 – 71.56	0.583
Swing time (% gait cycle)	35.53 ± 7.72 (18.53 – 44.72)	30.62 – 40.44	37.92 ± 7.33 (18.53 – 46.03)	33.27 – 42.58	0.203	28.86 ± 13.24 (1.54 – 44.76)	20.44 – 37.27	29.13 ± 11.18 (8.14 – 41.08)	22.02 – 36.24	0.814
Initial double support (% gait cycle)	16.27 ± 9.27 (6.85 – 42.92)	10.36 – 22.17	37.92 ± 7.33 (8.92 – 42.93)	33.27 – 42.58	0.388	19.4 ± 12.18 (8.06 – 52.52)	11.66 – 27.14	17.93 ± 9.83 (6.83 – 42.86)	11.68 – 24.18	0.347

5.2.4 Joint Kinematics

Key joint kinematic parameters of the pelvis, hip, knee and ankle were determined as part of the literature review (table 2.4) and further description of statistical analysis can be found in *Chapter 4: General* Methodology (page 125). For the purpose of this section, results have been presented in graph form and results table presenting peak and range of motion (RoM) measurements of each joint. All kinematic data were sampled at 120Hz, all force data were sampled at 1000Hz.

The following variables were non-parametric: kinematic and kinetic parameters of paretic limb (hip extension, hip internal rotation, knee abduction, knee external rotation, ankle dorsiflexion, ankle inversion, ankle eversion, ankle abduction and adduction, knee joint power, ankle joint power) and kinematic and kinetic parameters of the non-paretic limb (hip flexion, hip abduction, hip adduction, hip internal rotation, hip external rotation, knee flexion, knee abduction, knee internal rotation, ankle dorsiflexion, ankle inversion, ankle adduction, knee joint power). In these cases, Wilcoxon Signed Rank tests were conducted.

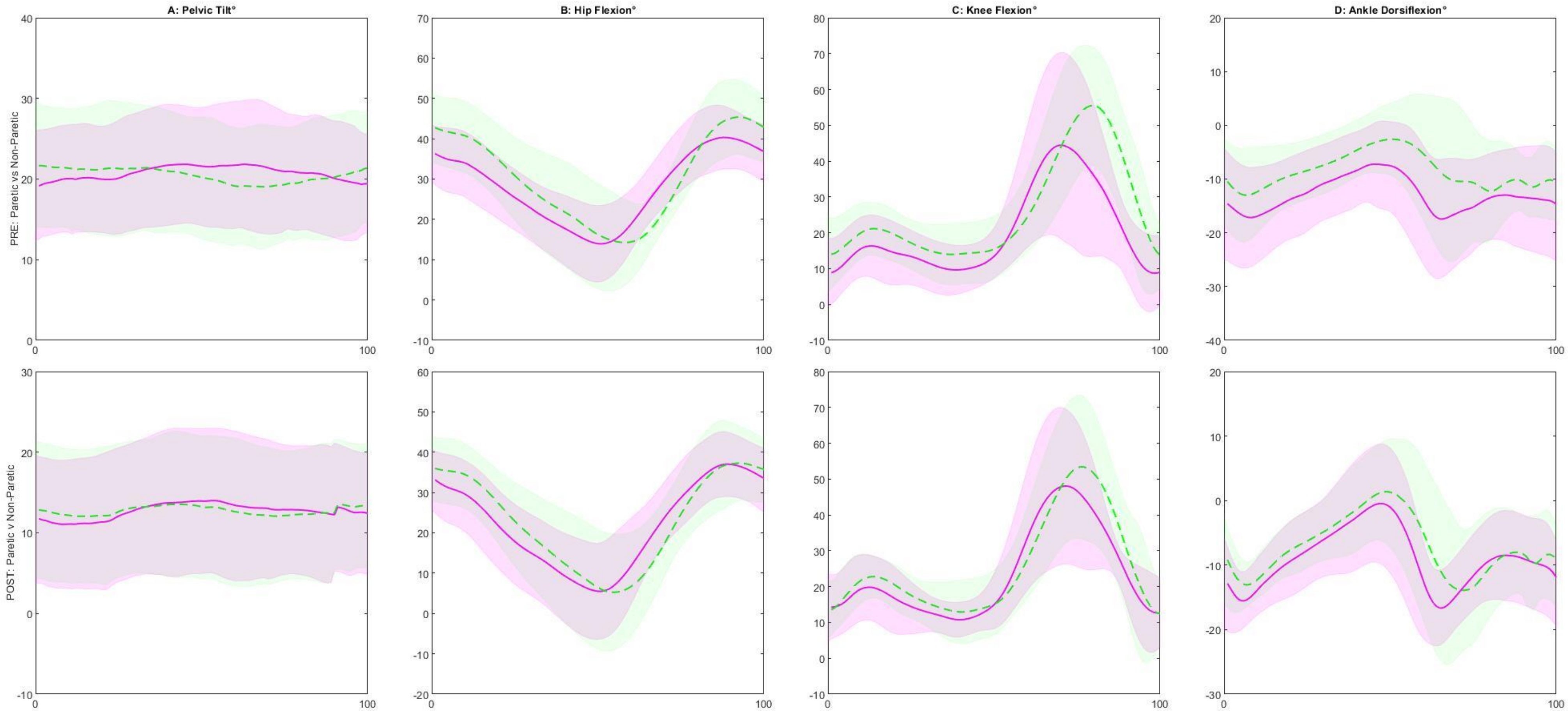


Figure 5.3: Pelvis, hip, knee and ankle joint angle of the paretic and non-paretic lower limb pre-intervention (top row) 0% to 100% the gait cycle in the sagittal plane. Pelvis, hip, knee and ankle angle of the paretic and non-paretic lower limb post-intervention (bottom row) 0% to 100% the gait cycle in the sagittal plane. Pink line and pink band represents paretic lower limb mean ± 1 standard deviation, green dashed line and green band represents post-intervention mean ± 1 standard deviation. On x-axis, 0% represents initial contact and 100% the following ipsilateral contact.

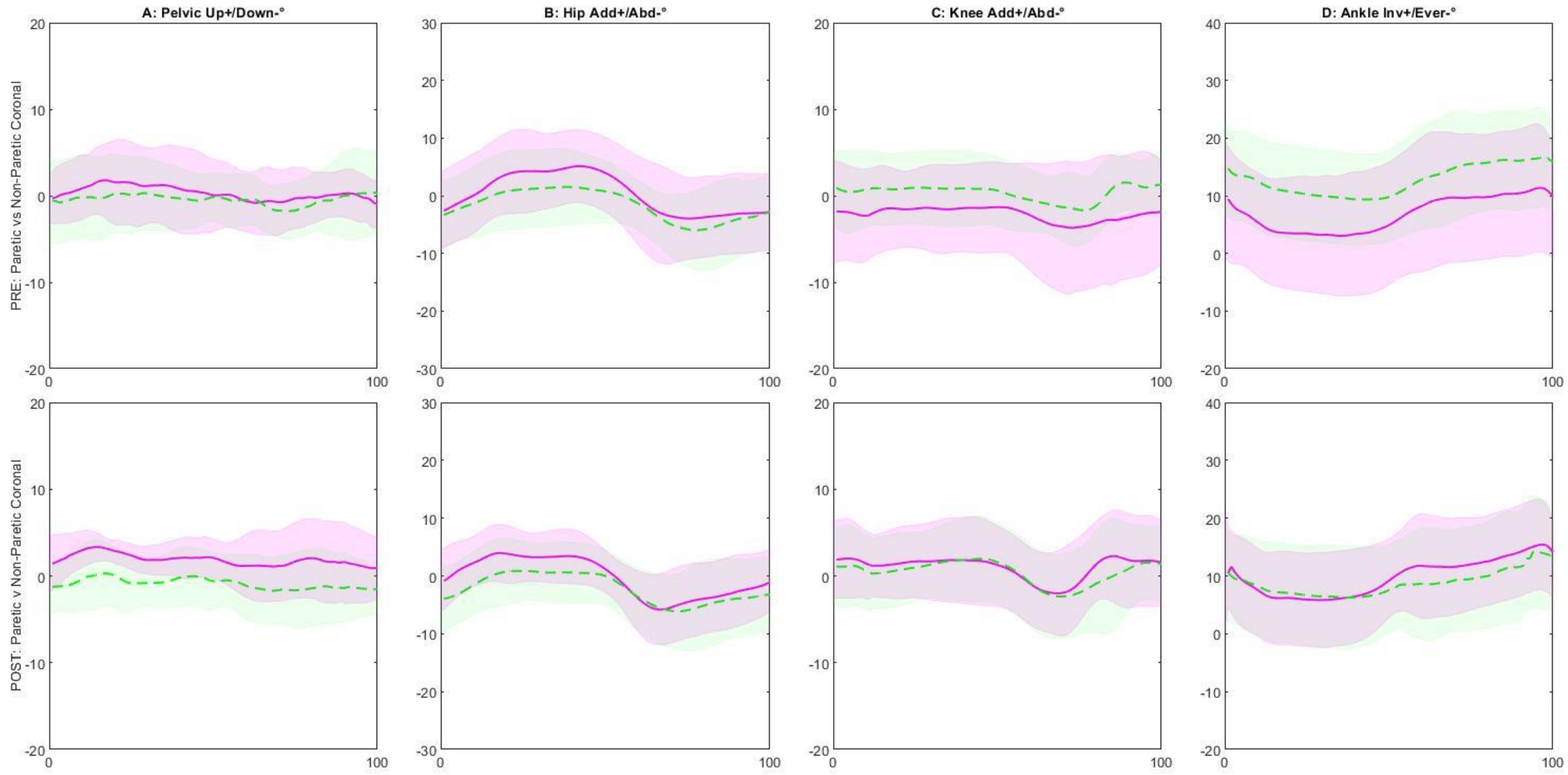


Figure 5.4: Pelvis, hip, knee and ankle angle of the paretic and non-paretic lower limb pre-intervention (top row) 0% to 100% the gait cycle in the coronal plane. Pelvis, hip, knee and ankle angle of the paretic and non-paretic lower limb post-intervention (bottom row) 0% to 100% the gait cycle in the coronal plane. Pink line and pink band represents paretic lower limb mean ± 1 standard deviation, green dashed line and green band represents post-intervention mean ± 1 standard deviation. On x-axis, 0% represents initial contact and 100% the following ipsilateral contact.

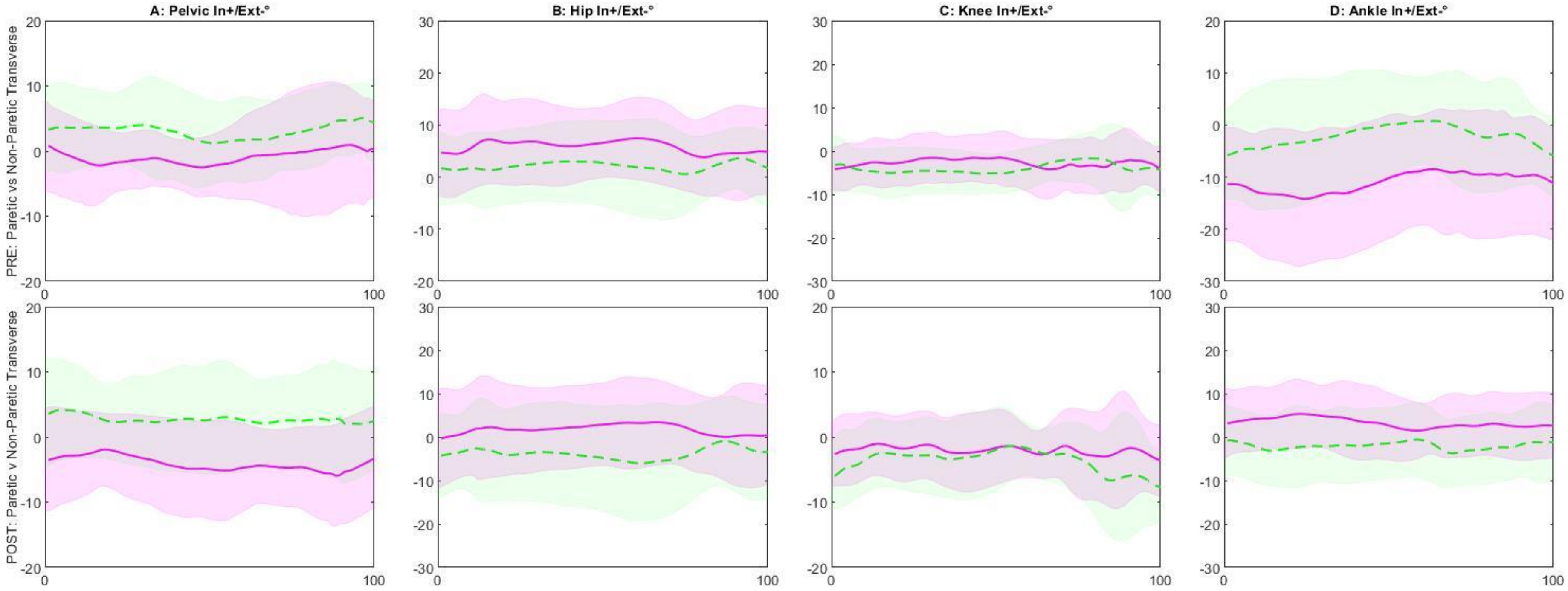


Figure 5.5: Pelvis, hip, knee and ankle angle of the paretic and non-paretic lower limb pre-intervention (top row) 0% to 100% the gait cycle in the transverse plane. Pelvis, hip, knee and ankle angle of the paretic and non-paretic lower limb post-intervention (bottom row) 0% to 100% the gait cycle in the transverse plane. Pink line and pink band represents paretic lower limb mean ± 1 standard deviation, green dashed line and green band represents post-intervention mean ± 1 standard deviation. On x-axis, 0% represents initial contact and 100% the following ipsilateral contact.

Table 5.6: Mean ± standard deviation, range and 95% CI for kinematic parameters of the pelvis during the gait cycle. *represents a significant difference between pre and post interventions.

Joint	Parameter	Paretic (PRE)		Paretic (POST)		P	Non-paretic (PRE)		Non-paretic (POST)		P
		Mean ± SD (Range)	95% CI	Mean ± SD (Range)	95% CI		Mean ± SD (Range)	95% CI	Mean ± SD (Range)	95% CI	
Pelvic tilt	Max Ant° (+ve)	23.43 ± 7.37 (11.11 – 32.14)	18.75 – 28.11	15.07 ± 8.76 (1.90-32.09)	9.50 – 20.64	0.001*	23.36 ± 7.67 (11.62 – 32.11)	18.21 – 28.52	15.63 ± 9.0 (1.96 – 33.12)	9.58 – 21.68	0.002*
	Max Post° (-ve)	17.79 ± 6.66 (6.02 – 26.54)	13.56 – 22.02	9.55 ± 8.06 (-0.54 – 26.21)	4.42 – 14.68	0.001*	17.43 ± 6.97 (6.02 – 27.89)	12.75 – 22.12	10.01 ± 8.54 (-3.29 – 25.33)	4.27 – 15.75	0.002*
	ROM°	5.63 ± 2.89 (1.87 – 11.10)	3.79 – 7.47	5.52 ± 2.45 (1.97 – 9.74)	3.96 – 7.07	0.865	5.92 ± 3.12 (2.49 – 10.91)	3.82 – 8.02	5.61 ± 2.22 (1.84 – 8.96)	4.12 – 7.11	0.677
Pelvic Obliquity	Max Up° (+ve)	3.71 ± 3.12 (-0.4 – 9.67)	1.73 – 5.70	5.33 ± 2.58 (2.58 – 10.85)	3.69 – 6.97	0.249	2.63 ± 4.52 (-4.97 – 11.35)	-0.4 – 5.67	2.29 ± 4.15 (-4.15 – 10.85)	-0.49 – 5.09	0.841
	Max Down° (-ve)	-2.95 ± 3.90 (-11.41 – 4.09)	-5.43 – -0.47	-1.20 ± 2.78 (-4.90 – 4.15)	-2.97 – 0.56	0.183	-3.42 ± 2.71 (-8.12 – 0.41)	-5.24 – -1.59	-3.94 ± 2.53 (-6.82 – 1.61)	-5.64 – -2.24	0.604
	ROM°	6.67 ± 2.16 (3.81 – 11.01)	5.29 – 8.04	6.54 ± 2.64 (1.91 – 11.31)	4.86 - 8.22	0.867	6.06 ± 2.8 (2.80 – 10.94)	4.17 – 7.94	6.24 ± 2.69 (2.21 – 11.31)	4.43 – 8.05	0.846
Pelvic Rotation	Max Int° (+ve)	4.18 ± 7.30 (-6.66 – 18.51)	-0.46 – 8.82	0.89 ± 6.93 (-8.84 – 13.51)	-3.51 – 5.30	0.086	8.52 ± 6.43 (-2.15 – 17.92)	4.2 – 12.84	7.84 ± 7.22 (-5.94 – 18.30)	2.99 – 12.69	0.119
	Max Ext° (-ve)	-5.86 ± 5.56 (-12.89 – 4.50)	-9.39 – -2.32	-9.27 ± 6.74 (-18.30 – 0.63)	-13.56 – -4.99	0.045*	-1.8 ± 5.72 (-10.83 – 5.64)	-5.65 – 2.05	-1.8 ± 8.33 (-17.29 – 8.84)	-7.40 – 3.78	0.894
	ROM°	10.04 ± 5.10 (3.77 – 18.47)	6.80 – 13.29	10.17 ± 5.09 (4.44 – 18.86)	6.93 – 13.41	0.897	10.32 ± 5.07 (4.13 – 19.39)	6.91 – 13.73	9.65 ± 4.76 (4.44 - 11.31)	6.45 – 12.84	0.641

Table 5.7: Mean ± standard deviation, range and 95% CI for kinematic parameters of the hip, knee and ankle during the gait cycle. *represents a significant difference between pre and post interventions.

Joint	Parameter	Paretic (PRE)		Paretic (POST)		*P*	Non-paretic (PRE)		Non-paretic (POST)		*P*
		Mean ± SD (Range)	95% CI	Mean ± SD (Range)	95% CI		Mean ± SD (Range)	95% CI	Mean ± SD (Range)	95% CI	
Hip Flex/Ext	Max Flex° (+ve) *During loading response*	41.20 ± 7.82 (27.54 – 52.24)	36.23 – 46.17	37.71 ± 7.95 (25.71 – 52.15)	32.66 – 42.76	0.032*	46.76 ± 8.93 (36.00 – 65.26)	40.75 – 52.76	39.72 ± 9.7 (25.34 – 55.88)	33.20 – 46.25	0.014*
	Max Ext° (-ve)	13.26 ± 9.41 (-6.02 – 25.99)	7.27 – 19.24	4.36 ± 11.84 (-11.46 – 28.06)	-3.15 – 11.89	0.001*	12.05 ± 10.91 (-8.93 – 26.05)	4.72 – 19.38	3.57 ± 13.42 (-16.23 – 28.06)	-5.44 – 12.59	0.007*
	ROM°	27.94 ± 11.35 (10.66 – 44.63)	20.73 – 35.16	33.34 ± 10.66 (15.72 – 49.25)	26.56 – 40.12	0.001*	34.70 ± 9.68 (13.90 – 45.95)	28.20 – 41.21	36.15 ± 12.02 (15.72 – 49.25)	28.07 – 44.22	0.560
Hip Add/Abd	Max Add° (+ve)	6.02 ± 6.41 (-4.32 – 19.88)	1.95 – 10.10	5.38 ± 4.31 (-2.41 – 9.66)	2.64 – 8.12	0.764	3.73 ± 5.58 (-6.94 – 11.66)	-0.02 – 7.48	4.14 ± 5.16 (-2.38 – 15.11)	0.47 – 7.82	0.887
	Max Abd° (-ve)	-5.41 ± 6.98 (-15.09 – 12.62)	-9.85 – -0.97	-6.75 ± 5.5 (-15.78 – 1.14)	-10.25 – -3.25	0.531	-7.91 ± 5.89 (-16.34 – 1.35)	-11.86 – -3.94	-8.53 ± 4.78 (-15.11 – 2.32)	-11.75 – -5.32	0.825
	ROM°	11.44 ± 3.87 (5.39 – 18.47)	8.98 – 13.90	12.14 ± 5.54 (5.62 – 22.61)	8.62 – 15.66	0.449	11.64 ± 3.42 (5.39 – 18.72)	9.34 – 13.94	12.68 ± 4.69 (6.68 – 19.71)	9.53 – 15.84	0.318
Knee Flex/Ext	Max Flex° (+ve) *During loading response*	16.36 ± 8.52 (-1.32 – 26.19)	10.94 – 21.77	19.81 ± 9.07 (4.32 – 31.76)	14.04 – 25.57	0.035*	21.12 ± 7.38 (6.78 – 32.94)	16.16 – 26.08	23.11 ± 6.11 (4.99 – 26.78)	19.0 – 27.22	0.237
	Max Ext° (-ve) *During stance*	9.65 ± 6.91 (-0.29 – 23.57)	5.26 – 14.04	10.75 ± 4.86 (4.92 – 19.86)	7.66 – 13.84	0.396	13.98 ± 8.51 (2.32 – 28.07)	8.25 – 19.7	13.25 ± 9.27 (1.30 – 29.22)	7.02 – 19.48	0.685
	Max Flex° (+ve) *During swing*	44.47 ± 25.45 (5.14 – 67.62)	28.29 – 60.64	48.04 ± 21.93 (6.08 – 68.25)	34.11 – 61.98	0.080	55.43 ± 16.88 (20.51 – 70.33)	44.08 – 66.77	52.86 ± 20.84 (9.62 – 71.22)	38.85 – 66.86	0.383
Ankle Dorsi/Plan	Dorsiflexion° *At Initial Contact*	-16.13 ± 9.83 (-30.28 – 9.99)	-22.38 - -9.87	-20.43 ± 4.48 (-27.19 - - 12.01)	-23.28 – - 17.59	0.111	-22.08 ± 7.15 (-8.34 – 11.48)	-26.89 – - 17.28	-21.72 ± 5.87 (-30.86 - - 11.38)	-25.64 – - 17.79	0.836
	Plantarflexion° *During stance*	-7.23 ± 7.21 (-18.18 – 3.20)	-11.81 – -2.64	0.89 ± 8.85 (-14.90 – 14.26)	-4.72 – 6.52	0.007*	2.31 ± 7.05 (1.90 – 32.09)	-2.42 – 7.05	4.04 ± 7.86 (-14.90 – 10.40)	-1.2 – 9.32	0.437

Key: Sagittal plane joint range of motion for paretic and non-paretic lower limbs of young adults who have had a stroke during the gait cycle. Positive angle indicates anterior tilt (pelvic tilt), flexion (hip and knee joints) and dorsiflexion (ankle joint). Negative angle indicates posterior tilt (pelvis), extension (hip and knee joint) and plantarflexion (ankle joint). Frontal plane of motion for paretic and non-paretic lower limbs during the gait cycle. Positive angle indicates upwards motion (pelvic obliquity) and adduction (hip joint). Negative angle indicates down movement (pelvic obliquity) and abduction (hip joint). Transverse plane of motion for paretic and non-paretic lower limbs during the gait cycle. Positive angle indicates internal rotation (pelvis). Negative angle indicates external rotation (pelvis).

Overall, joint range of motion were similar when comparing pre and post-intervention for both the paretic and non-paretic lower limbs, with the exception of pelvic tilt, hip extension and knee flexion for both the paretic and non-paretic lower limbs.

5.2.4.1 The Pelvis

The pelvis was more posteriorly tilted post-intervention in both the paretic (pre-intervention, 17.79° (13.56 – 22.02) post-intervention, 9.55° (4.42 – 14.68)) (*p*=0.001) and non-paretic (pre-intervention, 17.43° (12.75 – 22.12) post-intervention, 10.01° (4.27 – 15.75)) (*p*=0.002) lower limbs throughout the entire gait cycle, with peak posterior tilt of the paretic limb occurring during loading response in stance phase of the gait cycle, compared to pre-intervention, seen in figure 5.3 (A: Pelvic tilt). A reduction in anterior tilt was also observed post-intervention for both the paretic (pre-intervention, 23.43° (18.75 – 28.11)post-intervention, 15.07° (9.50 – 20.64)) (*p*=0.001) and non-paretic (pre-intervention, 23.36° (18.21 – 28.52) post-intervention, 15.63° (9.58 – 21.68)) (*p*=0.002) lower limbs throughout the entire gait cycle, with peak anterior tilt of the paretic limb occurring in the pre-swing phase of the gait cycle. However, pelvis range of motion in sagittal, coronal and transverse planes were similar between interventions for the paretic and non-paretic lower limbs. All other recorded parameters of the pelvis were found to not be significant.

5.2.4.2 The Hip

Reduction in hip flexion during loading response were observed for both the paretic (pre-intervention, 41.20° (36.23 – 46.17) post-intervention, 37.71° (32.66 – 42.76)) (*p*=0.032) and non-paretic lower limb (pre-intervention, 46.76° (40.75 – 52.76) post-intervention, 39.72° (33.20 – 46.25)) (*p*=0.014). Reduction in hip extension during pre-swing of stance phase was observed post-intervention in the paretic (pre-intervention, 13.26° (7.27 – 19.24) post-intervention, 4.36° (-3.15 – 11.89)) (*p*=0.001) and non-paretic (pre-intervention, 12.05° (4.72 – 19.38)) post-intervention, 3.57° (-5.44 – 12.59)) (*p*=0.007) lower limbs. Increase in hip range of motion in sagittal plane was seen for the paretic (pre-intervention, 27.94° (20.73 – 35.16) post-intervention, 33.34° (26.56 – 40.12)) (*p*=0.001) lower limb only. All other recorded parameters of the hip were found to not be significant.

5.2.4.3 The Knee

Peak knee flexion during loading response increased post- intervention for the paretic (pre-intervention, 16.36° (10.94 – 21.77) post-intervention, 19.81° (14.04 – 25.57)) (*p*=0.035) lower limb only. Peak knee flexion during mid-swing phase of gait cycle increased post-intervention for the paretic (pre-intervention, 44.47° (28.29 – 60.64) post-intervention, 48.04° (34.11 – 61.98)) (*p*=0.08) lower limb only. Peak knee extension was found to not be significant for either the paretic (*p*=0.396) and non-paretic (*p*=0.685) lower limb.

5.2.4.4 The Ankle

Ankle dorsiflexion at initial contact for paretic (*p*=0.111) and non-paretic (*p*=0.836) lower limbs were found to not be significant. Peak ankle plantarflexion during stance, at toe-off increased post-intervention for the paretic (PRE, -7.23° (-11.81 – -2.64) POST, 0.89° (-4.72 – 6.52)) (p=0.007) lower limb only.

5.2.5 Joint kinetics and Power

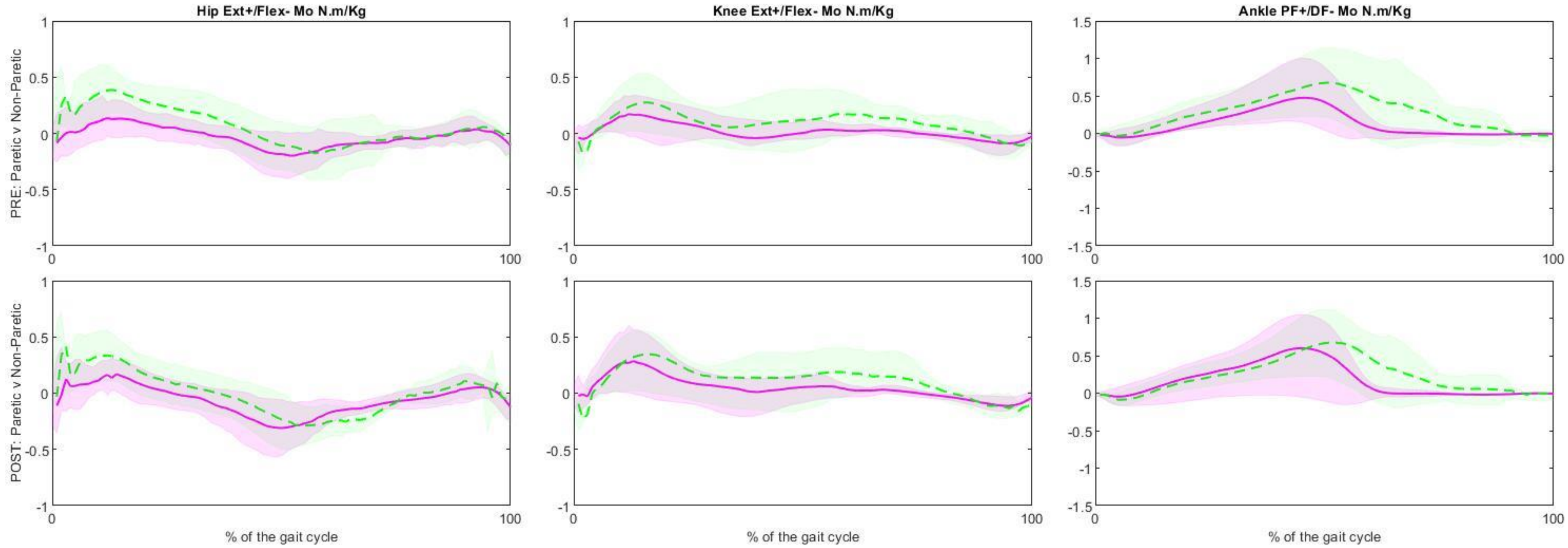


Figure 5.6: hip, knee and ankle moments of the paretic and non-paretic lower limb pre-intervention (top row) 0% to 100% the gait cycle in the sagittal plane. Pelvis, hip, knee and ankle angle of the paretic and non-paretic lower limb post-intervention (bottom row) 0% to 100% the gait cycle in the sagittal plane. Pink line and pink band represents paretic lower limb mean ± 1 standard deviation, green dashed line and green band represents post-intervention mean ± 1 standard deviation. On x-axis, 0% represents initial contact and 100% the following ipsilateral contact.

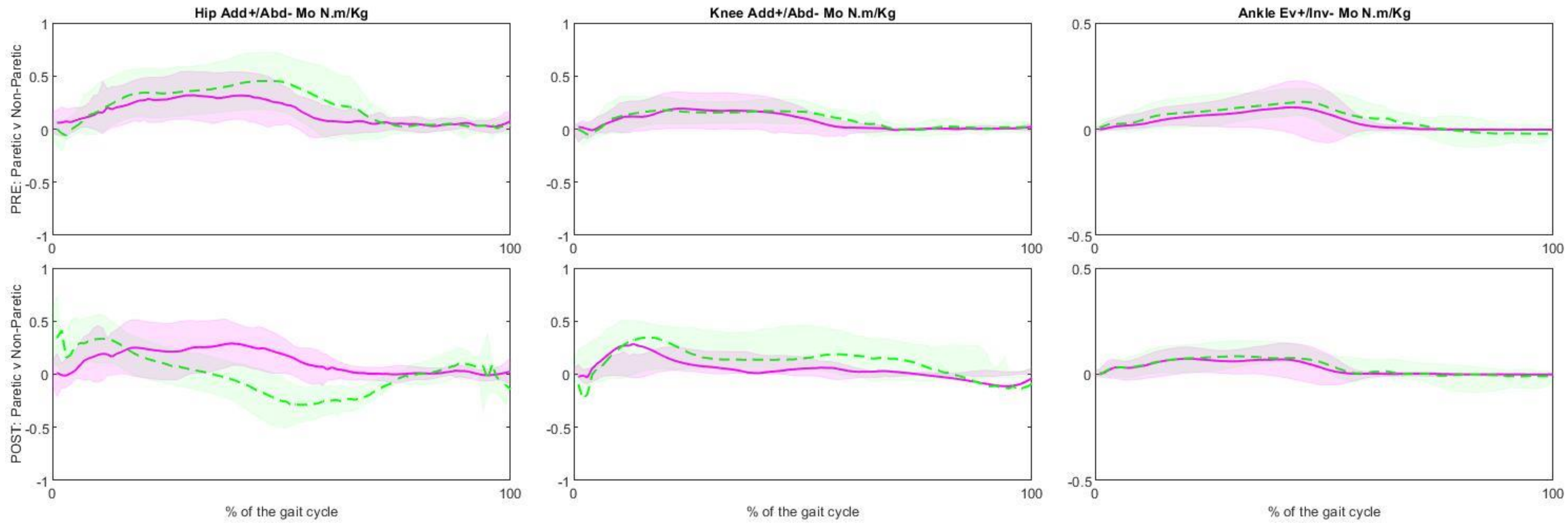


Figure 5.7: hip, knee and ankle moments of the paretic and non-paretic lower limb pre-intervention (top row) 0% to 100% the gait cycle in the coronal plane. Pelvis, hip, knee and ankle angle of the paretic and non-paretic lower limb post-intervention (bottom row) 0% to 100% the gait cycle in the coronal plane. Pink line and pink band represents paretic lower limb mean ± 1 standard deviation, green dashed line and green band represents post-intervention mean ± 1 standard deviation. On x-axis, 0% represents initial contact and 100% the following ipsilateral contact.

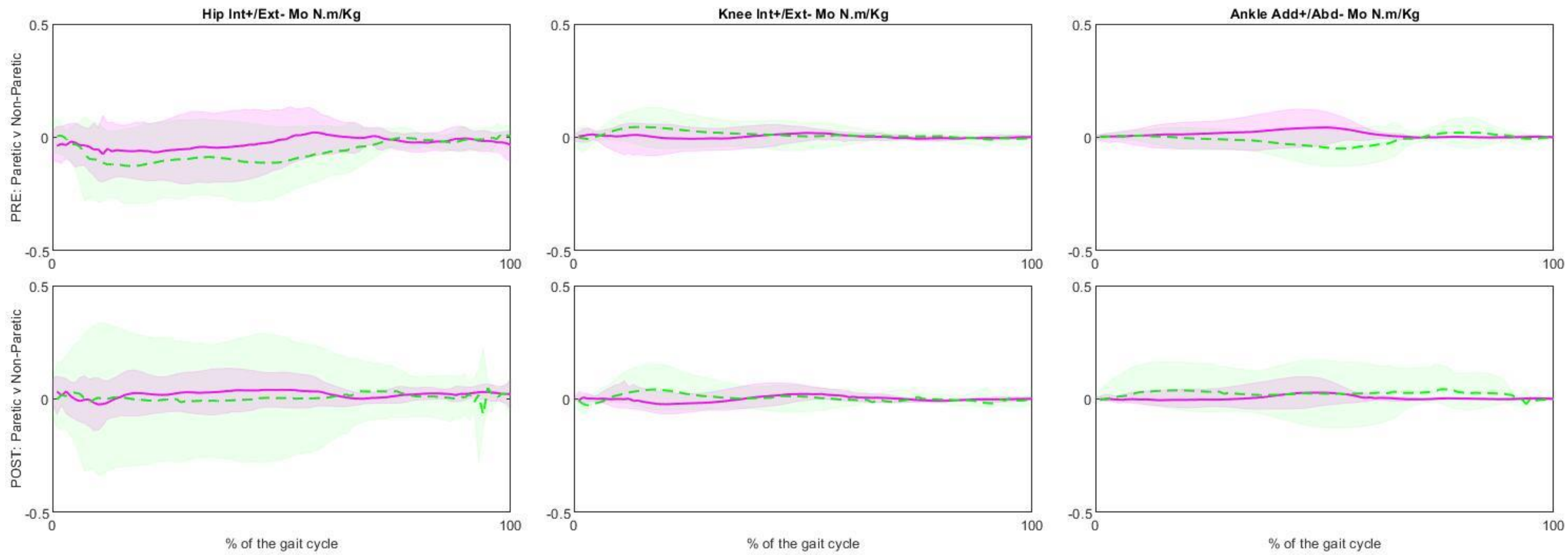


Figure 5.8: hip, knee and ankle moments of the paretic and non-paretic lower limb pre-intervention (top row) 0% to 100% the gait cycle in the transverse plane. Pelvis, hip, knee and ankle angle of the paretic and non-paretic lower limb post-intervention (bottom row) 0% to 100% the gait cycle in the transverse plane. Pink line and pink band represents paretic lower limb mean ± 1 standard deviation, green dashed line and green band represents post-intervention mean ± 1 standard deviation. On x-axis, 0% represents initial contact and 100% the following ipsilateral contact.

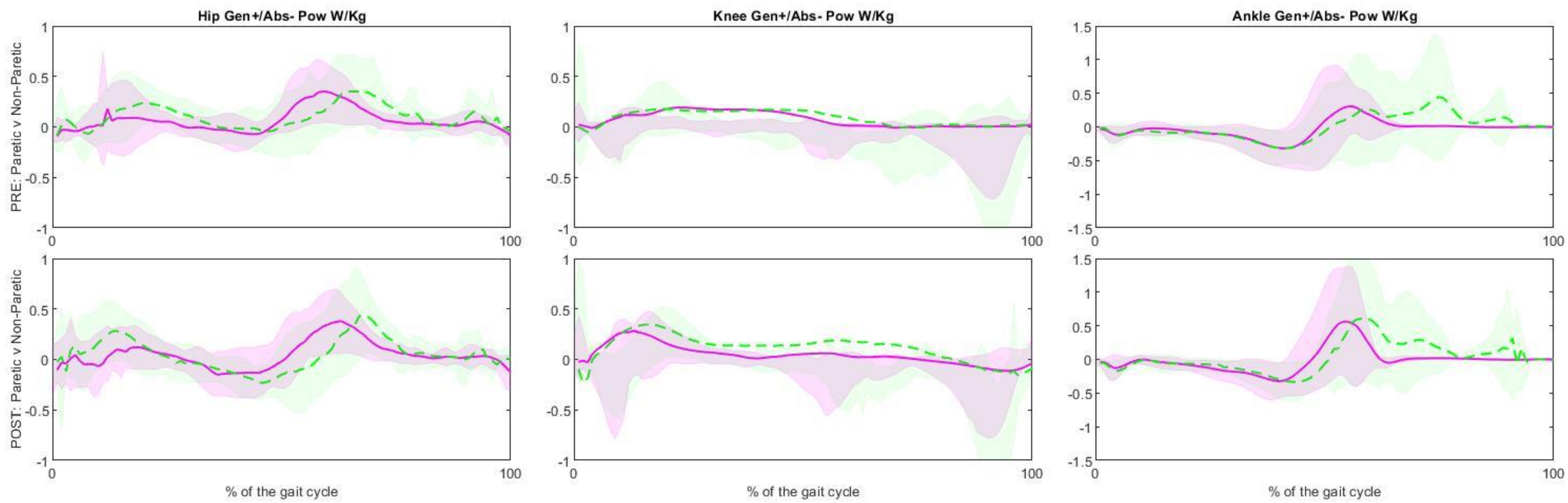


Figure 5.9: hip, knee and ankle joint powers of the paretic and non-paretic lower limb pre-intervention (top row) 0% to 100% the gait cycle. Pelvis, hip, knee and ankle joint powers of the paretic and non-paretic lower limb post-intervention (top row) 0% to 100% the gait cycle. Pink line and pink band represents paretic lower limb mean ± 1 standard deviation, green dashed line and green band represents post-intervention mean ± 1 standard deviation. On x-axis, 0% represents initial contact and 100% the following ipsilateral contact.

Table 5.8: Mean ± standard deviation, range and 95% CI for kinetic parameters of the hip joint moments during the gait cycle. *represents a significant difference between pre and post interventions.

Joint	Parameter	Paretic (PRE) Mean ± SD (Range)	Paretic (PRE) 95% CI	Paretic (POST) Mean ± SD (Range)	Paretic (POST) 95% CI	*P*	Non-paretic (PRE) Mean ± SD (Range)	Non-paretic (PRE) 95% CI	Non-paretic (POST) Mean ± SD (Range)	Non-paretic (POST) 95% CI	*P*
Hip Flex/Ext	Max Ext (+ve) *Moment during weight acceptance*	0.27 ± 0.18 (0.28 – 0.71)	0.15 – 0.39	0.32 ± 0.17 (0.15 – 0.64)	0.22 – 0.44	0.114	0.56 ± 0.21 (0.14 – 0.86)	0.36 – 0.63	0.57 ± 0.3 (0.08 – 1.15)	0.38 – 0.76	0.432
	Max Flex (-ve) *Moment during midstance*	-0.32 ± 0.11 (-0.54 - -0.19)	-0.39 - -0.25	-0.46 ± 0.19 (-0.76 - -0.18)	-0.58 - -0.34	0.010*	-0.33 ± 0.17 (-0.71 - -0.06)	-0.44 - -0.23	-0.46 ± 0.2 (-0.96 - -0.21)	-0.59 - -0.32	0.074
Hip Add/Abd	Max Add (+ve)	0.45 ± 0.21 (0.10 – 0.79)	0.32 – 0.59	0.42 ± 0.26 (0.11 – 0.85)	0.25 – 0.58	0.675	0.54 ± 0.23 (0.17 – 0.81)	0.39 – 0.69	0.66 ± 0.32 (0.27 – 1.51)	0.46 – 0.87	0.508
	Max Abd (-ve)	-0.06 ± 0.08 (-0.19 – 0.44)	-0.11 - -0.007	-0.16 ± 0.08 (-0.31 - -0.01)	-0.21 - -0.11	0.004*	-0.19 ± 0.13 (-0.45 - -0.04)	-0.27 - -0.11	-0.26 ± 0.19 (-0.76 - -0.09)	-0.38 - -0.14	0.386
Hip Joint power	H3 (+ve) *During propulsion*	0.54 ± 0.46 (0.12 – 1.77)	0.24 – 0.83	0.59 ± 0.28 (0.19 – 1.02)	0.4 – 0.77	0.640	0.66 ± 0.29 (0.32 – 1.26)	0.47 – 0.84	0.71 ± 0.37 (0.35 – 1.58)	0.48 – 0.95	0.495
	H2 (-ve) *During midstance*	-0.24 ± 0.14 (-0.54 - -0.11)	-0.32 - -0.15	-0.46 ± 0.25 (-0.89 - -0.12)	-0.62 - -0.3	0.002*	-0.35 ± 0.2 (-0.88 - -0.11)	-0.48 - -0.22	-0.59 ± 0.42 (-1.73 - -0.21)	-0.86 - -0.32	0.056
Knee Flex/Ext	Max Ext (+ve) *Moment during weight acceptance*	0.23 ± 0.15 (0.03 – 0.48)	0.12 – 0.33	0.35 ± 0.28 (0.03 – 0.95)	0.17 – 0.53	0.036*	0.38 ± 0.25 (0.07 – 0.86)	0.22 – 0.54	0.48 ± 0.2 (0.13 – 0.85)	0.36 – 0.62	0.211
	Max Flex (-ve)	-0.16 ± 0.07 (-0.3 - -0.05)	-0.2 - -0.11	-0.19 ± 0.1 (-0.4 - -0.06)	-0.26 - -0.13	0.242	-0.23 ± 0.11 (-0.56 - -0.11)	-0.3 - -0.16	-0.31 ± 0.13 (-0.56 - -0.13)	-0.39 - -0.22	0.028*
Knee Joint power	(+ve)	0.21 ± 0.16 (0.05 – 0.51)	0.11 – 0.31	0.39 ± 0.35 (0.05 – 1.07)	0.17 – 0.62	0.028*	0.5 ± 0.53 (0.18 – 1.94)	0.16 – 0.84	0.73 ± 0.58 (0.16 – 1.94)	0.37 – 1.1	0.074
	(-ve)	-0.46 ± 0.36 (-1.17 - -0.06)	-0.69 - -0.24	-0.66 ± 0.46 (-1.58 - -0.09)	-0.96 - -0.37	0.033*	-0.81 ± 0.48 (-1.17 - -0.06)	-1.12 - -0.51	-0.94 ± 0.43 (-1.76 - -0.4)	-1.22 - -0.66	0.293
Ankle Dorsi/Plan	Max PF (+ve)	0.58 ± 0.43 (0.02 – 1.18)	0.3 – 0.85	0.68 ± 0.47 (0.02 – 1.38)	0.38 – 0.98	0.120	0.89 ± 0.44 (0.07 – 1.7)	0.6 – 1.17	0.85 ± 0.39 (0.19 – 1.4)	0.59 – 1.1	0.613
	Max DF (-ve)	-0.14 ± 0.2 (-0.72 - -0.02)	-0.26 - -0.01	-0.09 ± 0.08 (-0.27 - -0.02)	-0.14 - -0.04	0.878	-0.16 ± 0.21 (-0.78 - -0.02)	-0.29 - -0.03	-0.14 ± 0.07 (-0.22 - -0.02)	-0.18 - -0.1	0.386
Ankle Joint power	(+ve) *A2 power during propulsion*	0.57 ± 0.61 (0.03 – 1.9)	0.18 – 0.96	0.88 ± 1.00 (0.01 – 2.65)	0.24 – 1.52	0.074	1.41 ± 0.76 (0.36 – 3.11)	0.95 – 1.92	1.72 ± 0.66 (0.36 – 2.51)	1.3 – 2.14	0.135
	(-ve)	-0.46 ± 0.35 (-1.18 - -0.02)	-0.69 - -0.24	-0.43 ± 0.28 (-1.03 - -0.06)	-0.61 - -0.25	0.508	-0.52 ± 0.27 (-0.91 - -0.07)	-0.69 - -0.35	-0.6 ± 0.39 (-1.63 - -0.07)	-0.85 - -0.35	0.173

Key: Sagittal plane joint moments for paretic and non-paretic lower limbs of young adults who have had a stroke during the gait cycle. Positive moment indicates extension (hip and knee joints) and plantarflexion (ankle joint). Negative angle indicates flexion (hip and knee joint) and dorsiflexion (ankle joint). Coronal plane joint moments for paretic and non-paretic lower limbs during the gait cycle. Positive angle indicates adduction (hip and knee joints) and eversion (ankle joint). Negative angle indicates abduction (hip and knee joints) and inversion (ankle joint). Transverse plane joint moments for paretic and non-paretic lower limbs during the gait cycle. Positive angle indicates internal rotation (hip and knee joints) and adduction (ankle joint). Negative angle indicates external rotation (hip and knee joints) and abduction (ankle joint).

5.2.5.1 The Hip

Peak hip flexor moment of the paretic lower limb increased from pre to post-intervention (PRE, -0.32 (-0.39 - -0.25) POST, -0.46 (-0.58 - -0.34)) (*p*=0.010) in midstance, suggesting increase in stability when bearing weight onto the paretic lower limb. Peak hip flexor moment of the non-paretic lower limb increased from -0.33 (-0.44 - -0.23) pre-intervention, to -0.46 (-0.59 - -0.32) (*p*= 0.074) post-intervention, during midstance. Marginal increase in peak hip extensor moment of the paretic lower limb was observed post-intervention during weight acceptance (PRE, 0.27 (0.15 - 0.39) POST, 0.32 (0.22 - 0.17)) (*p*= 0.114). peak hip extensor moment of the non-paretic lower limb (PRE, 0.5 (0.36 - 0.63) POST, 0.57 (0.38 - 0.76)) (*p*= 0.432) was not found to be significant. Peak abductor moment of the paretic lower limb increased post intervention (PRE, -0.06 (-0.11 - -0.08) POST, -0.16 (-0.21 - -0.11)) (*p*= 0.004). Peak hip power generation (H2) of the paretic lower limb increased post-intervention during midstance (PRE, -0.24 (-0.32 - -0.15) POST, -0.46 (-0.62 - -0.3)) (*p*= 0.002). Peak hip power generation (H2) of the non-paretic lower limb was not found to be significant (*p*= 0.056).

5.2.5.2 The Knee

Peak knee extensor moment of the paretic lower limb increased from pre to post-intervention (PRE, 0.23 (0.12 – 0.33) POST, 0.35 (0.17 – 0.53)) (p=0.036) during weight acceptance of the stance phase. Peak knee extensor moment of the non-paretic limb was found to not be significant (p= 0.211). Peak knee flexor moment of the non-paretic lower limb increased post-intervention (PRE, -0.23 (-0.11 – -0.16) POST, -0.31 (-0.39 – -0.22)) (p=0.028). Peak knee flexor moment of the paretic lower limb was found to not be significant (p=0.242). Peak knee joint power (+ve) of the paretic lower limb increased post-intervention (PRE, 0.21 (0.11 – 0.31) POST, 0.39 (0.17 – 0.62)) (p=0.028). Peak knee joint power (+ve) of the non-paretic lower limb was found to not be significant (p=0.074). Peak knee joint power (-ve) of the paretic lower limb increased post-intervention (PRE, -0.46 (-0.69 – -0.24) POST, -0.66 (-0.96 – -0.37)) (p=0.033). Peak knee joint power (-ve) of the non-paretic lower limb was found to not be significant (p=0.293).

5.2.5.3 The Ankle

Peak ankle joint power generation (A2) increased post-intervention (PRE, 0.57 (0.18 – 0.96) POST, 0.88 (0.24 – 1.52)) (p=0.074) during propulsion (at toe-off). Peak ankle joint power generation (-ve) was found to not be significant for either the paretic (p=0.508) and non-paretic lower limb (p=0.173). Peak ankle plantarflexor moment was found to not be significant for both the paretic (p=0.120) and non-paretic lower limb (p=0.613). Peak ankle dorsiflexor moment was found to not be significant for either the paretic (p=0.878) and non-paretic lower limb (p=0.386).

5.3 Discussion

This case-controlled study aimed to assess whether an outdoor-walking rehabilitation programme can improve walking performance parameters, such as walking speed, energy cost, walking distance, spatial-temporal parameters and lower limb joint kinematics, kinetics and powers of young adults who have had a stroke. This study is both novel in its approaches and the first study of its kind to have been conducted, by examining the role of an outdoor-walking rehabilitation programme through the reporting of walking performance parameters such as energy cost, spatial-temporal parameters and joint kinematics and kinetics data before and after participation in the rehabilitation intervention.

Walking in outdoor environments can be more demanding due to the complexities that this type of environment presents (Kim et al., 2014), such as uneven ground, different terrains and changeable weather (e.g. wind and rain) but also the requirement to step up, down and over obstacles. Outdoor-walking (e.g. community ambulation, walking in urban environments and outdoor natural environments) can therefore become a more arduous task for a young stroke survivor when they complete activities of daily living or community ambulation. Indoor-based rehabilitation programmes are not conducive to the hazards that walking in natural outdoor environments and community walking presents.

The key findings seen in this study included increased walking speed and walking distance, reduction in energy cost of walking (and therefore improved walking efficiency). Key spatial-temporal parameters such as stride length increased and step length of the paretic and non-paretic lower-limbs increased. Key joint kinematics and kinetics of the pelvis, hip knee and ankle showed improvements and will be explained further in this chapter.

5.3.1 Walking Speed and Spatial Temporal Parameters

As a result of this case-controlled study, significant increases in self-selected walking speed for both environments (indoor and outdoor) were reported, increasing by nearly 10% after participants received and completed the outdoor-walking rehabilitation programme. By delivering a supported walk in natural outdoor environments, participants' walking performance (e.g. walking speed, energy cost and walking distance) improved when walking over uneven terrain and different gradients.

Walking is fundamental to physical independence post-stroke (Jarvis et al., 2019) and in accordance with the majority of previous research, self-selected walking speed for indoor environments for this participant group was similar with previous studies (Platts et al., 2006; Kramer et al., 2016; Jarvis et al., 2019; Saunders et al., 2020). In this study, self-selected walking speed of 0.91m/s for the indoor-walking protocol and 0.89m/s for the outdoor-walking protocol, compared to 1.37m/s in healthy able-bodied control groups reported in other studies specific to stroke (Jarvis et al., 2019), highlight that walking speed within this young stroke cohort has been affected by stroke. However, the range in walking speed within the participant group needs to be addressed. Ten out of the twelve participants for example, walked at speeds between 0.47-1.45m/s pre intervention and 0.52-1.42m/s post intervention for the indoor walking protocol, highlighting the large variability in walking speed commonly seen in many stroke gait studies. As per the gait classification first proposed by Perry et al (1995) Three participants in this sample were walking at speeds similar to able-bodied individuals, raising the question as to whether the rehabilitation programme was necessary for them, or that it was useful in other aspects regarding mental health and social interaction (which is discussed in *Chapter Six* of this thesis). The walking speeds observed in this study creates a stark contrast to the two slowest walkers in the group, who during the indoor walking protocol walked between 0.07-0.15m/s pre intervention and 0.17-0.18m/s post intervention and are classified as having severe gait impairments as a result of stroke and causing them to be outliers in this sample. However, this rehabilitation programme for the two slowest walkers was overall successful in improving walking speed post-intervention.

Furthermore, though the role of assistive devices were not investigated as part of this study, it should be noted that three of the twelve participants who walked between 0.47-1.45m/s pre intervention and 0.52-1.42m/s post intervention, and two of the twelve participants who walked between 0.07-0.15m/s pre intervention and 0.17-0.18m/s post intervention wore AFOs and/ or used walking canes for increased support when walking during participation in the study. This was to replicate conditions of daily living and to ensure comfort and safety of the participant.

When comparing the indoor and outdoor environments used for this study, self-selected walking speed did not differ excessively between the two, with only a 2% difference between the indoor and outdoor walking protocols post-intervention. It can be predicted that the overall slower walking speed for the outdoor-walking protocol could be due to a number of psychological factors such as confidence and perceived risk of falling, which could be perceived as a barrier for the individual to participate in outdoor-walking. The faster walking speeds reported for the indoor walking protocol may be due to the perceived increased safety of the indoor environment (e.g. flat and even surfaces, increased availability for support) when compared to uneven terrain and non-linear nature of the outdoor environment. A slower self-selected walking speed overall is normally due to a combination of spatial-temporal abnormalities commonly seen post-stroke, such as reduced stride length, step length (Allen et al., 2011; Awad et al., 2015) and increased stride width (Chen et al., 2005;

Jarvis et al., 2019). Despite no significant reduction seen in stride width post-intervention, the reported stride width was similar to findings in previous gait studies in stroke (Chen et al., 2005; Chow and Stokic, 2019; Jarvis et al., 2019). Comparing with previous aforementioned gait studies, almost all participants in this study walked with a wider stride and could be a result of a number of reasons. One reason may be a functional compensatory mechanism adopted by the individual in order to improve lateral stability through increasing the base of support. It may also be an adaptation that occurs in response to altered kinematics discussed later in this discussion. However, as walking involves transitions from single to double stance, it causes increased medio-lateral sway at the trunk towards the non-paretic limb (qualitative observation by the researcher) and a wider stride may be needed to ensure that the centre of mass remains within the base of support. One explanation why walking speed increased post-intervention may be due to the increase of 21% in initial double limb support of the paretic limb, allowing the individual to stabilise their position on the paretic limb before commencing swing phase of the contralateral limb. Adopting a wider stride has been reported to be the cause of a reduction in step length and overall stride length but also increasing energy cost of walking (Chen et al., 2005a; Chow and Stokic, 2019; Jarvis et al., 2019).

Changes were seen in stride length that could be associated with the changes seen in step length for both the paretic and non-paretic lower limb post completion of the outdoor-walking programme and could be as a result of needing to adapt to the requirements of the outdoor environments, such as needing to step over obstacles (e.g. rocks, roots, transition between different terrains). Step length of the paretic lower limb was greater than step length seen in the contralateral limb. An important component of causing step length is forward propulsion, which is generated through the anterior-posterior ground reaction force of the stance leg, this facilitates forward progression of the trunk while the contralateral leg is in the swing phase (Balasubramanian et al., 2010; Allen et al., 2011; Roerdink and Beek, 2011). With insufficient propulsion during paretic leg stance, this can cause shorter non-paretic step length. This is evident in the marginal differences seen in this study, before and after completion of the outdoor-walking programme. The improvements observed resulting in greater step and stride length can be due to increased A2 ankle joint power (Winter, 2009) generation discussed further in this discussion.

Interestingly, participants in this study walked a marginally greater distance during the outdoor walking protocols (PRE= 98m, POST=114.16m) compared to indoors (PRE= 97.5m, POST=111.66m). A plausible explanation for this result in walking distance could be due to the large range in reported walking distances of the cohort and gives reason why 95% confidence intervals are reported for this study. However, because walking distance during a 3-minute walking protocol in an outdoor environment has not been recorded in other relevant studies, direct comparisons for outdoor walking distance were not possible. The exception to when outdoor-walking distance was reported was during a study by Kim et al (2014), however it is not comparable due to different protocols being used.

5.3.2 Energy cost of young adults who have had a stroke

Efficiency of walking is a common parameter to assess the effects of stroke on physical and functional ability (Platts et al., 2006; Kramer et al., 2016; Jarvis et al., 2019). In this study, the physiological cost index by Macgregor (1981) was utilised to measure energy cost of walking during both the indoor and outdoor 3-minute walking protocols. Despite no statistically significant ($p>0.05$) changes were observed between interventions for energy cost for either indoor or outdoor walking protocols, it should be of interest to note that a reduction in the mean variable for both indoor and outdoor walking protocols was seen post completion of the outdoor-walking rehabilitation programme, with similar findings been reported by Olney et al (2006) after completion of a 10-week exercise programme (unsupervised protocol). However, the PCI is not as robust in measuring energy cost compared to reporting metabolic cost via direct measurements of breath by breath analysis. Reasoning behind the increased efficiency of walking after completion of the outdoor-walking rehabilitation programme could be due to participants using more energy during the outdoor-walking rehabilitation programme sessions, despite perceiving the activity to be easier due to the natural environment that the programme takes place in, compared to exercising in indoor settings (Focht, 2009). If an individual believes and experiences that exercising outdoors feels easier, then this may be a useful mechanism in promoting future green exercise initiatives and rehabilitation for young stroke survivors.

Another reason may be due to improved spatial-temporal parameters such as increased stride and step length and other alterations in walking biomechanics. Strong correlations between walking speed and energy cost for both indoor and outdoor walking protocols were seen and potentially as a result of the programme focusing predominantly on aerobic training. A number of kinematic deviations reported in this study, isolated or combined, could contribute to the increased energy cost of gait in young stroke survivors, due to excessive movements that characterise gait post-stroke. However, improvements in gait via aerobic training seen in this study and the confidence to walk over uneven terrain (discussed in *Chapter Six* of this thesis) could be why energy cost reduced. It could be theorised that with a rehabilitation programme being conducted over a longer duration (e.g. six months, compared with the ten weeks the current study details), and increasing days of delivery, further significant increases in energy cost, walking speed and spatial- temporal parameters could be observed in young stroke survivors.

5.3.3 Joint kinematics and kinetics

Kinematic and kinetic gait deviations at the pelvis, hip, knee and ankle joint have previously been reported in older and mixed adult stroke populations in the sagittal and coronal plane but there is little research regarding gait patterns specifically reporting how young adult stroke survivors walk, aged between 18-65 years. The current study found some kinematic and kinetic gait deviations that were similar to previous literature specific to young stroke populations (Chen et al., 2005a; Stanhope et al., 2014; Jarvis et al., 2022). It is noted that although direct associations between these kinematic and kinetic deviations were not conducted as part of this study, some potential reasons behind such gait deviations are proposed and discussed below.

Numerous changes in the pelvis, hip, knee and ankle kinematics and hip and knee kinetics were found post completion of the outdoor-walking rehabilitation programme. For kinematics, the most significant of changes were seen in the paretic lower limb, in the sagittal plane. These included the pelvis, the hip joint in stance (loading response and terminal stance/pre-swing), knee joint during stance phase and the ankle during stance. In joint kinetics, the most notable changes were seen in hip flexor moment during midstance, peak hip abductor moment, peak hip joint power, peak knee flexor moment (during weight acceptance) and knee joint power of the paretic lower limb. Some of the parameters reported for this study that did not differ were found to have a low retrospective statistical power (between 0.05 and 0.89). therefore, it is viable that a greater sample size would reveal additional differences alongside the ones found in this study.

At the pelvis, reduction in both anterior and posterior tilt post-intervention was observed throughout the gait cycle, suggesting a more neutral position after completion of the outdoor-walking programme. Pre-intervention, the position of the pelvis on the paretic side was posteriorly tilted to facilitate heel strike/ initial contact, before transitioning into anterior tilt for a short amount of time during weight acceptance. This could possibly be due to the reluctance to load weight on to the paretic limb in stance, the pelvis shifts into posterior tilt to facilitate swing phase of the paretic limb in order to augment advancement of the thigh if the hip flexors are weak. As a result of the reluctance to transfer body weight on to the paretic limb, the hip joint is unable to continue to flex after initial contact and therefore is placed into a premature extended position reducing forward propulsion, with peak hip extension happening earlier in the gait cycle compared to the non-paretic limb. This compensatory mechanism therefore restricts knee flexion during weight acceptance in the stance phase. Though the pelvis is still presented in a more increased anterior tilt post-intervention, a more posterior tilt of the paretic limb can be seen in the swing phase, generating similar movement to the contralateral limb with peak hip extension post-intervention was occurring later on in the gait cycle and at a similar time to the non-paretic limb.

Though no significant changes in pelvic obliquity were reported after completion of the outdoor-walking programme, peak upwards movement of the pelvis increased slightly, a pelvic hike adopted to commonly adopted to assist with foot clearance of the swing limb when either the hip or knee flexion is inadequate (Perry et al., 1995). This may be a possible cause due to the reported decrease of 3.49° in peak hip flexion during loading response in the paretic lower limb and peak hip extension being greater by 8.9° during midstance, indicating that the hip is less flexed at this phase of the gait cycle than before the start of the outdoor-walking programme. In the transverse plane, excessive external rotation of the pelvis was seen in the paretic lower limb, alongside reduction of internal rotation after completion of the outdoor-walking programme. Though this improves trailing limb posture of the paretic limb and could be a cause of the increased step length and stride length post-intervention, and walking outdoors facilitating this change due to the constant need to adapt and alter gait patterns through different terrains and gradients the outdoor environment presents. However, this could also be a compensatory mechanism adopted to due to hip flexion contracture and calf muscle weakness during terminal stance.

Peak hip flexion during loading response reduced and peak hip extension at toe-off increased after completion of the outdoor-walking rehabilitation programme compared to prior participating in the programme. Though it is not clear what would cause reduction in hip flexion, the increase in hip extension of the paretic limb at toe-off (less flexed), suggests potential improvement in the mechanics of forward propulsion such as increased ankle power generation at toe-off, but also an increase in hip extension can be associated to increased self-selected walking speed as proposed by Boudarham et al (2013) and others (Olney et al., 1994; Jonkers et al., 2009).

At the knee joint, numerous gait abnormalities were evident in the paretic lower limb pre-intervention. Reduced knee flexion during loading response and greater knee extension during stance and reduced knee flexion during late-swing was found compared to the non-paretic lower limb and post-completion of the outdoor-walking programme. However, as proposed by Chen et al (2005) Knee flexion during loading response in the non-paretic limb tended to be greater than normal due to the exaggerated propulsion of the limb during pre-swing, and therefore unable to compare the paretic against the non-paretic lower limb. The reduced knee flexion during loading response by the paretic lower limb reduces the normal shock-absorbing mechanism and increased demand is placed on to the quadriceps to facilitate this (Perry et al,. 1992). Compared to post-intervention, as a result of reduced knee flexion, the knee of the paretic limb is placed into early extension, again due to weakness in the quadriceps as the muscle cannot sustain a flexed knee. After completion of the outdoor-walking programme, the paretic limb followed a similar position to the contralateral limb, potentially resulting in the increased stride length and step length of both the paretic and non-paretic lower limb, reported in this study.

In agreement with previous studies specific to stroke (Nadeau et al., 2013; Forghany et al., 2014; Roche et al., 2015) this study found in the sagittal plane that the ankle of the paretic lower limb was more plantarflexed pre-intervention throughout the duration of the gait cycle, compared to the contralateral limb. Dorsiflexion was also seen to be limited during the swing phase (a gait abnormality known as drop foot) for the paretic lower limb, whereas the ankle on the non-affected side stays in a varied state of dorsiflexion during swing phase. Keeping the ankle of the non-paretic lower limb in a dorsiflexed position during swing may be an adopted compensatory strategy to be able to be ready to place the foot onto the ground early, in order to transfer weight off the paretic limb, and may also be a reason why step length of the non-paretic limb is shorter compared to the paretic limb. However, after completion of the outdoor-walking rehabilitation programme, definitive changes in specific phases of the gait cycle for both the paretic and non-paretic lower limbs can be seen, with increased ankle plantarflexion at initial contact, increased dorsiflexion during midstance and increased ankle plantarflexion at toe-off. The improvements seen post-rehabilitation may be as a result of improved hip flexion and extension and hip and ankle power generation of the paretic lower limb (Jonkers et al., 2009), but also due to the nature of the outdoor-walking rehabilitation programme, as participants were required to make a conscious effort to facilitate toe clearance on uneven terrain (e.g. over roots, rocks, loose ground). The largest power generation when walking is at the ankle. In this study, power generation at both the hip and ankle at toe-off improved substantially, corresponding with the increase in peak hip extension and ankle plantarflexion at toe-off, improving forward propulsion post-intervention, which may have attributed to the increased walking speed in both indoor and outdoor walking protocols and increased step and stride length due to increased hip and ankle power generation.

5.3.4 Changes in the non-paretic lower limb

This study further observed changes in spatial temporal and kinematic parameters of the non-paretic lower limb, as discussed in this chapter, could be due to the rehabilitation programme focusing training both the paretic and non-paretic lower limb, defined as bilateral training. This was achieved by incorporating aerobic (outdoor-walking) and resistance exercise (home exercise programme involving bilateral and unilateral exercises) into the rehabilitation programme.

In this study, stride length was reported as one of the improvements, potentially as a result of bilateral training, a similar finding in previous research (Jeon and Hwang, 2018; Harjpal et al., 2022). Increased step length in the non-paretic lower limb post-intervention was also reported, suggesting that participants in this study were willing to bear more weight on the paretic lower limb to encourage a more symmetrical gait pattern. It can be theorised that lower limb muscle strength had improved, however muscle strength and muscle activation were not assessed in this study and have therefore been identified as recommendations for future research. Strength impairment in the non-paretic lower limb was reported by Bohannon et al (1995) when stroke survivors had muscle strength impairment, which was more proximally than distally for both upper and lower limbs. These correlations provide support for the inclusion of bilateral training activities in the management of post-stroke survivors.

Harjpal et al (2022) suggests that emphasis should be placed on training both lower limbs through bilateral training to enhance the recovery process, as many physiotherapists or healthcare professionals often place focus on rehabilitating the paretic lower limb, resulting in the non-paretic lower limb becoming unused and causing deconditioning effects, such as disuse atrophy (Jeon and Hwang, 2018).

5.4 Limitations: Walking performance

Although this study shows promising results that supports the use of an outdoor-walking rehabilitation programme to improve walking performance (e.g. walking speed, walking distance, walking efficiency and joint kinematics and kinetics) for young stroke survivors, inevitably, there are some key limitations that should be considered and addressed.

Firstly, one of the key limitations that should be addressed is the absence of a control group to make comparisons. This study was originally planned to be a randomised controlled clinical trial, whereby the intervention group would be given the outdoor-walking rehabilitation programme and home exercises in the form of eight targeted light stretches and eight targeted resistance exercises, and the control group given eight targeted light stretches and eight targeted resistance exercises only and continue with routine care. However, as previously detailed in *Chapter Four: General Methodology* (section 4.2: Study Design) as a result of the COVID-19 pandemic, recruitment for the study was made more difficult. Therefore, ending recruitment with a small sample size (n=12) and one intervention group, thus the study evolved into a case controlled study.

Secondly, due to increased risk COVID-19 posed to vulnerable groups, the Physiological cost index was used instead of the 'gold standard' breath by breath analysis that measures metabolic cost. However, this potentially makes the study easier to replicate due to not needing to use further expensive equipment to measure energy cost- this is all dependent on what is being measure (e.g. metabolic cost, energy expenditure, oxygen consumption). PCI is a simple clinical tool that physiotherapists can use to ascertain a stroke patients energy cost in relation to their walking speed and heart rate.

A third limitation to this study is the feasibility of translating the outdoor-walking rehabilitation programme within different organisational settings in the future. This study was successfully conducted as part of a funded academic research project, however, in order for a programme of this calibre to be implemented within healthcare organisations such as the NHS, changes to the programme design such as a non-residential programme, would be required for time and cost saving purposes. Moreover, changes such as a non-residential programme may have implications for reducing frequency and intensity of the walking activities, but also potential reduction seen in group support and socialisation between participants. Future studies and programmes need to ensure they have similar impact as the outcomes reported from the residential outdoor-walking rehabilitation programme examined within this thesis.

A final limitation of this research project highlights that no follow-up to re-assess walking speed was conducted. This has implications for the potential training effects that occurred during participation of the outdoor-walking rehabilitation programme and unfortunately there is no way to know whether these training effects remained or reduced over time. As part of this study, incorporating a form of long-term follow-up of the participants' walking performance would have been useful, especially because seven out of the twelve participants that completed the outdoor-walking rehabilitation programme reportedly continue to take part in outdoor-walking at least once a week. However, a long-term follow-up was not feasible due to the time frame of this research project, it would be valuable if future work could seek to explore this.

5.5 Conclusions

To conclude, this is the first study with demonstrable results, of the positive effects of a 10-week outdoor-walking rehabilitation programme of young adults who have had a stroke. Improvements from this study included walking speed, energy cost and a number of kinematic and kinetic parameters such as reduced peak anterior and posterior pelvic tilt of both the paretic and non-paretic lower limb, increased peak external pelvic rotation of the paretic lower limb, reduced peak hip flexion (during loading response) and peak hip extension of both the paretic and non-paretic lower limb, with increase in hip range of motion in the sagittal plane, increase in peak knee flexion (during loading response) in the paretic lower limb and significant increase in peak plantarflexion of the ankle during the stance phase of the gait cycle and peak A2 ankle power generation of the ankle.

Chapter Six

6. The influence of an outdoor-walking rehabilitation programme on quality of life of young adults who have had a stroke

6.1 Results

6.1.1 Participant Characteristics

Participant characteristics have already been described in *Chapter Five* of this thesis.

6.1.2 Stroke Aphasia Quality of Life Scale

Total SAQOL score were greater post-intervention (POST, 3.21 (2.76 – 3.66)) than pre-intervention (PRE, 2.76 (2.22 – 3.31)) (p=0.024). The physical domain of the SAQOL score increased from 2.53 (1.79 – 3.26) to 3.05 (2.31 – 3.80) (p=0.042) post-intervention. The communication domain of the SAQOL score increased from 3.78 (3.27 – 4.29) to 4.14 (3.66 – 4.62) (p=0.027) post-intervention. The energy domain of the SAQOL score increased from 2.06 (1.53 – 2.58) to 2.66 (2.14 – 3.18) (p=0.007) post-intervention. The psychosocial domain of the SAQOL was found to not be significant.

Table 6.1: Mean ± standard deviation, range and 95% CI for total SAQOL score and physical, psychosocial, communication and energy domain scores pre and post intervention for young adults who have had a stroke. *represents a significant difference between pre and post interventions.

Domain	PRE Mean ± SD (Range)	PRE 95% CI	POST Mean ± SD (Range)	POST 95% CI	*P*
Physical	2.53 ± 1.15 (1.0 – 4.8)	1.79 – 3.26	3.05 ± 1.17 (1.44 – 4.81)	2.31 – 3.80	0.042*
Psychosocial	2.70 ± 0.87 (1.58 – 4.0)	2.15 – 3.26	3.07 ± 0.67 (1.92 – 4.17)	2.64 – 3.49	0.051
Communication	3.78 ± 0.79 (1.86 – 4.86)	3.27 – 4.29	4.14 ± 0.75 (2.43 – 5.0)	3.66 – 4.62	0.027*
Energy	2.06 ± 0.82 (1.0 – 3.5)	1.53 – 2.58	2.66 ± 0.81 (1.5 – 4.25)	2.14 – 3.18	0.007*
Total SAQOL score	2.76 ± 0.85 (1.49 – 4.44)	2.22 – 3.31	3.21 ± 0.70 (2.31 – 4.49)	2.76 – 3.66	0.024*

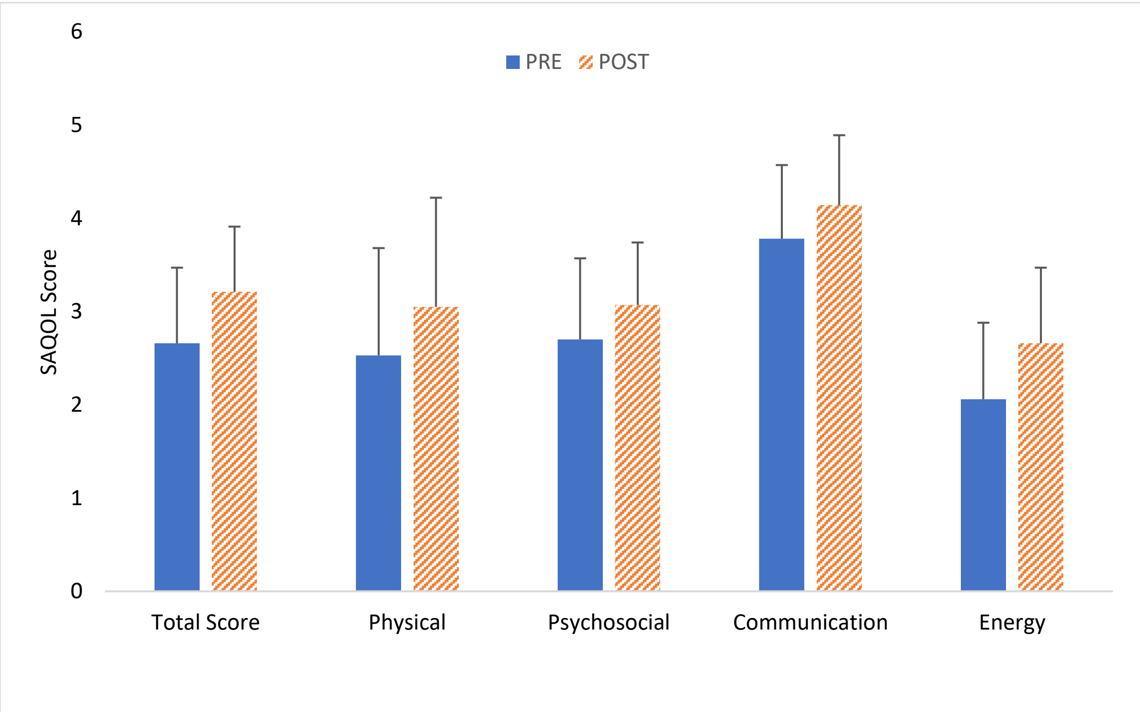


Figure 6.1: Total score and physical, psychosocial, communication and energy domain scores pre and post intervention for young adults who have had a stroke. Bars represent the mean, error bars represent standard deviation.

6.1.3 Confidence after Stroke Measure

Total CaSM score was greater post-intervention (pre-intervention, 48.25 (39.4 – 57.09) post-intervention, 51 (44.03 – 57.96) (*p*=0.024). The self-confidence domain of the CaSM score increased from 9.75 (5.11 – 14.39) to 11.06 (7.31 – 15.01) (*p*=0.140) post-intervention. The social confidence domain of the CaSM score increased from 3.78 (17.4 – 24.76) to 22 (18.82 – 25.17) (*p*=0.204) post-intervention. The positive attitude domain of the CaSM score increased from 17.42 (15.02 – 19.82) to 17.83 (16.16 – 19.49) (*p*=0.747) post-intervention.

Table 6.2: Mean ± standard deviation, range and 95% CI for total CaSM score and self-confidence, positive attitude and social confidence domain scores pre and post intervention for young adults who have had a stroke.

Domain	**PRE**		**POST**		***P***
	Mean ± SD (Range)	**95% CI**	**Mean ± SD (Range)**	**95% CI**	
Self-Confidence	9.75 ± 7.3 (90 – 27)	5.11 – 14.39	11.16 ± 6.05 (4 – 24)	7.31 – 15.01	0.140
Positive Attitude	17.42 ± 3.77 (10 – 24)	15.02 – 19.82	17.83 ± 2.62 (13 – 21)	16.16 – 19.49	0.747
Social Confidence	21.08 ± 5.79 (11 – 29)	17.4 – 24.76	22 ± 4.99 (11 – 28)	18.82 – 25.17	0.204
Total confidence score	48.25 ± 13.92 (25 – 72)	39.4 – 57.09	51 ± 10.96 (33 – 70)	44.03 – 57.96	0.155

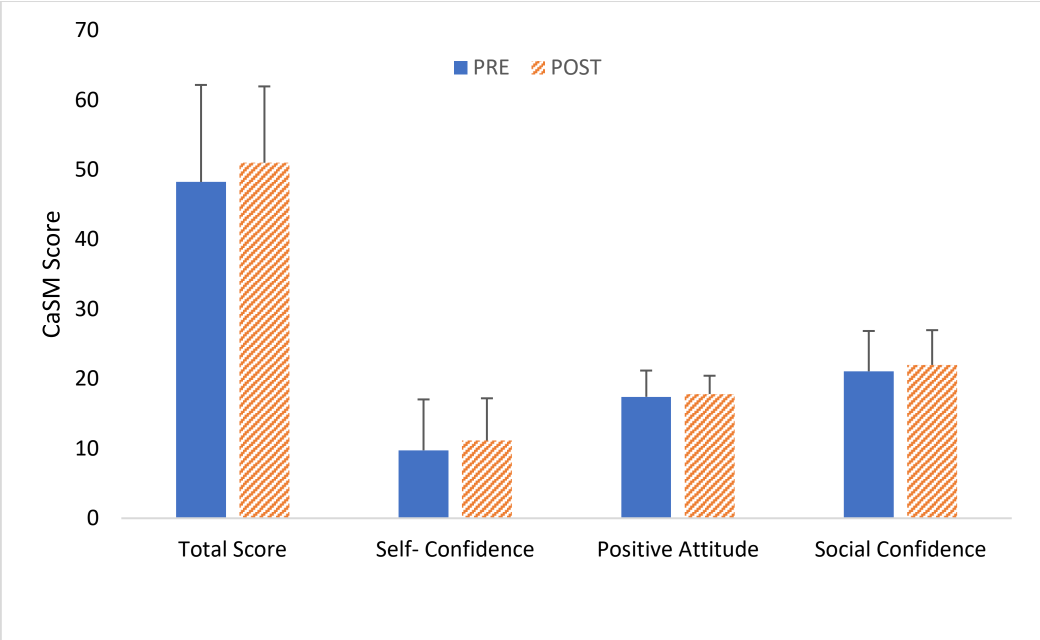


Figure 6.2: Total score and self-confidence, positive attitude and social confidence domain scores pre and post intervention for young adults who have had a stroke. Bars represent the mean, error bars represent standard deviation.

6.2.4 Nature-Relatedness Scale (NR)

Total Nature-Relatedness (NR) score was greater post-intervention (pre-intervention, 3.90 (3.52 – 4.27) post-intervention, 3.99 (3.66 – 4.32) (*p*=0.380). The Experience domain of the NR score increased from 4.03 (3.57 – 4.49) to 4.09 (3.59 – 4.59) (*p*=0.102) post-intervention. The Perspective domain of the NR score increased from 4.03 (3.57 – 4.49) to 4.09 (3.59 – 4.59) (*p*=0.452) post-intervention. The Self domain of the NR score increased from 3.98 (3.5 – 4.45) to 4.00 (3.53 – 4.46) (*p*=0.881) post-intervention.

Table 6.3: Mean ± standard deviation, 95% CI and range for total NR score and NR-self, NR-perspective and NR-experience domain scores pre and post intervention for young adults who have had a stroke.

Domain	PRE		POST		*P*
	Mean ± SD (Range)	**95% CI**	**Mean ± SD (Range)**	**95% CI**	
NR-Self	3.98 ± 0.74 (2.75 – 4.88)	3.5 – 4.45	4.00 ± 0.72 (2.75 – 5.0)	3.53 – 4.46	0.881
NR-Perspective	4.03 ± 0.72 (2.29 – 5.0)	3.57 – 4.49	4.09 ± 0.79 (3.0 – 5.0)	3.59 – 4.59	0.452
NR-Experience	3.69 ± 0.4 (3.17 – 4.33)	3.43 – 3.94	3.86 ± 0.38 (3.17 – 4.5)	3.61 – 4.10	0.102
Total NR score	3.90 ± 0.59 (2.81 – 4.57)	3.52 – 4.27	3.99 ± 0.52 (3.33 – 4.71)	3.66 – 4.32	0.380

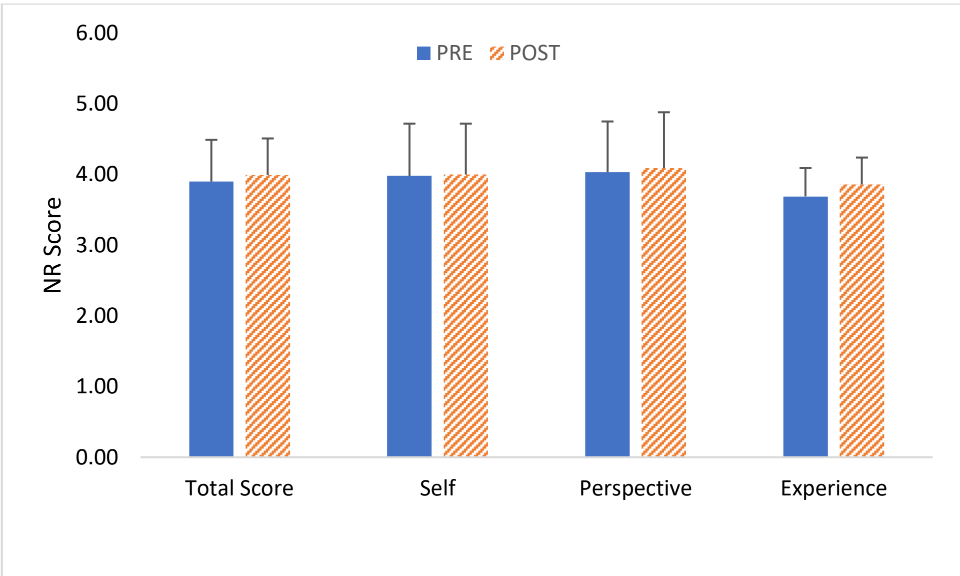


Figure 6.3: Total score and self, perspective and experience domain scores pre and post intervention for young adults who have had a stroke. Bars represent the mean, error bars represent standard deviation.

6.2.5 Correlation between Quality of Life, Confidence and Nature-relatedness

Pre-intervention, the correlation between QoL and confidence resulted in a small positive relationship. Post-intervention, correlation analysis reported that the positive relationship between QoL and confidence was greater. Poor relationship between QoL and Nature-relatedness was observed pre-intervention. Post-intervention, correlation between QoL and nature-relatedness resulted in a negative relationship being observed.

Table 6.4: Correlation analysis using Pearson's Rank Correlation, between QoL and confidence and QoL and nature-relatedness pre and post intervention

	PRE	POST
QoL and Confidence	*R* = 0.372 (0.233)	*R* = 0.512 (0.089)
QoL and Nature-Relatedness	*R* = 0.093 (0.774)	*R* = -0.567 (0.055)

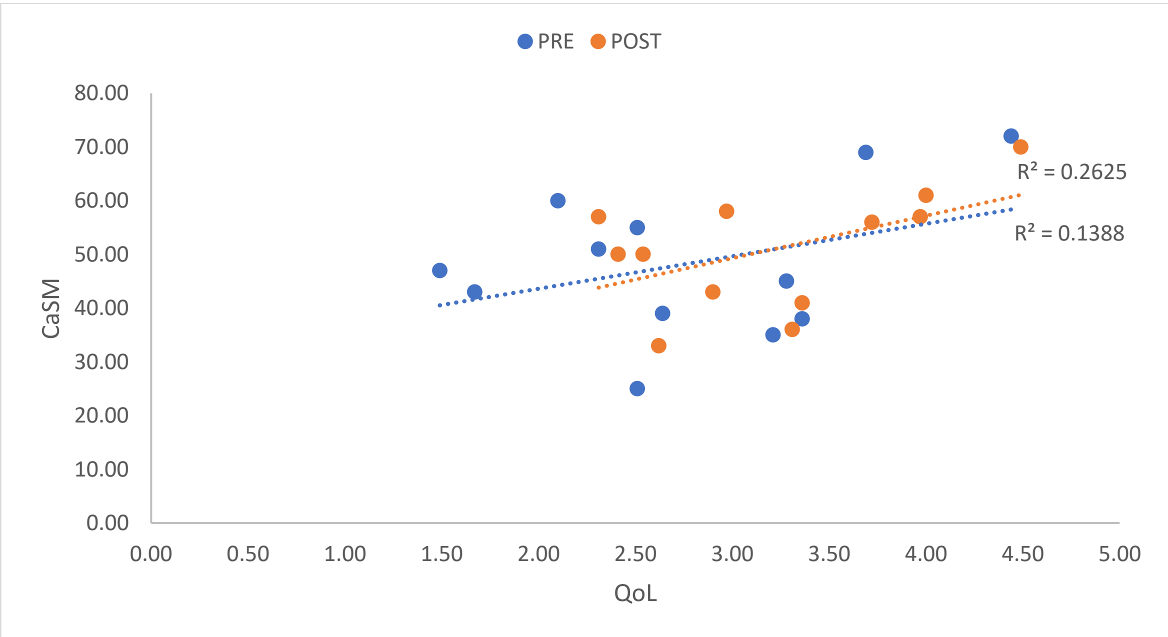


Figure 6.4: Scatter graph showing correlation between QoL total score and CaSM total score, pre and post intervention. Blue circular data plots with blue dashed linear trendline represents pre-intervention, orange triangular plots with orange dashed trendline represents post-intervention. R^2 values for linear trendlines are reported.

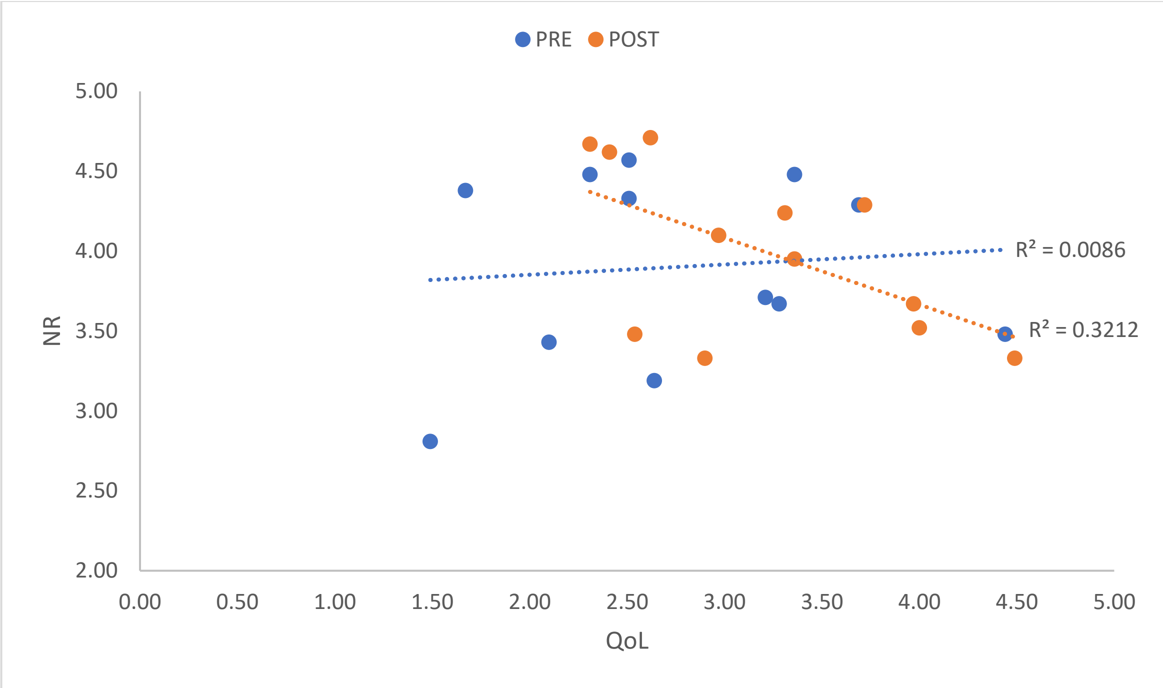


Figure 6.5: Scatter graph showing correlation between QoL total score and CaSM total score, pre and post intervention. Blue circular data plots with blue dashed linear trendline represents pre-intervention, orange triangular plots with orange dashed trendline represents post-intervention. R^2 values for linear trendlines are reported.

6.2.6 Three Aims and Difficulties

Table 6.5: Key aims pre and post-intervention of young adult stroke survivors. Key themes and sub-themes within those are reported with an example quote from a young stroke survivor

Intervention	Key Theme	Sub-themes	Example quote
PRE Aims	Walk (n=6, 50%)	Walk further Outdoor-walking	*"I would like to be able to walk further"* *"To be able to walk outdoors to meet family and friends*
	Physical Ability (n=5, 42%)	Improve function	*"To increase physical strength"* *"To be able to walk up the stairs"*
	ADL (n=4, 33%)	Back to normality	*"To feel more confident doing everyday tasks"* *"Get back to doing odd jobs around the house, painting…"*
	Driving (n=4, 33%)	Driving	*"Drive a manual car"* *"Hope to be able to drive again"*
	Confidence (n=5, 42%)	Confidence when walking	*"To feel more confident when walking alone outdoors"* *"To improve my walking confidence*
	Fatigue (n=2, 17%)		*"I would like to not feel as drained as I do now, even after a small amount of activity"*
POST Aims	Mental Health (n=2, 17%)	Positive attitude	*"To be the best I can"* *"to get to a happy place"* *"To improve all the time"*
	Walk (n=8, 67%)	Walking distance Walking speed Outdoor-walking	*"To walk 15 miles outdoors"* *"Walking further distances"* *"To walk faster!"* *"To climb local hills and mountains"* *To go on more regular walks around our beautiful country"*
	Independence (n=3, 25%)	Walking independence	*"Walking more independently and confidently"* *"To walk without a stick"*

Prior to taking part in the outdoor-walking rehabilitation programme, "walk" was a key aim of n=6 (50%) of young adults who have had a stroke. This was analysed into two sub-themes of wanting to "walk further" and "outdoor-walking". 42% (n=5) of young stroke survivors expressed that a key aim was to improve "physical ability", with a sub-theme of "improve function" by increasing physical strength or to be able to walk up the stairs. The key aim "ADL" (activities of daily living) was expressed by 33% (n=4) of participants, by being able to return to doing odd jobs around the house. 42% (n=5) of participants wanted to improve confidence, specifically confidence when walking. 17% (n=2) of participants expressed that their aim was to not feel as fatigued on a regular basis.

Post outdoor-walking rehabilitation programme, 67% (n=8) wanted to improve their walking ability, by being able to either increase their walking speed, walking distance and taking part in more walks in the outdoor environment. A key aim of mental health, with a sub-theme of "positive attitude" was expressed 17% (n=2) of participants. 25% (n=3) of participants said they wanted to improve walking independence.

Table 6.6: Key Difficulties pre and post-intervention of young adult stroke survivors. Key themes and sub-themes within those are reported with an example quote from a young stroke survivor

Intervention	Key Theme	Sub-themes	Example quote
PRE Difficulties	Fatigue (n=4, 33%)	Physical fatigue	*"Standing for a long time"* *"Having the energy to do more- only good in the morning"*
	Limb weakness (n=3, 25%)		*"Not enough strength on left side to be able to walk unaided"*
	ADL (n=4, 33%)	Confidence	*"Lack of confidence undertaking day to day activities"*
	Walk (n=6, 50%)	Outdoor environment Walking and tiredness	*"Walking over uneven ground and in windy conditions"* *"Cannot go far without feeling extremely tired"*
	Cognition (n=3, 25%)	Concentration Memory	*"To have more patience at times"* *"Having to consciously concentrate on skills that prior to my stroke were automatic"*
POST Difficulties	Support (n=2, 17%)		*"Unable to support my family"* *"Being a burden"* *"Relying on others for help"*
	Mental health (n=3, 25%)	Frustration	*"Getting frustrated when things don't go well"*
	Walk (n=4, 33%)	Outdoor environment Fatigue	*"Walking on uneven ground"* *"The severity of slopes and the terrain"*

Prior to taking part in the outdoor-walking rehabilitation programme, a key difficulty mentioned by 33% (n=4) of participants was "fatigue", as a difficulty post-stroke, and affecting energy levels with one participant stating they are *'only good in the mornings'*. 25% (n=3) of participants reported "limb weakness" as a difficulty post-stroke. 33% (n=4) of participants reported "ADL" to be a difficulty, specifically having the confidence to undertake day to day activities post-stroke. 50% (n=6) participants reported walking to be a key difficulty, with sub-themes including the "outdoor environment" and "walking and tiredness". 25% (n=3) of participants reported a key difficulty of "cognition" such as concentration and memory.

Post outdoor-walking rehabilitation programme, 17% (n=2) of participants reported a key difficulty of "support", specifically by not being able to support themselves and feeling a like a burden on family members. 25% (n=3) of participants reported a key difficulty of "mental health" and more specifically frustration due to post-stroke difficulties. 33% (n=4) of participants reported "walk" to be a key difficulty.

6.2.7 Pre and Post-Rehabilitation Questionnaires

All participants (12/12) responded to both the pre and post-rehabilitation questionnaires, which asked the four same questions:

1. Do you participate in physical activity?
2. How confident do you feel to walk outdoors?
3. How do activities of daily living affect you?
4. Do you experience any difficulties when outdoor walking?

Responses from pre-rehabilitation and post-rehabilitation are compared for each question in this section.

6.2.7.1 Question 1: Do you participate in outdoor physical activity?

Prior to taking part in the outdoor-walking rehabilitation programme, two out of twelve participants reported that they did not take part in any outdoor physical activity. One of which reported that it was due to *"left side weakness has affected my ability"*. Six out of twelve participants reported that they regularly took part in a form of walking activity, either in natural outdoor environments (4/12) or walking the dog specifically (2/12). Three out of twelve participants also reported that they take part in group-based activity, with one participant stating *"I am part of a stroke group set up by Llandough Hospital, for walks around Cosmeston Lake, we meet once a week"* for the social participation. Post-rehabilitation, all participants reported to completing some form of outdoor physical activity, with eight out of twelve participants reporting that they walk regularly (e.g. Once per week). Two out of twelve participants also reported that they now take part in the gardening as a form of ADL and outdoor physical activity.

6.2.7.2 Question 2: How confident do you feel to walk outdoors?

Pre-rehabilitation, eleven out of twelve participants reported that they were 'fairly' confident to walk outdoors, though there were several factors that determined their level of confidence. Quality of the terrain underfoot (e.g. the path surface) and having enough time to complete a walk were the main determinants. Balance when walking outdoors was reported by two out of twelve participants, seemed to reduce confidence. Another two out of twelve participants reported that they confident in familiar areas *"… but not in strange and new place".* As a result of taking part in the outdoor-walking rehabilitation programme, all participants reported that they felt much more confident to walk outdoors, with one participant stating *"… this course has helped to build up confidence".*

6.2.7.3 Question 3: How do activities of daily living affect you?

Pre-rehabilitation, three out of twelve participants reported that they are dependent on others, with one participant stating *"I rely totally on support for everyday life, which is my wife and son who live with me"*. Two out of twelve participants reported that fatigue affects activities of daily living. However, post-rehabilitation, four out of twelve participants (an increase of two from pre-rehabilitation results) state that fatigue is still having an effect on activities of daily living. Three out of twelve participants report clearly that they now have independence to complete activities of daily living.

6.2.7.4 Question 4: Do you experience any difficulties when walking outdoors?

Pre-rehabilitation, three out of twelve participants reported that balance was the main cause of difficulty for walking in outdoor spaces, as a result of having a stroke. Three out of twelve participants also reported fatigue to be another difficulty for when walking outdoors. Post-rehabilitation, responses changed from internal difficulties (e.g. balance and fatigue) to more external difficulties that are a part of the surrounding environment. Three out of twelve participants reported outdoor accessibility to be a difficulty when participating in outdoor-walking, such as *"Stiles make life difficult"* and another participant stating *"I find it makes you select where you go because of accessibility".* Two out of twelve participants reported that a lack of social participation and inclusion to be a difficulty for outdoor-walking, with wanting *"company to go on long walks"* and *"I just don't walk as fast as the others"*.

6.2.9 Three-Month Follow-up: Participant Testimonies

Participants were asked three-months post completion of the outdoor-walking rehabilitation programme to express their thoughts and perspectives regarding their time taking part in the outdoor-walking rehabilitation programme. Such as, how it has allowed them to improve their confidence and how the group-based design of the programme helped with their rehabilitation. A total of seven participants out of the twelve, who took part in the outdoor-walking rehabilitation programme returned responses to the researcher. From these responses, two overarching key themes were identified; 1. Camaraderie in the outdoors, 2. Building of self-confidence and determination. These themes will be discussed as separate sections in this chapter.

6.2.9.1 Camaraderie in the Outdoors

The largest key theme highlighted from the participant testimonies was "Camaraderie" that was built between the participant cohort. Camaraderie was voiced by all participants to be an important part of the success of the outdoor-walking rehabilitation programme. The first sub-theme identified was "social interaction with others". Participants (5/7) expressed that being able to converse freely and openly with other stroke survivors, both on walks and during more social/ relaxing periods of the residential programme.

The second sub-theme identified was "the willingness to share experiences". Participants (4/7) highlighted that being able to gain an understanding of the varied impacts of strokes and how others had adapted their daily lives post-stroke was highly beneficial part of the outdoor-walking rehabilitation programme.

"I really enjoyed the experience of getting to know other people with the same condition as myself, getting help and tips to build up my confidence, and making friends forever."

The third sub-theme related to the key theme of "camaraderie" is "lasting group support". Participants (4/7) expressed that they felt like 'part of a team' and that they have been able to 'make friends forever' through the outdoor-walking rehabilitation programme. Two participants (%) highlighted that a WhatsApp group, set up by the researcher and participants, enabled all participants to be in contact with each other, offering the ability to help each other over other technologies.

6.2.9.2 Building of Self Confidence and Determination

In the testimonies received by the researcher, confidence was highlighted to be a main theme throughout. The first sub-theme identified was "the restoration of confidence". Participants (3/7) highlighted that the role the outdoor-walking rehabilitation programme played in their stroke recovery increased their confidence through the improvement in walking performance.

"Being so close to the Brecon Beacons national park and Wye valley it provided an abundance of varied walks and terrains/ gradients to re familiarise-stroke survivors with varying conditions for walking and re-testing balance abilities and quickly re-establishing walking confidence."

Participants (4/7) also felt that as their walking performance improved, they have been able to reduce the reliance on walking aids (e.g. walking cane), increase walking distance (of their own volition) and having a sense of achievement in any activity they since took part in post-completion of the study, no matter how small.

The second sub-theme identified was "confident to be independent", this was seen in all testimonies from participants (7/7). Participants expressed that the outdoor-walking rehabilitation programme helped to improve fitness levels, allowing them to feel more able to be out and independent. One participant highlighted that the programme *"gave me tremendous amount of confidence, as for the 8 months previous I was at home with my wife for 24/7 and this course gave me the opportunity to be able to be independent for those 3 days, which really built up my confidence"*. Another participant expressed that they are now *"now able to confidently leave the house alone and go walking on various terrain types without any fear of falling over"*.

The third sub-theme identified was "change in attitude and determination" as participants (3/7) expressed that taking part in the outdoor-walking rehabilitation programme gave them *"the push I needed"* to regain a life they had previously before having the stroke.

6.3 Discussion

This case-controlled study aimed to assess whether quality of life and confidence of young adults who have had a stroke can be improved through participation of an outdoor-walking rehabilitation programme. Although previous literature has assessed whether taking part in physical activity in outdoor environments can help to improve mental health and wellbeing, this study is the first of its kind to demonstrate a novel approach to stroke rehabilitation. This study placed emphasis on understanding the needs of young stroke survivors and the role of natural outdoor environments can have to improve their recovery. All traditional stroke rehabilitation takes place exclusively indoors and is not specific to the needs and priorities of an increasing younger stroke population (Rudd et al., 2017).

The key findings from this study included improved self-reported quality of life, with additional improvements seen in the quality of life domains (physical, communication and energy) and increase in self-reported confidence and nature-relatedness. Key findings from 'Three Aims and Three Difficulties' included less of an emphasis on confidence post-intervention and more on increasing walking distance as an aim. Key findings from the post-rehabilitation questionnaire and the 3-month follow-up (participant testimonies) reported that the rehabilitation programme helped substantially with confidence, independence and social networking (e.g. group support and camaraderie). These will be explained further in this chapter.

6.3.1 Quality of life

It is well established from previous literature (Chen and Rimmer, 2011; Pang et al., 2013; Saunders et al., 2020; Ali et al., 2021) that self-reported health-related QoL increases after participation of mixed methods design exercise programmes for the older stroke population, with little research specific to young stroke survivors (de Bruijn et al., 2015; Saunders et al., 2020). However, this is the first time that an outdoor-walking rehabilitation programme has been used as a form of stroke rehabilitation that is specific for young adults. As to be expected, total QOL score and domain scores were low pre-intervention and relatively similar findings were seen in other studies (Naess and Nyland, 2013; van Mierlo et al., 2014) who report that quality of life is worse post-stroke compared to prior to having a stroke. This is as a result of physical and psychological barriers that are not realised until stroke survivors return home and resume their social routines and activities of daily living (Daniel et al., 2009). However, after completion of the outdoor-walking rehabilitation programme, mean scores for the total QoL score and the domains presented in the SAQOL (physical, psychosocial, communication and energy) significantly improved. It can be predicted that participating in the outdoor-walking rehabilitation programme elucidated changes in QoL because of increased enjoyment and positive engagement of taking part in exercise in natural outdoor environments. This study was also group-based, participants were able to form social connections with like-minded individuals. The physical and energy domains of the QoL scale were found to be the lowest scoring domains, which is also evident in previous studies (Ahlsiö et al., 1984; Niemi et al., 1988), for both pre and post completion of the outdoor-walking rehabilitation programme, displaying that the young stroke survivors who took part in this study to be moderately impaired in physical function and ability. However, the scores for these domains did marginally improve post intervention, potentially due to the participants taking part in an activity they once thought they were unable to access and enjoy post-stroke.

Pre and post completion of the rehabilitation programme, physical impairments due to stroke as a cause of reduced QoL, was evident in the qualitative questionnaire assessing “Aims and Difficulties” of young stroke survivors. Activities that required physical function such as walking, activities of daily living and driving, were reported as both aims and difficulties. Pre-rehabilitation, improving physical function and walking were key aims reported by 50% of participants, wanting to be able to walk further and being able to participate in social activities with family and friends when walking outdoors. Post-stroke, walking ability (including walking speed and distance) is often affected most and reduced walking ability is subsequently detrimental to all aspects of a young stroke survivor's day to day activities, such as returning to employment, social activities and independence, as previously reported in other studies (Daniel et al., 2009; Jarvis et al., 2019). This is further highlighted in other aims reported by the participants in this study as 33% of participants reported wanting to get back to normality and to feel more confident doing everyday tasks. Daniel et al (2009) suggested this may be because young stroke survivors do no want to feel like a burden to their family.

Post-rehabilitation, it was interesting to see that walking was a key aim, reported by 67% of participants, an increase of 17% from pre-rehabilitation. Wanting to be able to walk further distances, to walk faster and to walk in the local outdoor environments were common statements from participants. Post- rehabilitation, the increased emphasis of wanting to improve walking performance (e.g. walking speed and distance) may be a result of taking part in the outdoor-walking rehabilitation programme. Walking was the main form of physical activity and may have encouraged behaviour change or attitudes to walking outdoors may have become more positive, with studies suggesting that green exercise can increase intention for future participation (Focht, 2009; Thompson Coon et al., 2011). Despite the study taking place for a duration of ten weeks, it can be argued that this may not have been enough time for change in behaviour to develop and this cannot be assessed due to lack of a follow-up period.

Stroke is the main cause of many difficulties that young stroke survivors face on a daily basis. The Aims and Difficulties questionnaire provided insight into these difficulties. Pre-rehabilitation, the key difficulty was walking, with 50% of the cohort expressing that specifically walking outdoors, such as on uneven ground and in windy conditions can be a barrier to taking part in outdoor-walking as a physical activity. Over the duration of the 10-week rehabilitation programme, participants were continually exposed to these difficulties (uneven terrain, changeable weather conditions) the natural outdoor environment presented, with additional support. Though the number of participants reporting walking as a difficulty reduced post completion of the rehabilitation programme, the natural outdoor environment and the hazards (terrain, gradients and uneven ground) this environment presents were still reported as difficulties and are potential barriers to young stroke survivors doing physical activity (such as walking) unsupported.

6.3.2 Confidence

Confidence has been regarded as one of the top research priorities relating to life after stroke (Pollock et al., 2014; Horne et al., 2017). Measuring perceived confidence held by an individual in a given activity could provide an important insight to understanding both successes and lack of progress in rehabilitation (Jones et al., 2008). The confidence after Stroke Measure (CaSM) by Horne et al (2017) was chosen to be used in the present study as it is the first known comprehensive measure of confidence to be developed for use specifically after a stroke. Though results from this measure were not significant in the present study, confidence was a key factor in walking performance during the outdoor-walking rehabilitation programme. There were marginal increases in mean scores for total confidence and the sub-domains of the CaSM, suggesting confidence did improve overall as a result of taking part in the outdoor-walking rehabilitation programme. However, the domain “self-confidence” saw the most difference between pre to post rehabilitation scores and potentially the most important of the domains as improving self-confidence leads to increased QoL by being able to carry out activities of daily living, and an improvement in self-belief (Horne et al., 2017).

Confidence was also expressed as a key aim pre-rehabilitation by 42% of participants, indicating that participants felt confidence is an important factor to improve. Confidence was found to be interlinked with walking performance when participants were asked about their aims and difficulties, as many expressed that they wanted to "improve walking confidence" and "feel more confident when walking alone outdoors". The outdoor-walking rehabilitation programme was able to aid in improving confidence when walking through the exposure of being in the natural environment and challenging terrain. Conducting a rehabilitation programme in this environment also affords the space and freedom for a large group-based activity, which facilitated socialisation and inter-group motivation, compared to the confines of indoor settings. After completion of the outdoor-walking rehabilitation programme, confidence was reported as less of priority aim by the majority of participants. It can be interpreted that participation in the outdoor-walking rehabilitation programme increased confidence through being exposed to natural environments and walking in a more challenging environment.

6.3.3 Nature-Relatedness

There is limited empirical data on the connection between nature-relatedness and mental and physical health and wellbeing (Dean et al., 2018). The Nature-relatedness scale by Nisbet et al (2009) is one of few measures that assesses the individual's subjective connectedness with nature. In the present study, however results were not statistically significant with regards to total nature-relatedness score, or in the three domains (perspective, experience and self) though it should be mentioned that all scores did increase and therefore can be assumed participation in the outdoor-walking rehabilitation programme improved aspects seen in the nature-relatedness scale. The most notable change from pre to post completion of the rehabilitation programme was seen in the domain 'experience', which assessed a person's attraction to and physical familiarity with nature (Tam, 2013; Dean et al., 2018). Taking part in the outdoor-walking rehabilitation programme, participants felt more attracted to and enjoyed the experience of being in the natural outdoor environment, which included increased sensory stimulation from the flora and fauna and the mountainside of the Brecon Beacons and also encouraged participants to take part in outdoor activities, such as gardening, closer to home. Although, it could be argued that prior to taking part in the outdoor-walking rehabilitation programme, participants already enjoyed being emersed in nature and can be reflected in the high pre-intervention results, as mean scores for Nature-relatedness and the subsequent domains can only vary between 1 and 5. By this finding, this study may have recruited young stroke survivors who already enjoy participating in the natural outdoor environments.

Prior to participating in the outdoor-walking rehabilitation programme, though there was no statistically significant relationship/ association between total QoL and nature-relatedness scores, a marginal positive linear relationship can be seen in figure 6.5. However, what is most striking is the unforeseen negative linear relationship between QoL and nature-relatedness post completion of the outdoor-walking rehabilitation programme and it is unclear why the negative relationship in total QoL and Nature-relatedness would be seen and is contradictory to findings seen in a study by Dean et al (2018). Zelenski and Nisbet (2012) found that nature-relatedness was more likely to correlate with indicators of positive wellbeing than indicators of negative mental health. Studies (Dean et al., 2018) that have assessed nature-relatedness and mental and/or physical wellbeing have used scales/ measures, such as the Depression Anxiety Stress Scale (DASS-21) (Lovibond, 1996). These focus on one aspect compared to a quality of life scale, which takes into account several different factors. Furthermore, of the studies (Nisbet et al., 2009; Dean et al., 2018) that have assessed nature-relatedness over the past fifteen years, the sample have been from a healthy population with no life-altering physical conditions like stroke.

Although the importance and the role the natural outdoor environment can play in improving physical and mental wellbeing of healthy populations is increasing and would therefore give premise to help individuals with life-changing conditions, as seen in this study, there is still a fundamental lack of research exploring the role of the outdoors in life-long conditions such as stroke.

6.4 Limitations: Quality of Life

Although this study shows promising results that could support the use of an outdoor-walking rehabilitation programme to improve self-reported quality of life for young stroke survivors, inevitably, there is some key limitations that should be considered and addressed.

Firstly, although the Stroke and Aphasia quality of life scale included psychosocial domains, no standardised assessment of mental wellbeing was included in the present study and was therefore overlooked. For instance, depression and anxiety are common psychological conditions of mental ill health in young stroke survivors and exploring the relationship between mental health and nature-relatedness would have increased the importance of the study further. Also, the nature-relatedness scale was developed to assess the 'affective, cognitive and physical relationship individuals have with the natural world' (Nisbet et al., 2009). However, this is not necessarily developed with individuals with physical and cognitive conditions (e.g. stroke) in mind. This questionnaire was also one of the only standardised questionnaires that assessed the individual's perceptions of the outdoors, giving potential grounds to develop a questionnaire for less able-bodied individuals in mind.

A final limitation of this research project highlights that no long-term follow-up to re-assess quality of life was conducted. This has implications for the potential effects on self-reported quality of life and confidence, which occurred during participation of the outdoor-walking rehabilitation and unfortunately there is no way to know whether these effects remained or reduced over time, but also whether participants had the same or different three aims and three difficulties. Although participant testimonies were collected three months post completion of the outdoor-walking rehabilitation programme, incorporating a form of long-term follow-up using the standardised questionnaires (e.g. SAQOL, CaSM and NR) would have been insightful, especially because seven out of twelve participants that completed the outdoor-walking rehabilitation programme reportedly continue to take part in outdoor-walking at least once a week. However, a long-term follow-up was not feasible due to the time frame of this research project, it would be valuable if future work could seek to explore this.

6.5 Conclusions

To conclude, this is the first study with demonstrable results, of the positive effects of a 10-week outdoor-walking rehabilitation programme on quality of life and confidence of young adults who have had a stroke. These findings highlight that outdoor-walking in natural outdoor environments is a viable option as a form of rehabilitation for young stroke survivors, especially where QoL and confidence are low.

Chapter Seven

7. Researcher Insight to the Outdoor-walking Rehabilitation Programme

This research project, which investigated the effects of an outdoor-walking rehabilitation programme on walking performance and quality of life of young stroke survivors, brought about many interesting observations from the researcher. This chapter will therefore discuss the researcher's perspective of the outdoor-walking rehabilitation programme, in terms of the process of designing and delivering the project and the challenges faced and changes made as a result of COVID-19. This chapter will also discuss whether the outdoor-walking rehabilitation programme was successful, in the opinion of the researcher and whether it has a place in informing future clinical guidelines.

7.1 Design of the Outdoor-walking Rehabilitation Programme

As detailed in *Chapter Four: General Methodology* of this thesis, the outdoor-walking rehabilitation programme was originally designed to be a randomised clinical trial, consisting of two patient groups; an intervention group and a control group, rather than a case study design. In implementing the randomised clinical trial design, this would have made the study overall more robust and more impervious to critique due to the increased power of the data. The study design of a randomised clinical trial also would have generated better conclusions, such as being able to suggest further that participating in an outdoor-walking rehabilitation programme does improve multiple outcomes (e.g. improvement in walking speed, energy cost, biomechanical function, quality of life and confidence) when compared against control group data. These conclusions are what the current research is fundamentally lacking. My current work on using the natural outdoor environments and this research project (and the results) detailed in this thesis, does highlight that there is a need for alternative rehabilitation for clinical conditions such as stroke.

7.1.1 COVID-19

It is understandable that many research studies planned to take place in the years 2020 and 2021 were heavily affected by the COVID-19 pandemic. With regards to the outdoor-walking rehabilitation programme and this research project specifically, the coronavirus pandemic brought about multiple issues and disruptions concerning study design, inability to use certain pieces of equipment, participant recruitment and logistics.

This study was first and foremost severely affected by time constraints, caused by the COVID-19 pandemic. This study was due to originally take place in the Summer of 2020 as a three-month randomised clinical trial. However, delays and suspension of research activities by HRA NHS Ethics, multiple national lockdowns (which then ended March 2021) and differing guidelines between England and Wales meant that the study needed to be put on hold and pushed further into late Summer of 2021.

Recruitment for this study was unfortunately poor and directly affected the design of this study. Only twelve participants were recruited for this study and is reported in this thesis as a major limitation. This study originally planned to recruit 47 young stroke survivors from three health board sites in Wales, which would have allowed for two large patient groups; intervention and control. There were two main issues resulting in low recruitment rate; 1. Health boards and 2. Patient's reluctance to participate due to COVID-19. Firstly, recruitment relied on the participating health board sites to identify young stroke survivors who fitted the inclusion and exclusion criteria of this study. However, due to site PI's being redeployed to other departments within their respective health boards during the COVID-19 pandemic, site

PI's were not having regular contact stroke patients in their care. Secondly, many stroke patients who did manage to have contact with site PI's, were extremely reluctant to participate in research due to fear and risk of catching the coronavirus.

7.2 Delivery of the Outdoor-Walking Rehabilitation Programme

For this section in order to assess the overall delivery of the outdoor-walking rehabilitation programme, I utilise three elements of the Consensus for Exercising Template (CERT). They are the following; support, delivery and tailoring.

7.2.1 How well was the programme supported?

The choice to use Gilwern Outdoor Education Centre (Gilwern OEC) in Abergavenny, to support the outdoor-walking rehabilitation programme for young stroke survivors worked particularly well for various reasons. Every walking activity throughout the outdoor-walking rehabilitation programme was supported by two outdoor activity instructors, who each had a wealth of knowledge of the Brecon Beacons National Park and experience of working with individuals with debilitating physical conditions. Before each activity, and as a way of reassuring the participants regarding the safety of the walking activity, the instructors would brief the participant group with the plan of the day. The brief would include visual aids of where the participants were going to walk using Ordnance Survey mapping software. This allowed participants to view the route in real time, understand the distance that would be walked and the potential gradients (e.g. uphill ascents and downhill descents). This software also displayed a satellite image of the route, showing the condition of the proposed path and allowing the participants to ask questions, dispelling any worry the participants may have had about the environment and helping the participants to enjoy the planned walking activity of that day. Alongside a detailed brief of the walking activity, reporting of the weather was done prior to starting the walking activity, to ensure all participants had the correct equipment for that walk. This showed great support and safety considerations from the staff at Gilwern OEC, ensuring each participant was aware of what each walk entailed.

During the walking activity, even though all participants supported each other, the outdoor activity instructors (and researcher) carried additional outdoor equipment should participants need another jacket or layer of clothing, water or food. Furthermore, instructors were very involved in helping participants how to use trekking poles to their advantage and offering physical support and more difficult sections of the route. From observations by the researcher, instructors built strong rapports with the participants, making the participants feel at ease in the natural outdoor environments and creating a supportive space while also encouraging independence.

Furthermore, the accommodation at Gilwern OEC enabled for all participants to have their own bedroom and separate ensuite shower facilities on the ground floor. Participants were therefore not required to climb stairs and all facilities were easily accessible. This enabled individuals with more severe physical impairments to still be independent and take part in the study. Secondly, transport at Gilwern OEC proved to work well, each minibus used for the outdoor-walking rehabilitation programme were supplied with steps to make it easier for participants to get on and off the minibus with plenty of grab handles and space to make climbing on to the minibus easier.

7.2.2 How well was the programme delivered?

As found in the feasibility study, detailed in *Chapter Three* of this thesis, outdoor-walking was easy to manage and deliver to a group of twelve young stroke survivors. This was in part due to the decision to have outdoor-walking as the sole form of physical activity for the outdoor-walking rehabilitation programme. This allowed participants to have continuity throughout each residential and to focus on improving walking performance.

Prior to each walking session with young stroke survivors, proposed walking routes for each residential were checked for suitability to reduce safety concerns. Assessing suitability involved checking the terrain, gradient and distance of the route, but also investigating whether there will be any obstacles and hazards that would cause increased difficulty for the participants. Outdoor activity instructors would then have updated information on the route, which would be passed onto participants during the morning brief. This method of delivery worked very well as participants were able to be made aware of potential difficulties they may experience during the activity that day.

7.2.3 Was the programme able to be tailored to each individual participant?

As physical impairments post-stroke vary in severity, it was important to have a flexible and adaptable programme, for all participants to be able to take part in and enjoy, but also find challenging. Therefore having outdoor-walking as the only activity to be included into the rehabilitation programme allowed for this. Each walking activity over the four residentials gradually increased in difficulty, either in distance, gradient or terrain.

Due to the large range in physical impairments and stroke severity presented in the current participant cohort, the decision was made to divide the intervention group into two. This allowed for those with minor to moderate physical impairments to take part in a more challenging walking route. The participants who had more increased physical impairments and walked much more slowly compared to rest of the participant group, took part in a walking programme that allowed them to have plenty of rest and cover shorter distances. It was in this group that being in the natural outdoor setting was more important as they were appreciative of the relaxing qualities of the landscape, flora and fauna.

7.3 Success of the Outdoor-Walking Rehabilitation Programme

Despite the research project being fraught with multiple obstacles, mainly due to the COVID-19 pandemic, I believe that the outdoor-walking rehabilitation programme was mostly a success. This is down to the participants who took part in the study and the help and support given from Gilwern Outdoor Education Centre, in Abergavenny.

The reasons why this study is seen to be successful is because first and foremost, the adherence rate of 100% for pre and post intervention data collection and for the outdoor-walking rehabilitation residentials. This allowed for full data sets to be collected, analysed and reported in this thesis. Though this cannot be applied to the 'three-month follow-up' questionnaire (also known in this thesis as participant testimonies), where only seven out of twelve (58%) participants returned responses.

In the opinion of the researcher, evidenced via observation during the study residentials by the researcher and in the qualitative data (participant responses), all participants took great enjoyment in taking part in the outdoor-walking rehabilitation programme as a result of a number of reasons. I witnessed a group of individuals who all had one thing in common: Stroke. The participants were from different walks of life, different ages, and stroke had affected them all differently. From the first residential, I could see a group of strangers conversing freely with each other and sharing their experiences of life after stroke. For five of the participants, this was invaluable due to having their strokes during the national lockdowns due to the COVID-19 pandemic. They expressed that they had not spoken with any other stroke survivor before and being unable to share their experiences with others who understood what they were going through. They therefore felt isolated due to the coronavirus and that they did not have any support from others until they attended and took part in the outdoor-walking rehabilitation programme. The sharing of personal experiences and through this, the building of group support and camaraderie contributed largely to the success of the outdoor-walking rehabilitation programme.

During each residential, I observed the group support and camaraderie developing more within the participant group as an integral part of this outdoor-walking rehabilitation programme. All participants gave physical support to one another and words of motivation and encouragement to continue on during each walking activity. During each residential as part of the outdoor-walking rehabilitation programme, I built lasting rapports with all participants, asking them their experiences of life after stroke, offering advice on how they can improve their walking ability and listening to their life stories. This in person group support then transpired into an online support group using WhatsApp, allowing all participants to communicate with each outside of the outdoor-walking rehabilitation programme.

Ultimately, I view this study being a success for the aforementioned reasons, I underestimated as a researcher, how effective group support and camaraderie would be in improving both walking performance, quality of life and confidence of young stroke survivors. Future studies investigating the benefits of rehabilitation programmes in natural outdoor settings should take into account the pastoral role of group support and every effort should be made to strengthen the case that programmes such as the one detailed in this thesis have the potential to inform future clinical guidelines for the stroke condition in the chronic phase with varying degrees of stroke severity and physical motor impairments.

Chapter Eight

8. Clinical Implications

The findings reported from this thesis demonstrates that a natural outdoor environment can be used as an alternative setting for stroke rehabilitation and that rehabilitation does not need to be confined to indoor clinical settings in order to promote recovery of walking ability and improve quality of life of young adults who have had a stroke. The findings reported in this thesis also significantly contributes further towards the understanding of kinematic and kinetic gait deviations, quality of life and confidence of young adults who have had a stroke.

The clinical implications of the walking performance parameters, which are captured and reported in this thesis include faster walking speeds, reduction in energy cost of walking, improvement in stride length and step length and improved kinematics and kinetics. For instance, as a result of participating in the outdoor-walking rehabilitation programme participants were able to extend the hip of the paretic limb more during late stance and increase in peak ankle power at toe-off to facilitate forward propulsion and initiate swing phase of the gait cycle. This we can hypothesise is a potential mechanism for why participants in this study were able to walk faster.

Although only minor changes were seen in the standardised questionnaires such as the SAQOL, CaSM and NR. Qualitative data analysis of participants' written responses from the Aims and Difficulties questionnaire, Pre and Post-Rehabilitation questionnaires and the 3-month follow-up questionnaire, clearly demonstrated that an outdoor-walking rehabilitation programme has multiple applications in improving quality of life via increasing confidence, mental and physical wellbeing and independence.

It should be noted however, that these findings should not lead to any immediate changes in current practice of stroke recovery and rehabilitation, without further confirmation from future research studies that involve larger data samples and addressing the limitations of this study first and foremost, which were discussed in *Chapters 5 and 6*. Therefore, in this chapter, I discuss the novel contribution to work that this research project brings forward and the following future recommendations; Research, Clinical and Societal.

8.1 Recommendations

8.1.1 Clinical Recommendations

The findings within this thesis demonstrate highly beneficial effects of a 10-week outdoor-walking rehabilitation programme for young adults who have had a stroke who have mild-moderate physical impairments. The natural outdoor environment is a highly effective setting to improve one of main priorities in stroke rehabilitation, by improving walking ability, through increasing walking speed and efficiency and reduction in various kinematic and kinetic deviations (Jarvis et al., 2019). This is due to participants being exposed to a highly changeable environment such as uneven ground, different terrains and weather conditions, which is a stark contrast to indoor clinical settings.

The assessment of quality of life and confidence in young adults who have had a stroke highlight that more is needed to improve physical ability and confidence. Many rehabilitation programmes already assess quality of life, however improving rehabilitation programmes that also focus on increasing confidence in walking ability and independence of young stroke survivors should form a key aspect of future interventions specific to young stroke using natural outdoor settings. Another potential way to facilitate increase in confidence is the development of group-based supported rehabilitation interventions for social participation

(Gladwell et al., 2013), increase motivation (Fraser et al., 2019)and are more likely to increase intention for future participation (Thompson Coon et al., 2011).

Due to the nature and large variability of how stroke affects each individual, it is understandable that health care professionals can be apprehensive in promoting outdoor forms of exercise (McCluskey and Middleton, 2010). However, for young stroke survivors who have mild to moderate impairments, this study has presented that with the correct support, outdoor-walking is safe to be promoted. Therefore, this thesis calls for changes in policy for stroke rehabilitation to include activities that focus on improving walking performance and increasing social interaction with others, in outdoor settings and to assess functional independence and confidence as a result of outdoor-based rehabilitation. Future policies should also consider offering training or education opportunities for health care professionals, regarding new and alternative rehabilitation approaches taking place in outdoor settings. Health care professionals should also refer to the NHS 'Green Social Prescribing' (NHS, 2021) guidelines when developing commissioning guidance for rehabilitation programmes, for stroke and other clinical populations.

8.1.2 Societal Recommendations

The findings from this thesis have important implications for the young stroke survivor. As detailed in *Chapter Two: Literature Review* of this thesis, it is well known in the literature that dependence on others and increase in social isolation and psychological problems such as depression, anxiety and ill mental health are prominent issues after stroke. Evidenced in the responses of the participants who took part in this study (detailed in *Chapter 6* of this thesis), there is a role that this alternative form of rehabilitation, specifically taking place in outdoor environments, can play in society.

Although this study did not collect data on socio-economic cost of stroke or societal challenges faced by the young stroke survivor, having a rehabilitation programme that focuses on utilising challenging, real-world environments, has enabled those who participated in this study, to be and feel more functionally independent, by being more able to complete activities of daily living with less support from others (e.g. family members) and increase social support. It should be highlighted also, that the activities the participants took part within this programme can be classed as normal activities, which anyone can participate in on a daily basis. A common priority of many stroke survivors is to return to 'normal' and one reason for the improved walking performance is the translatable nature of the outdoor-walking programme, which can also be continued at home. One participant stated the following in their 3-month post-rehabilitation testimony:

"The course gave me tremendous amount of confidence, as for the 8 months previous I was at home with my wife for 24/7 and this course gave me the opportunity to be able to be independent for those 3 days, which really built up my confidence."

Recommendations should be made for rehabilitation programmes and healthcare community initiatives to encourage walking in natural outdoor environments for stroke and other similar conditions, to promote the benefits of group-based activity, improve physical function and quality of life. Though such initiatives via charity organisations (e.g. selected Stroke Association groups, Headway, The Ramblers Association) do already exist, they are not well publicised, not accessible to many individuals and are not included into health policy. Green Social Prescribing guidance (NHS, 2021) can help to further inform healthcare community initiatives. Moreover, consultation with young stroke survivors and individuals who present with similar physical impairments, should be required as their voice is an important step to empower their rights as active agents of policy change (Madsen et al., 2021).

From the 3-month post-rehabilitation testimony data, there is a call for more research and more creative rehabilitations to be developed, like the one detailed in this thesis to help others who find themselves in similar situations after stroke:

Participant 8: *"My recommendation would be that all Stroke associations and health boards give maximum support to this and other such project in the future."*

Participant 11: *"Being out in the fresh air and walking at whatever pace suits you ,either by yourself or even better in company is a great tonic for everyone and any encouragement to people to enable them to do this this should be fully supported in any way it can."*

8.1.3 Research Recommendations and Future Directions for Research

The outcomes of this research project have prompted several research recommendations and future research directions that would further add to the understanding of physical challenges and impact of stroke on quality of life in young adults, and to the role of exercising in natural outdoor environments for young stroke survivors.

A clear outcome from this research project is a greater knowledge of both the physical benefits and positive impact on quality of life and confidence of exercising in natural outdoor environments for young adults who have had a stroke. This thesis provides the first convincing evidence that outdoor-walking improves certain walking performance parameters such as walking speed, distance, efficiency and biomechanical function in this cohort.

Future studies should aim to increase the validity of this research, firstly by comparing an intervention group against a control group. As the study detailed in this thesis was heavily affected by the COVID-19 pandemic of 2020 and 2021, the disruption resulted in the study evolving into a case study instead of a randomised clinical trial. It should be proposed to replicate the methods used in the present study and to conduct a randomised clinical trial, with intervention and control groups to compare against. Table 8.1 utilises the Consensus for exercise reporting template (CERT ref) to aid with the development of the study design.

Future studies should also aim to establish the influence of the outdoor-walking rehabilitation programme frequency, intensity, but also feasibility of delivery during different stages of post-stroke rehabilitation. It would be better to determine the optimal frequency and intensity of outdoor-walking in young adults who have had a stroke as understandably this may differ greatly between the severity of physical motor impairments caused by stroke. Although this thesis provides evidence of a positive effect of outdoor-walking in young stroke, and provides an established walking speed threshold for individuals with mild-moderately affected physical impairments, an important question remains; how much is too much? In order to enable health professionals to give detailed advice regarding the frequency and intensity of an outdoor-walking rehabilitation programme for young stroke, future research should seek to establish more thresholds between which all can benefit from partaking in outdoor-walking.

Another potential research direction that emanated from the outcomes of this thesis is the improvements identified in certain walking performance parameters. Specifically the improvements seen in gait kinematics and kinetics after participation of the outdoor-walking rehabilitation programme. It is known that muscle strength has a role to play in gait post-stroke, and is highlighted in *Chapter Five* of this thesis as a potential reason for improved gait, however muscle strength and muscle activation were not assessed within this thesis. Therefore, it would be advantageous for future studies to examine these potential associations between walking performance in outdoor settings and changes in muscle strength and muscle activation, as this would provide greater direction for the design of future outdoor-walking rehabilitation programmes for young adults who have had a stroke.

An important finding within this thesis was the improvements seen in quality of life and confidence as a result of participating in the outdoor-walking rehabilitation programme. Although this thesis utilised qualitative methods in the form of structured questionnaires, further investigation into the impact of stroke on quality of life and mental wellbeing using semi-structured interviews/ conversations may offer more in-depth and true accounts from participants regarding the effects of outdoor-walking in natural environments.

Finally, the positive impact of an outdoor-walking rehabilitation programme specific for young adults who have had a stroke, demonstrated by this thesis, promotes outdoor-walking as an evolving area of research for stroke. The findings generate a plethora of research questions, such as how to increase accessibility to the outdoors and understanding the barriers that cause reluctance to use natural outdoor environments for settings of stroke rehabilitation.

Chapter 9

9. Conclusion

9.1 Summary of findings

The aim of the research presented in this thesis and my original contribution to knowledge was to examine the impact of an outdoor-walking rehabilitation programme on walking performance and quality of life of young adults who have had a stroke, presenting an alternative and novel approach to traditional stroke rehabilitation. This thesis further contributes to current evidence that improves life of young adults after stroke, an area of research that is still severely lacking.

In order to accomplish this, it was necessary to firstly determine the delivery and adherence of an outdoor-based rehabilitation programme for young stroke survivors, and secondly to assess participant capability of an outdoor-based rehabilitation programme. The key findings from the small-scale pilot and feasibility study, detailed in *Chapter Three*, determined that using outdoor-walking in natural environments as the sole form of physical activity was feasible, deliverable to a larger cohort and improved self-reported quality of life of young stroke survivors with mild to moderate physical impairments. From this study, a walking speed lower threshold was also implemented as part of the inclusion and exclusion criteria for the main study. It was established young stroke survivors who walked at a speed of 0.6m/s or faster were able to cope with the demands and hazards commonly associated with outdoor-walking in natural outdoor settings.

Chapter Five of this thesis aimed to examine the effect of a 10-week outdoor-walking rehabilitation programme on walking performance, such as walking speed, energy cost and joint kinematics and kinetics in young adults who have had a stroke. This study is the first to assess the effects of an outdoor-walking rehabilitation programme on walking performance in the young stroke population and importantly the findings reveal that outdoor-walking is highly beneficial for improving walking performance in these individuals.

Improved walking performance parameters included increased walking speed and distance for both indoor and outdoor environments, step length of both the paretic and non-paretic lower limbs, and overall stride length. Kinematic and kinetic improvements saw increased hip and knee flexion at initial contact and during loading response, increased knee flexion during swing phase, increased dorsiflexion at initial contact and during swing phase. The outdoor-walking rehabilitation programme also improved several gait kinetic deviations and enhanced propulsive forces in young stroke, shown by increase in maximum hip flexor moment during stance and increase in peak plantarflexor power generation during late stance.

The kinematic and kinetic adaptations discussed above contribute towards the increased indoor and outdoor walking speeds and likely contribute towards increased confidence and independence for outdoor and community ambulation, while also potentially reducing fall risk in young stroke.

Chapter Six of this thesis aimed to assess whether an outdoor-walking rehabilitation programme can improve self-reported quality of life and confidence of young adults who have had a stroke. This study is novel in the investigation of the effect of an outdoor-walking rehabilitation programme on quality of life and confidence of young adults who have had a stroke and examination of aims that young stroke survivors hope to achieve and the difficulties they have currently. Positive effects of the outdoor-walking rehabilitation programme on quality of life and confidence were found in a population of young adults who have had a stroke. Overall quality of life was improved, but also perceived physical health and energy, psychosocial (such as depression) and confidence were improved after completion of the outdoor-walking rehabilitation programme.

9.1.1 Global Summary

Walking performance, quality of life and confidence were described in young adults who have had a stroke. Importantly, the use of natural outdoor environments as an alternative setting for stroke rehabilitation for young adults was found to be highly feasible and beneficial towards managing and improving many of these impairments of young stroke survivors. Not only did participating in this rehabilitation programme positively increase and improve many walking performance parameters, quality of life and confidence, additional benefits were seen in social participation and attitudes of young adults who have had a stroke.

The key message from these findings is that an outdoor-walking rehabilitation programme is an incredibly innovative way of improving walking performance, quality of life and confidence of young adults who have had a stroke with mild to moderate physical impairments and that stroke rehabilitation should not need to be confined to indoor clinical settings. Furthermore, supplementary to the quantitative findings of this study, the anecdotal outcomes from this study truly encapsulate the positive impact that the outdoor-walking rehabilitation programme had on this group of individuals.

In addition, this thesis forms part of a movement to alter perceptions that stroke rehabilitation does not need to be based in indoor clinical settings, where it is traditionally placed. Future health policies need to reflect the important role that outdoor environments can play, to promote and improve recovery. Although the NHS has recently commissioned 'Green Social Prescription' and is live in a handful of Integrated Care Systems across the United Kingdom, policies (e.g. National Institute for Health and Care Excellence, Stroke

Organisation, NHS) specific to rehabilitation for stroke and other clinical populations need to be updated to reflect this movement.

Below are excerpts from some of the participants 3-month follow-up testimonies (all testimonies in Appendix 11):

Participant 4: . Being able to participate on the research project therefore provided me with an alternative course of rehab both with the experience and guidance of outdoor walking and the programme of home based exercises… Overall being able to participate on the outdoor research project provided me with a very unique opportunity to receive monitored and assessed rehabilitation outside the usual health care setting of a hospital or clinic and has significantly assisted in improving & sustaining my overall wellbeing, including my mental wellbeing which had faltered in my post stroke rehabilitation period and prior to being a participant on the project

Participant 1: This type of study, outdoors in beautiful country side, promotes awareness, of not just ourselves, but others and nature. It wakes up part of the brain, to say, " hey, all is not lost, this is a major setback in your life, but LOOK around you, you are definitely not alone"

Participant 3: The days were challenging but I enjoyed rising to the challenges and really did feel good when we reflected back each day on what we had achieved. It was also good to be helping other people as I am more able bodied than some of the group. My walking speed has most definitely improved and I have also found that my stamina is also better making me able to walk further and longer. I have also enjoyed making many new friends.

9.2 Global Conclusion

It is overwhelmingly evident that young adults who have had a stroke display physical and motor impairments that affect walking performance and in turn, their quality of life and confidence and affecting their day to day living. The findings from this thesis establishes the true effectiveness of an outdoor-walking rehabilitation programme based in natural outdoor settings, to both improve and manage the debilitating physical impairments and quality of life, but also promote confidence and independence of young adults with stroke. The outdoor-walking rehabilitation programme is shown to be very beneficial and is an innovative treatment option, by allowing young adults with stroke to actively partake in improving their physical and mental health and help to inform future stroke rehabilitation policies. It is imperative that the view, that stroke rehabilitation should take place exclusively indoors, is changed. The findings of this thesis go some way towards helping to inform and catalyse that change.

Reference List

Abbott, C. A., Chatwin, K. E., Foden, P., Hasan, A. N., Sange, C., Rajbhandari, S. M., Reddy, P. N., Vileikyte, L., Bowling, F. L. and Boulton, A. J. M. (2019) 'Innovative intelligent insole system reduces diabetic foot ulcer recurrence at plantar sites: a prospective, randomised, proof-of-concept study.' *The Lancet Digital Health*. Elsevier, 1(6) pp. e308–e318.

Abe, H., Michimata, A., Sugawara, K., Sugaya, N. and Izumi, S.-I. (2009) 'Improving gait stability in stroke hemiplegic patients with a plastic ankle-foot orthosis.' *The Tohoku journal of experimental medicine*. Tohoku University Medical Press, 218(3) pp. 193–199.

Ahlsiö, B., Britton, M., Murray, V. and Theorell, T. (1984) 'Disablement and quality of life after stroke.' *Stroke*. United States, 15(5) pp. 886–890.

Ahtiainen, J. P., Pakarinen, A., Alen, M., Kraemer, W. J. and Häkkinen, K. (2005) 'Short vs. long rest period between the sets in hypertrophic resistance training: influence on muscle strength, size, and hormonal adaptations in trained men.' *Journal of strength and conditioning research*. United States, 19(3) pp. 572–582.

Aigner, A., Grittner, U., Rolfs, A., Norrving, B., Siegerink, B. and Busch, M. A. (2017) 'Contribution of Established Stroke Risk Factors to the Burden of Stroke in Young Adults.' *Stroke*, 48(7) pp. 1744–1751.

Akbas, T., Prajapati, S., Ziemnicki, D., Tamma, P., Gross, S. and Sulzer, J. (2019) 'Hip circumduction is not a compensation for reduced knee flexion angle during gait.' *Journal of Biomechanics*, 87 pp. 150–156.

Ali, A., Tabassum, D., Baig, S. S., Moyle, B., Redgrave, J., Nichols, S., McGregor, G., Evans, K., Totton, N. and Cooper, C. (2021) 'Effect of Exercise Interventions on Health-Related Quality of Life After Stroke and Transient Ischemic Attack: A Systematic Review and Meta-Analysis.' *Stroke*. Am Heart Assoc p. STROKEAHA-120.

Allen, J. L., Kautz, S. A. and Neptune, R. R. (2011) 'Step length asymmetry is representative of compensatory mechanisms used in post-stroke hemiparetic walking.' *Gait & posture*, 33(4) pp. 538–543.

Allet, L., Leemann, B., Guyen, E., Murphy, L., Monnin, D., Herrmann, F. R. and Schnider, A. (2009) 'Effect of different walking aids on walking capacity of patients with poststroke hemiparesis.' *Archives of physical medicine and rehabilitation*. United States, 90(8) pp. 1408–1413.

Almurdhi, M. M., Reeves, N. D., Bowling, F. L., Boulton, A. J., Jeziorska, M. and Malik, R. A. (2016) 'Reduced Lower-Limb Muscle Strength and Volume in Patients With Type 2 Diabetes in Relation to Neuropathy, Intramuscular Fat, and Vitamin D Levels.' *Diabetes Care*, 39(3) pp. 441–447.

Ardestani, M. M., Henderson, C. E. and Hornby, T. G. (2019) 'Improved walking function in laboratory does not guarantee increased community walking in stroke survivors: Potential role of gait biomechanics.' *J Biomech*, 91 pp. 151–159.

Askari, J., Saberi-Kakhki, A., Taheri, H. and Yassini, S. M. (2017) 'The effect of aerobic indoor exercise compared with green exercise on different symptoms of depression: An investigation of psychological mediators of stress and coping.' *Open Journal of Medical Psychology*. Scientific Research Publishing, 6(3) pp. 197–212.

Awad, L. N., Palmer, J. A., Pohlig, R. T., Binder-Macleod, S. A. and Reisman, D. S. (2015) 'Walking speed and step length asymmetry modify the energy cost of walking after stroke.' *Neurorehabilitation and neural repair*, 29(5) pp. 416–423.

Baker, R. and Hart, H. M. (2013) *Measuring walking: a handbook of clinical gait analysis*. Mac Keith Press London.

Balasubramanian, C. K., Bowden, M. G., Neptune, R. R. and Kautz, S. A. (2007) 'Relationship between step length asymmetry and walking performance in subjects with chronic hemiparesis.' *Archives of physical medicine and rehabilitation*. Elsevier, 88(1) pp. 43–49.

Balasubramanian, C. K., Neptune, R. R. and Kautz, S. A. (2010) 'Foot placement in a body reference frame during walking and its relationship to hemiparetic walking performance.' *Clinical biomechanics (Bristol, Avon)*. 2010/03/02, 25(5) pp. 483–490.

Barnes, C. and Oliver, M. (1993) *Disability: A sociological phenomenon ignored by sociologists*. University of Leeds Leeds.

Barton, J., Griffin, M. and Pretty, J. (2012) 'Exercise-, nature- and socially interactive-based initiatives improve mood and self-esteem in the clinical population.' *Perspectives in public health*. United States, 132(2) pp. 89–96.

Barton, J. and Pretty, J. (2010) 'What is the best dose of nature and green exercise for improving mental health? A multi-study analysis.' *Environmental science & technology*. United States, 44(10) pp. 3947–3955.

Béjot, Y., Daubail, B., Jacquin, A., Durier, J., Osseby, G.-V., Rouaud, O. and Giroud, M. (2014) 'Trends in the incidence of ischaemic stroke in young adults between 1985 and 2011: the Dijon Stroke Registry.' *Journal of neurology, neurosurgery, and psychiatry*. England, 85(5) pp. 509–513.

Benedetti, M. G., Catani, F., Leardini, A., Pignotti, E. and Giannini, S. (1998) 'Data management in gait analysis for clinical applications.' *Clinical biomechanics*. Elsevier, 13(3) pp. 204–215.

Bernhardt, J., Dewey, H., Thrift, A. and Donnan, G. (2004) 'Inactive and alone: physical activity within the first 14 days of acute stroke unit care.' *Stroke*, 35(4) pp. 1005–1009.

Bevan, H., Sharma, K. and Bradley, W. (1990) 'Stroke in young adults.' *Stroke*. United States, 21(3) pp. 382–386.

Billinger, S. A., Arena, R., Bernhardt, J., Eng, J. J., Franklin, B. A., Johnson, C. M., MacKay-Lyons, M., Macko, R. F., Mead, G. E., Roth, E. J., Shaughnessy, M. and Tang, A. (2014) 'Physical Activity and Exercise Recommendations for Stroke Survivors: A Statement for Healthcare Professionals From the American Heart Association/American Stroke Association.' *Stroke*, 45(8) pp. 2532–2553.

Billinger, S. A., Mattlage, A. E., Ashenden, A. L., Lentz, A. A., Harter, G. and Rippee, M. A. (2012) 'Aerobic exercise in subacute stroke improves cardiovascular health and physical performance.' *Journal of neurologic physical therapy : JNPT*, 36(4) pp. 159–165.

Blake, H., Lincoln, N. B. and Clarke, D. D. (2003) ‘Caregiver strain in spouses of stroke patients.’ *Clinical rehabilitation*. England, 17(3) pp. 312–317.

Bohannon, R. W. and Andrews, A. W. (1995) ‘Limb Muscle Strength is Impaired Bilaterally after Stroke.’ *Journal of Physical Therapy Science*, 7(1) pp. 1–7.

Borg, G. (1982) ‘Ratings of perceived exertion and heart rates during short-term cycle exercise and their use in a new cycling strength test.’ *Int J Sports Med*, 3(3) pp. 153–158.

Boudarham, Julien, Roche, N., Pradon, D., Bonnyaud, C., Bensmail, D. and Zory, R. (2013) ‘Variations in kinematics during clinical gait analysis in stroke patients.’ *PloS one*, 8(6) p. e66421.

Boudarham, J, Zory, R., Genet, F., Vigné, G., Bensmail, D., Roche, N. and Pradon, D. (2013) ‘Effects of a knee-ankle-foot orthosis on gait biomechanical characteristics of paretic and non-paretic limbs in hemiplegic patients with genu recurvatum.’ *Clinical biomechanics (Bristol, Avon)*. England, 28(1) pp. 73–78.

Bousser, M.-G. and Welch, K. M. A. (2005) ‘Relation between migraine and stroke.’ *The Lancet. Neurology*. England, 4(9) pp. 533–542.

Bowden, M. G., Balasubramanian, C. K., Behrman, A. L. and Kautz, S. A. (2008) ‘Validation of a speed-based classification system using quantitative measures of walking performance poststroke.’ *Neurorehabilitation and neural repair*, 22(6) pp. 672–675.

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M. and Pullin, A. S. (2010) ‘A systematic review of evidence for the added benefits to health of exposure to natural environments.’ *BMC Public Health*, 10(1) p. 456.

Brandstater, M. E., de Bruin, H., Gowland, C. and Clark, B. M. (1983) ‘Hemiplegic gait: analysis of temporal variables.’ *Archives of physical medicine and rehabilitation*, 64(12) pp. 583–587.

Brey, R. L. (2005) ‘Antiphospholipid antibodies in young adults with stroke.’ *Journal of thrombosis and thrombolysis*. Netherlands, 20(2) pp. 105–112.

Brogårdh, C. and Lexell, J. (2012) ‘Effects of cardiorespiratory fitness and muscle-resistance training after stroke.’ *PM & R : the journal of injury, function, and rehabilitation*. United States, 4(11) pp. 901–7; quiz 907.

Broomfield, N. M., Laidlaw, K., Hickabottom, E., Murray, M. F., Pendrey, R., Whittick, J. E. and Gillespie, D. C. (2011) ‘Post-stroke depression: the case for augmented, individually tailored cognitive behavioural therapy.’ *Clinical psychology & psychotherapy*. England, 18(3) pp. 202–217.

Brouwer, B., Parvataneni, K. and Olney, S. J. (2009) ‘A comparison of gait biomechanics and metabolic requirements of overground and treadmill walking in people with stroke.’ *Clinical biomechanics (Bristol, Avon)*. England, 24(9) pp. 729–734.

de Bruijn, M. A. A. M., Synhaeve, N. E., van Rijsbergen, M. W. A., de Leeuw, F.-E., Mark, R. E., Jansen, B. P. W. and de Kort, P. L. M. (2015) ‘Quality of Life after Young Ischemic Stroke of Mild Severity Is Mainly Influenced by Psychological Factors.’ *Journal of stroke and cerebrovascular diseases : the official journal of National Stroke Association*. United States, 24(10) pp. 2183–2188.

De Bruin, E. D., Schoene, D., Pichierri, G. and Smith, S. T. (2010) 'Use of virtual reality technique for the training of motor control in the elderly: some theoretical considerations.' *Zeitschrift für Gerontologie und Geriatrie*. Springer-Verlag, 43(4) pp. 229–234.

Bütefisch, C., Hummelsheim, H., Denzler, P. and Mauritz, K.-H. (1995) 'Repetitive training of isolated movements improves the outcome of motor rehabilitation of the centrally paretic hand.' *Journal of the Neurological Sciences*, 130(1) pp. 59–68.

Buurke, J. H., Nene, A. V, Kwakkel, G., Erren-Wolters, V., Ijzerman, M. J. and Hermens, H. J. (2008) 'Recovery of gait after stroke: what changes?' *Neurorehabilitation and neural repair*. United States, 22(6) pp. 676–683.

Campanini, I., Merlo, A. and Damiano, B. (2013) 'A method to differentiate the causes of stiff-knee gait in stroke patients.' *Gait & posture*. England, 38(2) pp. 165–169.

Cappozzo, A., Cappello, A., Della Croce, U. and Pensalfini, F. (1997) 'Surface-marker cluster design criteria for 3-D bone movement reconstruction.' *IEEE transactions on bio-medical engineering*. United States, 44(12) pp. 1165–1174.

Cappozzo, A., Catani, F., Leardini, A., Benedetti, M. G. and Croce, U. Della (1996) 'Position and orientation in space of bones during movement: experimental artefacts.' *Clinical biomechanics (Bristol, Avon)*. England, 11(2) pp. 90–100.

Carlozzi, N. E. and Tulsky, D. S. (2013) 'Identification of health-related quality of life (HRQOL) issues relevant to individuals with Huntington disease.' *Journal of health psychology*. 2012/03/16, 18(2) pp. 212–225.

Caro, C. C., Costa, J. D. and Cruz, D. M. C. da (2018) 'The use of mobility assistive devices and the functional independence in stroke patients.' *Cadernos Brasileiros de Terapia Ocupacional*. SciELO Brasil, 26 pp. 558–568.

Carod-Artal, F. J. and Egido, J. A. (2009) 'Quality of life after stroke: the importance of a good recovery.' *Cerebrovascular diseases (Basel, Switzerland) U6 - ctx_ver=Z39.88-2004&ctx_enc=info:ofi/enc:UTF-8&rfr_id=info:sid/summon.serialssolutions.com&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&rft.genre=article&rft.atitle=Quality+of+life+after+stroke:+the+importanc*, 27 Suppl 1 p. 204.

Carod-Artal, J., Egido, J. A., González, J. L. and Varela de Seijas, E. (2000) 'Quality of life among stroke survivors evaluated 1 year after stroke: experience of a stroke unit.' *Stroke*. United States, 31(12) pp. 2995–3000.

Carvalho, C., Sunnerhagen, K. S. and Willen, C. (2010) 'Walking speed and distance in different environments of subjects in the later stage post-stroke.' *Physiother Theory Pract*, 26(8) pp. 519–527.

Ceci, R. and Hassmén, P. (1991) 'Self-monitored exercise at three different RPE intensities in treadmill vs field running.' *Medicine and science in sports and exercise*, 23(6) pp. 732–738.

Cella, D. F. (1995) 'Measuring quality of life in palliative care.' *Seminars in oncology*. United States, 22(2 Suppl 3) pp. 73–81.

Chen, G., Patten, C., Kothari, D. H. and Zajac, F. E. (2005a) 'Gait deviations associated with post-stroke hemiparesis: improvement during treadmill walking using weight support, speed, support stiffness, and handrail hold.' *Gait & posture*. England, 22(1) pp. 57–62.

Chen, G., Patten, C., Kothari, D. H. and Zajac, F. E. (2005b) 'Gait differences between individuals with post-stroke hemiparesis and non-disabled controls at matched speeds.' *Gait & posture*. England, 22(1) pp. 51–56.

Chen, M.-D. and Rimmer, J. H. (2011) 'Effects of exercise on quality of life in stroke survivors: a meta-analysis.' *Stroke*. Am Heart Assoc, 42(3) pp. 832–837.

Chow, J. W. and Stokic, D. S. (2019) 'Gait Impairments in Patients Without Lower Limb Hypertonia Early Poststroke Are Related to Weakness of Paretic Knee Flexors.' *Archives of physical medicine and rehabilitation*. United States, 100(6) pp. 1091–1101.

Chow, J. W. and Stokic, D. S. (2021) 'Longitudinal Changes in Temporospatial Gait Characteristics during the First Year Post-Stroke.' *Brain Sciences*.

Christensen, D., Johnsen, S. P., Watt, T., Harder, I., Kirkevold, M. and Andersen, G. (2008) 'Dimensions of post-stroke fatigue: a two-year follow-up study.' *Cerebrovascular Diseases*. Karger Publishers, 26(2) pp. 134–141.

Coley, R. L., Sullivan, W. C. and Kuo, F. E. (1997) 'Where does community grow? The social context created by nature in urban public housing.' *Environment and behavior*. Sage Publications, Inc. 2455 Teller Road, Thousand Oaks, CA 91320, 29(4) pp. 468–494.

Comstock, B. A., Thomas, G. A., Dunn-Lewis, C., Volek, J. S., Szivak, T. K., Hooper, D. R., Kupchak, B. R., Flanagan, S. D., Denegar, C. R. and Kraemer, W. J. (2013) 'Effects of acute resistance exercise on muscle damage and perceptual measures between men who are lean and obese.' *Journal of strength and conditioning research*. United States, 27(12) pp. 3488–3494.

Coole, C., Radford, K., Grant, M. and Terry, J. (2013) 'Returning to Work After Stroke: Perspectives of Employer Stakeholders, a Qualitative Study.' *Journal of Occupational Rehabilitation*, 23(3) pp. 406–418.

Cruz, T. H., Lewek, M. D. and Dhaher, Y. Y. (2009) 'Biomechanical impairments and gait adaptations post-stroke: multi-factorial associations.' *Journal of biomechanics*, 42(11) pp. 1673–1677.

da Cunha-Filho, I. T., Henson, H., Wankadia, S. and Protas, E. J. (2003) 'Reliability of measures of gait performance and oxygen consumption with stroke survivors.' *Journal of rehabilitation research and development*. United States, 40(1) pp. 19–25.

Daniel, K., Wolfe, C. D. A., Busch, M. A. and McKevitt, C. (2009) 'What are the social consequences of stroke for working-aged adults?: a systematic review.' *Stroke*, 40(6) pp. e431–e440.

Danielsson, A. and Sunnerhagen, K. S. (2000) 'Oxygen consumption during treadmill walking with and without body weight support in patients with hemiparesis after stroke and in healthy subjects.' *Archives of physical medicine and rehabilitation*. United States, 81(7) pp. 953–957.

Danielsson, A., Willén, C. and Sunnerhagen, K. S. (2007) 'Measurement of Energy Cost by the Physiological Cost Index in Walking After Stroke.' *Archives of Physical Medicine and*

Rehabilitation, 88(10) pp. 1298–1303.

Daryabor, A., Kobayashi, T., Yamamoto, S., Lyons, S. M., Orendurff, M. and Akbarzadeh Baghban, A. (2022) 'Effect of ankle-foot orthoses on functional outcome measurements in individuals with stroke: a systematic review and meta-analysis.' *Disability and Rehabilitation*. Taylor & Francis, 44(22) pp. 6566–6581.

Dasilva, S. G., Guidetti, L., Buzzachera, C. F., Elsangedy, H. M., Krinski, K., De Campos, W., Goss, F. L. and Baldari, C. (2011) 'Psychophysiological responses to self-paced treadmill and overground exercise.' *Med Sci Sports Exerc*, 43(6) pp. 1114–1124.

Dean, J. C., Embry, A. E., Stimpson, K. H., Perry, L. A. and Kautz, S. A. (2017) 'Effects of hip abduction and adduction accuracy on post-stroke gait.' *Clinical biomechanics (Bristol, Avon)*. 2017/03/02, 44, May, pp. 14–20.

Dean, J. H., Shanahan, D. F., Bush, R., Gaston, K. J., Lin, B. B., Barber, E., Franco, L. and Fuller, R. A. (2018) 'Is Nature Relatedness Associated with Better Mental and Physical Health?' *International journal of environmental research and public health*. MDPI, 15(7) p. 1371.

Delussu, A. S., Morone, G., Iosa, M., Bragoni, M., Paolucci, S. and Traballesi, M. (2014) 'Concurrent validity of Physiological Cost Index in walking over ground and during robotic training in subacute stroke patients.' *BioMed research international*, 2014 p. 384896.

Desrosiers, J., Noreau, L., Rochette, A., Bourbonnais, D., Bravo, G. and Bourget, A. (2006) 'Predictors of long-term participation after stroke.' *Disability and rehabilitation*. England, 28(4) pp. 221–230.

Detweiler, M. B. and Warf, C. (2005) 'Dementia wander garden aids post cerebrovascular stroke restorative therapy: a case study.' *Alternative therapies in health and medicine*. United States, 11(4) pp. 54–58.

DeVellis, R. F. (2016) *Scale development: Theory and applications*. Sage publications.

Dickstein, R. (2008) 'Rehabilitation of gait speed after stroke: a critical review of intervention approaches.' *Neurorehabilitation and neural repair*. United States, 22(6) pp. 649–660.

Donkor, E. S. (2018) 'Stroke in the 21(st) Century: A Snapshot of the Burden, Epidemiology, and Quality of Life.' *Stroke research and treatment*. Hindawi, 2018, November, p. 3238165.

Dorsch, T. E., Richards, K. A. R., Swain, J. and Maxey, M. (2016) 'The effect of an outdoor recreation program on individuals with disabilities and their family members: A case study.' *Therapeutic Recreation Journal*. Sagamore Publishing LLC, 50(2) p. 155.

Downward, P. and Rasciute, S. (2015) 'Exploring the covariates of sport participation for health: an analysis of males and females in England.' *Journal of sports sciences*. Taylor & Francis, 33(1) pp. 67–76.

Duncan, P., Studenski, S., Richards, L., Gollub, S., Lai, S. M., Reker, D., Perera, S., Yates, J., Koch, V., Rigler, S. and Johnson, D. (2003) 'Randomized Clinical Trial of Therapeutic Exercise in Subacute Stroke.' *Stroke*, 34(9) pp. 2173–2180.

Efird, J. (2011) 'Blocked randomization with randomly selected block sizes.' *International journal of environmental research and public health*. 2010/12/23, Molecular Diversity

Preservation International (MDPI), 8(1) pp. 15–20.

Ekker, M. S., Boot, E. M., Singhal, A. B., Tan, K. S., Debette, S., Tuladhar, A. M. and de Leeuw, F. E. (2018) 'Epidemiology, aetiology, and management of ischaemic stroke in young adults.' *Lancet Neurol*, 17(9) pp. 790–801.

Ellul, M. A., Benjamin, L., Singh, B., Lant, S., Michael, B. D., Easton, A., Kneen, R., Defres, S., Sejvar, J. and Solomon, T. (2020) 'Neurological associations of COVID-19.' *The Lancet. Neurology*, 19(9) pp. 767–783.

Eng, J. J. (2010) 'Fitness and Mobility Exercise (FAME) Program for stroke.' *Topics in geriatric rehabilitation*, 26(4) pp. 310–323.

Eng, J. J., Chu, K. S., Kim, C. M., Dawson, A. S., Carswell, A. and Hepburn, K. E. (2003) 'A community-based group exercise program for persons with chronic stroke.' *Medicine and science in sports and exercise*. PMC Canada manuscript submission, 35(8) p. 1271.

Erickson, K. I., Gildengers, A. G. and Butters, M. A. (2013) 'Physical activity and brain plasticity in late adulthood.' *Dialogues Clin Neurosci*, 15(1) pp. 99–108.

Evers, S. M. A. A., Struijs, J. N., Ament, A. J. H. A., van Genugten, M. L. L., Jager, J. H. C. and van den Bos, G. A. M. (2004) 'International comparison of stroke cost studies.' *Stroke*. United States, 35(5) pp. 1209–1215.

Federici, A. (2021) 'Enjoying natural environments safely: sports, adventure, risk and safeguarding health.' *Journal of Physical Education and Sport*. Universitatea din Pitesti, 21 pp. 520–525.

Feigin, V. L., Roth, G. A., Naghavi, M., Parmar, P., Krishnamurthi, R., Chugh, S., Mensah, G. A., Norrving, B., Shiue, I., Ng, M., Estep, K., Cercy, K., Murray, C. J. L. and Forouzanfar, M. H. (2016) 'Global burden of stroke and risk factors in 188 countries, during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013.' *The Lancet Neurology*, 15(9) pp. 913–924.

Fifi, J. T. and Mocco, J. (2020) 'COVID-19 related stroke in young individuals.' *The Lancet. Neurology*, 19(9) pp. 713–715.

Finestone, H. M., Greene-Finestone, L. S., Foley, N. C. and Woodbury, M. G. (2003) 'Measuring longitudinally the metabolic demands of stroke patients: resting energy expenditure is not elevated.' *Stroke*. United States, 34(2) pp. 502–507.

Flansbjer, U.-B., Miller, M., Downham, D. and Lexell, J. (2008) 'Progressive Resistance Training After Stroke: Effects on Muscle Strength, Muscle Tone, Gait Performance and Perceived Participation.' *Journal of Rehabilitation Medicine*, 40(1) pp. 42–48.

Fleuren, J. F. M., Snoek, G. J., Voerman, G. E. and Hermens, H. J. (2009) 'Muscle activation patterns of knee flexors and extensors during passive and active movement of the spastic lower limb in chronic stroke patients.' *Journal of electromyography and kinesiology : official journal of the International Society of Electrophysiological Kinesiology*. England, 19(5) pp. e301-10.

Focht, B. C. (2009) 'Brief walks in outdoor and laboratory environments: effects on affective responses, enjoyment, and intentions to walk for exercise.' *Research quarterly for exercise* *and sport*. United States, 80(3) pp. 611–620.

Forghany, S., Nester, C. J., Tyson, S. F., Preece, S. and Jones, R. K. (2014) 'The effect of stroke on foot biomechanics; underlying mechanisms and the functional consequences.' *In Journal of Foot and Ankle Research*. BioMed Central, pp. 1–2.

Fraser, M., Munoz, S.-A. and MacRury, S. (2019) 'What Motivates Participants to Adhere to Green Exercise?' *International Journal of Environmental Research and Public Health* .

Fraser, M., Polson, R., Munoz, S.-A. and MacRury, S. (2020) 'Psychological effects of outdoor activity in type 2 diabetes: a review.' *Health promotion international*. England, 35(4) pp. 841–851.

Fredrickson, E., Ruff, R. L. and Daly, J. J. (2007) 'Physiological Cost Index as a proxy measure for the oxygen cost of gait in stroke patients.' *Neurorehabilitation and neural repair*. United States, 21(5) pp. 429–434.

Fritz, T., Caidahl, K., Osler, M., Ostenson, C. G., Zierath, J. R. and Wändell, P. (2011) 'Effects of Nordic walking on health-related quality of life in overweight individuals with type 2 diabetes mellitus, impaired or normal glucose tolerance.' *Diabetic medicine : a journal of the British Diabetic Association*, 28(11) pp. 1362–1372.

Gambassi, B. B., Coelho-Junior, H. J., Schwingel, P. A., Almeida, F. de J. F., Gaspar Novais, T. M., Lauande Oliveira, P. de L., Sauaia, B. A., Melo, C. D., Uchida, M. C. and Rodrigues, B. (2017) 'Resistance Training and Stroke: A Critical Analysis of Different Training Programs.' *Stroke research and treatment*, 2017 p. 4830265.

George, M. G., Tong, X. and Bowman, B. A. (2017) 'Prevalence of Cardiovascular Risk Factors and Strokes in Younger Adults.' *JAMA neurology*, 74(6) pp. 695–703.

Gibson, J. J. (1994) 'The visual perception of objective motion and subjective movement.' *Psychological Review*. American Psychological Association, 101(2) p. 318.

Gladwell, V. F., Brown, D. K., Wood, C., Sandercock, G. R. and Barton, J. L. (2013) 'The great outdoors: how a green exercise environment can benefit all.' *Extreme physiology & medicine*, 2(1) p. 3.

Gladwell, V. F., Kuoppa, P., Tarvainen, M. P. and Rogerson, M. (2016) 'A Lunchtime Walk in Nature Enhances Restoration of Autonomic Control during Night-Time Sleep: Results from a Preliminary Study.' *International journal of environmental research and public health*. MDPI, 13(3) p. 280.

Goodwin, D., Peco, J. and Ginther, N. (2009) 'Hiking excursions for persons with disabilities: Experiences of interdependence.' *Therapeutic Recreation Journal*, 43(1) p. 42.

Gordon, C. D., Wilks, R. and McCaw-Binns, A. (2013) 'Effect of aerobic exercise (walking) training on functional status and health-related quality of life in chronic stroke survivors: a randomized controlled trial.' *Stroke*. United States, 44(4) pp. 1179–1181.

Gray, V., Rice, C. L. and Garland, S. J. (2012) 'Factors that influence muscle weakness following stroke and their clinical implications: a critical review.' *Physiotherapie Canada*, 64(4) pp. 415–426.

Griffiths, D. and Sturm, J. (2011) ‘Epidemiology and etiology of young stroke.’ *Stroke research and treatment*. 2011/07/18, SAGE-Hindawi Access to Research, 2011 p. 209370.

de Groot, J. C., de Leeuw, F.-E., Oudkerk, M., Hofman, A., Jolles, J. and Breteler, M. M. B. (2000) ‘Cerebral White Matter Lesions and Depressive Symptoms in Elderly Adults.’ *Archives of General Psychiatry*, 57(11) pp. 1071–1076.

Gudavalli, M. R., DeVocht, J., Tayh, A. and Xia, T. (2013) ‘Effect of sampling rates on the quantification of forces, durations, and rates of loading of simulated side posture high-velocity, low-amplitude lumbar spine manipulation.’ *Journal of manipulative and physiological therapeutics*. United States, 36(5) pp. 261–266.

de Haan, R. d, Aaronson, N., Limburg, M., Hewer, R. L. and Van Crevel, H. (1993) ‘Measuring quality of life in stroke.’ *stroke*. Am Heart Assoc, 24(2) pp. 320–327.

Hak, L., Houdijk, H., van der Wurff, P., Prins, M. R., Beek, P. J. and van Dieën, J. H. (2015) ‘Stride frequency and length adjustment in post-stroke individuals: influence on the margins of stability.’ *Journal of rehabilitation medicine*. Sweden, 47(2) pp. 126–132.

Harjpal, P., Qureshi, M. I., Kovela, R. K. and Jain, M. (2022) ‘Efficacy of Bilateral Lower-Limb Training Over Unilateral Lower-Limb Training To Reeducate Balance and Walking in Post-Stroke Survivors: A Randomized Clinical Trial.’ *Cureus*. United States, 14(10) p. e30748.

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S. and Gärling, T. (2003) ‘Tracking restoration in natural and urban field settings.’ *Journal of Environmental Psychology*, 23(2) pp. 109–123.

Hartig, T., Mang, M. and Evans, G. W. (1991) ‘Restorative Effects of Natural Environment Experiences.’ *Environment and Behavior*. SAGE Publications Inc, 23(1) pp. 3–26.

Hawkins, K. A., Clark, D. J., Balasubramanian, C. K. and Fox, E. J. (2017) ‘Walking on uneven terrain in healthy adults and the implications for people after stroke.’ *NeuroRehabilitation*, 41(4) pp. 765–774.

Hess, D. C., Eldahshan, W. and Rutkowski, E. (2020) ‘COVID-19-Related Stroke.’ *Translational stroke research*. 2020/05/07, Springer US, 11(3) pp. 322–325.

Hicks, J. L., Delp, S. L. and Schwartz, M. H. (2011) ‘Can biomechanical variables predict improvement in crouch gait?’ *Gait & posture*, 34(2) pp. 197–201.

Hilari, K., Byng, S., Lamping, D. L. and Smith, S. C. (2003) ‘Stroke and Aphasia Quality of Life Scale-39 (SAQOL-39): evaluation of acceptability, reliability, and validity.’ *Stroke*, 34(8) pp. 1944–1950.

Hollman, J. H., McDade, E. M. and Petersen, R. C. (2011) ‘Normative spatiotemporal gait parameters in older adults.’ *Gait & Posture*, 34(1) pp. 111–118.

Horne, J. C., Hooban, K. E., Lincoln, N. B. and Logan, P. A. (2019) ‘Regaining Confidence after Stroke (RCAS): a feasibility randomised controlled trial (RCT).’ *Pilot and feasibility studies*. BioMed Central, 5(1) pp. 1–12.

Horne, J. C., Lincoln, N. B. and Logan, P. A. (2017) ‘Measurement of confidence: the development and psychometric evaluation of a stroke-specific, measure of confidence.’ *Clinical rehabilitation*, 31(11) pp. 1529–1537.

Hsu, A.-L., Tang, P.-F. and Jan, M.-H. (2003) 'Analysis of impairments influencing gait velocity and asymmetry of hemiplegic patients after mild to moderate stroke.' *Archives of physical medicine and rehabilitation*. United States, 84(8) pp. 1185–1193.

Hug, S.-M., Hartig, T., Hansmann, R., Seeland, K. and Hornung, R. (2009) 'Restorative qualities of indoor and outdoor exercise settings as predictors of exercise frequency.' *Health & place*. England, 15(4) pp. 971–980.

Huizenga, D., Rashford, L., Darcy, B., Lundin, E., Medas, R., Shultz, S. T., DuBose, E. and Reed, K. B. (2021) 'Wearable gait device for stroke gait rehabilitation at home.' *Topics in Stroke Rehabilitation*. Taylor & Francis, 28(6) pp. 443–455.

Hwang, S. and Song, C.-S. (2023) 'Assistive Technology Involving Postural Control and Gait Performance for Adults with Stroke: A Systematic Review and Meta-Analysis.' *In Healthcare*. MDPI, p. 2225.

Investigators, W. H. O. M. P. P. (1988) 'The World Health Organization MONICA Project (monitoring trends and determinants in cardiovascular disease): a major international collaboration.' *Journal of clinical epidemiology*. Elsevier, 41(2) pp. 105–114.

Ivey, F. M., Hafer-Macko, C. E., Ryan, A. S. and Macko, R. F. (2010) 'Impaired leg vasodilatory function after stroke: adaptations with treadmill exercise training.' *Stroke*, 41(12) pp. 2913–2917.

James, L., Shing, J., Mortenson, W. Ben, Mattie, J. and Borisoff, J. (2018) 'Experiences with and perceptions of an adaptive hiking program.' *Disability and rehabilitation*. England, 40(13) pp. 1584–1590.

Jarvis, H. L., Brown, S. J., Butterworth, C., Jackson, K., Clayton, A., Walker, L., Rees, N., Price, M., Groenevelt, R. and Reeves, N. D. (2022) 'The gait profile score characterises walking performance impairments in young stroke survivors.' *Gait & posture*. England, 91, January, pp. 229–234.

Jarvis, H. L., Brown, S. J., Price, M., Butterworth, C., Groenevelt, R., Jackson, K., Walker, L., Rees, N., Clayton, A. and Reeves, N. D. (2019) 'Return to Employment After Stroke in Young Adults: How Important Is the Speed and Energy Cost of Walking?' *Stroke*, 50(11) pp. 3198–3204.

Jaul, E. and Barron, J. (2017) 'Age-Related Diseases and Clinical and Public Health Implications for the 85 Years Old and Over Population.' *Frontiers in public health*. Frontiers Media S.A., 5, December, p. 335.

Jeon, H. J. and Hwang, B. Y. (2018) 'Effect of bilateral lower limb strengthening exercise on balance and walking in hemiparetic patients after stroke: a randomized controlled trial.' *Journal of physical therapy science*. Japan, 30(2) pp. 277–281.

Jones, F., Partridge, C. and Reid, F. (2008) 'The Stroke Self-Efficacy Questionnaire: measuring individual confidence in functional performance after stroke.' *Journal of clinical nursing*. Wiley Online Library, 17(7b) pp. 244–252.

Jonkers, I., Delp, S. and Patten, C. (2009) 'Capacity to increase walking speed is limited by impaired hip and ankle power generation in lower functioning persons post-stroke.' *Gait & posture*, 29(1) pp. 129–137.

Jutai, J., Coulson, S., Teasell, R., Bayley, M., Garland, J., Mayo, N. and Wood-Dauphinee, S. (2007) 'Mobility assistive device utilization in a prospective study of patients with first-ever stroke.' *Archives of physical medicine and rehabilitation*. Elsevier, 88(10) pp. 1268–1275.

Kadam, P. and Bhalerao, S. (2010) 'Sample size calculation.' *International journal of Ayurveda research*, 1(1) pp. 55–57.

Kaplan, R. (2001) 'The nature of the view from home: Psychological benefits.' *Environment and behavior*. Sage Publications Sage CA: Thousand Oaks, CA, 33(4) pp. 507–542.

Karakkattil, P. S., Trudelle-Jackson, E., Medley, A. and Swank, C. (2020) 'Effects of two different types of ankle–foot orthoses on gait outcomes in patients with subacute stroke: a randomized crossover trial.' *Clinical Rehabilitation*. SAGE Publications Sage UK: London, England, 34(8) pp. 1094–1102.

Keegan, R., Middleton, G., Henderson, H. and Girling, M. (2016) 'Auditing the socio-environmental determinants of motivation towards physical activity or sedentariness in work-aged adults: a qualitative study.' *BMC Public Health*. BioMed Central, 16(1) pp. 1–20.

Kelly, S., Martin, S., Kuhn, I., Cowan, A., Brayne, C. and Lafortune, L. (2016) 'Barriers and facilitators to the uptake and maintenance of healthy behaviours by people at mid-life: a rapid systematic review.' *PloS one*. Public Library of Science San Francisco, CA USA, 11(1) p. e0145074.

Kerrigan, D. C., Frates, E. P., Rogan, S. and Riley, P. O. (1999) 'Spastic paretic stiff-legged gait: biomechanics of the unaffected limb.' *American journal of physical medicine*, 78(4) pp. 354–360.

Kerrigan, D. C., Frates, E. P., Rogan, S. and Riley, P. O. (2000) 'Hip hiking and circumduction: quantitative definitions.' *American journal of physical medicine & rehabilitation*. United States, 79(3) pp. 247–252.

Kim, H.-S., Chung, S.-C., Choi, M.-H., Gim, S.-Y., Kim, W.-R., Tack, G.-R., Lim, D.-W., Chun, S.-K., Kim, J.-W. and Mun, K.-R. (2016) 'Primary and secondary gait deviations of stroke survivors and their association with gait performance.' *Journal of physical therapy science*. 2016/09/29, The Society of Physical Therapy Science, 28(9) pp. 2634–2640.

Kim, M., Cho, K. and Lee, W. (2014) 'Community walking training program improves walking function and social participation in chronic stroke patients.' *The Tohoku journal of experimental medicine*. Japan, 234(4) pp. 281–286.

Kim, P., Warren, S., Madill, H. and Hadley, M. (1999) 'Quality of life of stroke survivors.' *Quality of life research : an international journal of quality of life aspects of treatment, care and rehabilitation*. Netherlands, 8(4) pp. 293–301.

King, R. B. (1996) 'Quality of Life After Stroke.' *Stroke*, 27(9) pp. 1467–1472.

Korpela, K. M., Ylén, M., Tyrväinen, L. and Silvennoinen, H. (2008) 'Determinants of restorative experiences in everyday favorite places.' *Health & place*. Elsevier, 14(4) pp. 636–652.

Kraemer, W. J. and Ratamess, N. A. (2004) 'Fundamentals of resistance training: progression and exercise prescription.' *Medicine and science in sports and exercise*. United States, 36(4) pp. 674–688.

Kramer, S. Ms., Johnson, L. P., Bernhardt, J. P. and Cumming, T. P. (2016) 'Energy Expenditure and Cost During Walking After Stroke: A Systematic Review.' *Archives of Physical Medicine and Rehabilitation*, 97(4) pp. 619–632.

Lance, J. W. (1980) 'The control of muscle tone, reflexes, and movement: Robert Wartenberg Lecture.' *Neurology*, 30(12) pp. 1303–1313.

Langhammer, B. and Stanghelle, J. K. (2010) 'Exercise on a treadmill or walking outdoors? A randomized controlled trial comparing effectiveness of two walking exercise programmes late after stroke.' *Clinical rehabilitation*. England, 24(1) pp. 46–54.

Laufer, Y. (2004) 'The use of walking aids in the rehabilitation of stroke patients.' *Reviews in Clinical Gerontology*. 2005/05/09, Cambridge University Press, 14(2) pp. 137–144.

Lenzi, G. L., Altieri, M. and Maestrini, I. (2008) 'Post-stroke depression.' *Revue neurologique*. France, 164(10) pp. 837–840.

Leslie, E., Cerin, E. and Kremer, P. (2010) 'Perceived neighborhood environment and park use as mediators of the effect of area socio-economic status on walking behaviors.' *Journal of physical activity and health*. Human Kinetics, Inc., 7(6) pp. 802–810.

Leung, L. Y., Melkumova, E. and Thaler, D. E. (2017) 'Longitudinal Care for Young Adults With Stroke.' *JAMA Neurology*, 74(10) pp. 1163–1164.

Li, S., Francisco, G. E. and Zhou, P. (2018) 'Post-stroke Hemiplegic Gait: New Perspective and Insights.' *Frontiers in physiology*. Switzerland, 9 p. 1021.

Lin, P.-Y., Yang, Y.-R., Cheng, S.-J. and Wang, R.-Y. (2006) 'The relation between ankle impairments and gait velocity and symmetry in people with stroke.' *Archives of physical medicine and rehabilitation*. United States, 87(4) pp. 562–568.

Logan, P. A., Gladman, J. R. F., Avery, A., Walker, M. F., Dyas, J. and Groom, L. (2004) 'Randomised controlled trial of an occupational therapy intervention to increase outdoor mobility after stroke.' *BMJ (Clinical research ed.)*, 329(7479) pp. 1372–1375.

Lord, S. E., McPherson, K., McNaughton, H. K., Rochester, L. and Weatherall, M. (2004) 'Community ambulation after stroke: how important and obtainable is it and what measures appear predictive?' *Archives of physical medicine and rehabilitation*. United States, 85(2) pp. 234–239.

Lord, S. E. and Rochester, L. (2005) 'Measurement of community ambulation after stroke: current status and future developments.' *Stroke*. Am Heart Assoc, 36(7) pp. 1457–1461.

Lovibond, S. H. and Lovibond, P. F. (1996) *Manual for the depression anxiety stress scales*. Psychology Foundation of Australia.

Luengo-Fernandez, R., Violato, M., Candio, P. and Leal, J. (2020) 'Economic burden of stroke across Europe: A population-based cost analysis.' *European stroke journal*, 5(1) pp. 17–25.

Maaijwee, N. A. M. M., Rutten-Jacobs, L. C. A., Schaapsmeerders, P., van Dijk, E. J. and de Leeuw, F.-E. (2014) 'Ischaemic stroke in young adults: risk factors and long-term consequences.' *Nature reviews. Neurology*. England, 10(6) pp. 315–325.

Maaijwee, N. A., Tendolkar, I., Rutten-Jacobs, L. C., Arntz, R. M., Schaapsmeerders, P., Dorresteijn, L. D., Schoonderwaldt, H. C., van Dijk, E. J. and de Leeuw, F. E. (2016) 'Long-term depressive symptoms and anxiety after transient ischaemic attack or ischaemic stroke in young adults.' *Eur J Neurol*, 23(8) pp. 1262–1268.

Maas, J., Verheij, R. A., Spreeuwenberg, P. and Groenewegen, P. P. (2008) 'Physical activity as a possible mechanism behind the relationship between green space and health: a multilevel analysis.' *BMC public health*, 8(1) p. 206.

MacGregor, J. (1981) 'The evaluation of patient performance using long-term ambulatory monitoring technique in the domiciliary environment.' *Physiotherapy*. England, 67(2) pp. 30–33.

Mackay, G. J. and Neill, J. T. (2010) 'The effect of "green exercise" on state anxiety and the role of exercise duration, intensity, and greenness: A quasi-experimental study.' *Psychology of sport and exercise*. Elsevier, 11(3) pp. 238–245.

Mackey, J. (2014) 'Evaluation and management of stroke in young adults.' *Continuum (Minneapolis, Minn.)*. United States, 20(2 Cerebrovascular Disease) pp. 352–369.

Mackintosh, C., Griggs, G. and Tate, R. (2018) 'Understanding the growth in outdoor recreation participation: an opportunity for sport development in the United Kingdom.' *Managing Sport and Leisure*. Routledge, 23(4–6) pp. 315–335.

Macko, R. F., Ivey, F. M., Forrester, L. W., Hanley, D., Sorkin, J. D., Katzel, L. I., Silver, K. H. and Goldberg, A. P. (2005) 'Treadmill exercise rehabilitation improves ambulatory function and cardiovascular fitness in patients with chronic stroke: A randomized, controlled trial.' *Stroke*, 36(10) pp. 2206–2211.

Madsen, Louise S, Handberg, C., Jensen, C. M. and Nielsen, C. V (2021) 'Community-based rehabilitation approaches in outdoor settings: A systematic review of people with disabilities' and professionals' experiences and perceptions.' *Disability & Society*. Taylor & Francis, 36(7) pp. 1073–1098.

Madsen, Louise Sofia, Poulsen, D. V., Nielsen, C. V. and Handberg, C. (2021) '"It Was Definitely an Eye-Opener to Me"—People with Disabilities' and Health Professionals' Perceptions on Combining Traditional Indoor Rehabilitation Practice with an Urban Green Rehabilitation Context.' *International Journal of Environmental Research and Public Health*. MDPI, 18(11) p. 5994.

Maeda, N., Kato, J., Azuma, Y., Okuyama, S., Yonei, S., Murakami, M. and Shimada, T. (2009) 'Energy expenditure and walking ability in stroke patients: Their improvement by ankle-foot orthoses.' *Isokinetics and Exercise Science*. IOS Press, 17 pp. 57–62.

Maki, B. E. (1997) 'Gait changes in older adults: predictors of falls or indicators of fear.' *Journal of the American Geriatrics Society*. United States, 45(3) pp. 313–320.

Mallick, A. A. and O'Callaghan, F. J. K. (2009) 'The epidemiology of childhood stroke.' *European Journal of Paediatric Neurology*, 14(3) pp. 197–205.

Mansfield, A., Wong, J. S., McIlroy, W. E., Biasin, L., Brunton, K., Bayley, M. and Inness, E. L. (2015) 'Do measures of reactive balance control predict falls in people with stroke returning to the community?' *Physiotherapy*. Elsevier, 101(4) pp. 373–380.

Marini, C., Russo, T. and Felzani, G. (2010) 'Incidence of stroke in young adults: a review.' *Stroke research and treatment*. SAGE-Hindawi Access to Research, 2011, December, p. 535672.

Marini, C., Totaro, R., De Santis, F., Ciancarelli, I., Baldassarre, M. and Carolei, A. (2001) 'Stroke in young adults in the community-based L'Aquila registry: incidence and prognosis.' *Stroke*. United States, 32(1) pp. 52–56.

Marsh, A. P., Katula, J. A., Pacchia, C. F., Johnson, L. C., Koury, K. L. and Rejeski, W. J. (2006) 'Effect of treadmill and overground walking on function and attitudes in older adults.' *Medicine & Science in Sports & Exercise*. LWW, 38(6) pp. 1157–1164.

Maujean, A., Davis, P., Kendall, E., Casey, L. and Loxton, N. (2014) 'The daily living self-efficacy scale: a new measure for assessing self-efficacy in stroke survivors.' *Disability and rehabilitation*. England, 36(6) pp. 504–511.

McCluskey, A. and Middleton, S. (2010) 'Delivering an evidence-based outdoor journey intervention to people with stroke: barriers and enablers experienced by community rehabilitation teams.' *BMC health services research*, 10(1) p. 18.

Mehta, S., Pereira, S., Viana, R., Mays, R., McIntyre, A., Janzen, S. and Teasell, R. W. (2012) 'Resistance training for gait speed and total distance walked during the chronic stage of stroke: a meta-analysis.' *Topics in stroke rehabilitation*. England, 19(6) pp. 471–478.

Meijering, L., Lettinga, A. T., Nanninga, C. S. and Milligan, C. (2017) 'Interpreting therapeutic landscape experiences through rural stroke survivors' biographies of disruption and flow.' *Journal of Rural Studies*. Elsevier, 51 pp. 275–283.

van Mierlo, M. L., van Heugten, C. M., Post, M. W. M., Lindeman, E., de Kort, P. L. M. and Visser-Meily, J. M. A. (2014) 'A longitudinal cohort study on quality of life in stroke patients and their partners: Restore4Stroke Cohort.' *International journal of stroke : official journal of the International Stroke Society*. United States, 9(1) pp. 148–154.

Morris, L., Cramp, M. and Turton, A. (2022) 'User perspectives on the future of mobility assistive devices: Understanding users' assistive device experiences and needs.' *Journal of rehabilitation and assistive technologies engineering*. SAGE Publications Sage UK: London, England, 9 p. 20556683221114790.

Morris, R. (2011) 'The psychology of stroke in young adults: the roles of service provision and return to work.' *Stroke research and treatment*, 2011, March, p. 534812.

Mukherjee, D. and Patil, C. G. (2011) 'Epidemiology and the global burden of stroke.' *World neurosurgery*. United States, 76(6 Suppl) pp. S85-90.

Nadeau, S., Betschart, M. and Bethoux, F. (2013) 'Gait analysis for poststroke rehabilitation: the relevance of biomechanical analysis and the impact of gait speed.' *Physical medicine and rehabilitation clinics of North America*. United States, 24(2) pp. 265–276.

Naess, H. M. D. P. and Nyland, H. M. D. (2013) 'Poor Health-related Quality of Life is Associated with Long-term Mortality in Young Adults with Cerebral Infarction.' *Journal of Stroke and Cerebrovascular Diseases*, 22(7) pp. e79–e83.

Nascimento, L. R., de Oliveira, C. Q., Ada, L., Michaelsen, S. M. and Teixeira-Salmela, L. F.

(2015) 'Walking training with cueing of cadence improves walking speed and stride length after stroke more than walking training alone: a systematic review.' *Journal of Physiotherapy*, 61(1) pp. 10–15.

Neptune, R. R., Kautz, S. A. and Zajac, F. E. (2001) 'Contributions of the individual ankle plantar flexors to support, forward progression and swing initiation during walking.' *Journal of biomechanics*. United States, 34(11) pp. 1387–1398.

Niemi, M. L., Laaksonen, R., Kotila, M. and Waltimo, O. (1988) 'Quality of life 4 years after stroke.' *Stroke*. United States, 19(9) pp. 1101–1107.

Nilsson, J. and Thorstensson, A. (1989) 'Ground reaction forces at different speeds of human walking and running.' *Acta physiologica Scandinavica*. England, 136(2) pp. 217–227.

Nisbet, E. K., Zelenski, J. M. and Murphy, S. A. (2009) 'The nature relatedness scale: Linking individuals' connection with nature to environmental concern and behavior.' *Environment and behavior*, 41(5) pp. 715–740.

Noseworthy, M., Peddie, L., Buckler, E. J., Park, F., Pham, M., Pratt, S., Singh, A., Puterman, E. and Liu-Ambrose, T. (2023) 'The effects of outdoor versus indoor exercise on psychological health, physical health, and physical activity behaviour: a systematic review of longitudinal trials.' *International journal of environmental research and public health*. MDPI, 20(3) p. 1669.

Olney, S. J., Griffin, M. P. and McBride, I. D. (1994) 'Temporal, Kinematic, and Kinetic Variables Related to Gait Speed in Subjects With Hemiplegia: A Regression Approach.' *Physical Therapy*, 74(9) pp. 872–885.

Olney, S. J., Nymark, J., Brouwer, B., Culham, E., Day, A., Heard, J., Henderson, M. and Parvataneni, K. (2006) 'A randomized controlled trial of supervised versus unsupervised exercise programs for ambulatory stroke survivors.' *Stroke*. United States, 37(2) pp. 476–481.

Outermans, J., Pool, J., van de Port, I., Bakers, J. and Wittink, H. (2016) 'What's keeping people after stroke from walking outdoors to become physically active? A qualitative study, using an integrated biomedical and behavioral theory of functioning and disability.' *BMC neurology*, 16(1) p. 137.

Paddle, E. and Gilliland, J. (2016) 'Orange Is the New Green: Exploring the Restorative Capacity of Seasonal Foliage in Schoolyard Trees.' *International journal of environmental research and public health*, 13(5).

Pang, M. Y. C., Charlesworth, S. A., Lau, R. W. K. and Chung, R. C. K. (2013) 'Using aerobic exercise to improve health outcomes and quality of life in stroke: Evidence-based exercise prescription recommendations.' *Cerebrovascular Diseases*, 35(1) pp. 7–22.

Pang, M. Y. C., Eng, J. J., Dawson, A. S., McKay, H. A. and Harris, J. E. (2005) 'A community-based fitness and mobility exercise program for older adults with chronic stroke: a randomized, controlled trial.' *Journal of the American Geriatrics Society*, 53(10) pp. 1667–1674.

Parry, D., Chinnasamy, C. and Micklewright, D. (2012) 'Optic flow influences perceived exertion during cycling.' *Journal of Sport and Exercise Psychology*. Human Kinetics, Inc., 34(4) pp. 444–456.

Pedersen, M. R. L., Bredahl, T. V. G., Elmose-Østerlund, K. and Hansen, A. F. (2022) 'Motives and barriers related to physical activity within different types of built environments: implications for health promotion.' *International Journal of Environmental Research and Public Health*. MDPI, 19(15) p. 9000.

Perry, J. (2010) 'Gait Analysis: Normal and Pathological Function.' *Journal of Sports Science & Medicine* p. 353.

Perry, J., Garrett, M., Gronley, J. K. and Mulroy, S. J. (1995) 'Classification of walking handicap in the stroke population.' *Stroke*, 26(6) pp. 982–989.

Peters, K., Elands, B. and Buijs, A. (2010) 'Social interactions in urban parks: Stimulating social cohesion?' *Urban forestry & urban greening*. Elsevier, 9(2) pp. 93–100.

Platts, M. M., Rafferty, D. and Paul, L. (2006) 'Metabolic Cost of Overground Gait in Younger Stroke Patients and Healthy Controls.' *Medicine and Science in Sports and Exercise*, 38(6) pp. 1041–1046.

Plummer-D'Amato, P., Altmann, L. J. P., Saracino, D., Fox, E., Behrman, A. L. and Marsiske, M. (2008) 'Interactions between cognitive tasks and gait after stroke: a dual task study.' *Gait & posture*. England, 27(4) pp. 683–688.

Plummer, P., Behrman, A. L., Duncan, P. W., Spigel, P., Saracino, D., Martin, J., Fox, E., Thigpen, M. and Kautz, S. A. (2007) 'Effects of stroke severity and training duration on locomotor recovery after stroke: a pilot study.' *Neurorehabilitation and neural repair*. United States, 21(2) pp. 137–151.

Pollock, A., St George, B., Fenton, M. and Firkins, L. (2014) 'Top 10 research priorities relating to life after stroke--consensus from stroke survivors, caregivers, and health professionals.' *International journal of stroke : official journal of the International Stroke Society*. United States, 9(3) pp. 313–320.

Ponto, J. (2015) 'Understanding and Evaluating Survey Research.' *Journal of the advanced practitioner in oncology*. United States, 6(2) pp. 168–171.

Pretty, J., Peacock, J., Hine, R., Sellens, M., South, N. and Griffin, M. (2007) 'Green exercise in the UK countryside: Effects on health and psychological well-being, and implications for policy and planning.' *Journal of Environmental Planning and Management*. Routledge, 50(2) pp. 211–231.

Pretty, J., Peacock, J., Sellens, M. and Griffin, M. (2005) 'The mental and physical health outcomes of green exercise.' *International journal of environmental health research*. England, 15(5) pp. 319–337.

Putaala, J., Metso, A. J., Metso, T. M., Konkola, N., Kraemer, Y., Haapaniemi, E., Kaste, M. and Tatlisumak, T. (2009) 'Analysis of 1008 consecutive patients aged 15 to 49 with first-ever ischemic stroke: the Helsinki young stroke registry.' *Stroke*. United States, 40(4) pp. 1195–1203.

Putaala, J., Yesilot, N., Waje-Andreassen, U., Pitkäniemi, J., Vassilopoulou, S., Nardi, K., Odier, C., Hofgart, G., Engelter, S., Burow, A., Mihalka, L., Kloss, M., Ferrari, J., Lemmens, R., Coban, O., Haapaniemi, E., Maaijwee, N., Rutten-Jacobs, L., Bersano, A., Cereda, C., Baron, P., Borellini, L., Valcarenghi, C., Thomassen, L., Grau, A. J., Palm, F., Urbanek, C., Tuncay, R., Durukan-Tolvanen, A., van Dijk, E. J., de Leeuw, F.-E., Thijs, V., Greisenegger, S., Vemmos, K., Lichy, C., Bereczki, D., Csiba, L., Michel, P., Leys, D., Spengos, K., Naess, H., Bahar, S. Z. and Tatlisumak, T. (2012) 'Demographic and geographic vascular risk factor differences in European young adults with ischemic stroke: the 15 cities young stroke study.' *Stroke*. United States, 43(10) pp. 2624–2630.

Rappe, E. and Topo, Päi. (2007) 'Contact with Outdoor Greenery Can Support Competence Among People with Dementia.' *Journal of Housing For the Elderly*, 21(3–4) pp. 229–248.

Renner, K. E., Peebles, A. T., Socha, J. J. and Queen, R. M. (2022) 'The impact of sampling frequency on ground reaction force variables.' *Journal of Biomechanics*, 135 p. 111034.

Renwick, R. E., Brown, I. E. and Nagler, M. E. (1996) *Quality of life in health promotion and rehabilitation: Conceptual approaches, issues, and applications.* Sage Publications, Inc.

Robinson-Smith, G. and Pizzi, E. R. (2003) 'Maximizing stroke recovery using patient self-care self-efficacy.' *Rehabilitation nursing : the official journal of the Association of Rehabilitation Nurses*. United States, 28(2) pp. 48–51.

Robinson, J. M., Stone, M. H., Johnson, R. L., Penland, C. M., Warren, B. J. and Lewis, R. D. (1995) 'Effects of different weight training exercise/rest intervals on strength, power, and high intensity exercise endurance.' *The Journal of Strength & Conditioning Research*. LWW, 9(4) pp. 216–221.

Roche, N., Bonnyaud, C., Geiger, M., Bussel, B. and Bensmail, D. (2015) 'Relationship between hip flexion and ankle dorsiflexion during swing phase in chronic stroke patients.' *Clinical Biomechanics*. Elsevier, 30(3) pp. 219–225.

Roelker, S. A., Bowden, M. G., Kautz, S. A. and Neptune, R. R. (2019) 'Paretic propulsion as a measure of walking performance and functional motor recovery post-stroke: A review.' *Gait & posture*, 68, February, pp. 6–14.

Roerdink, M. and Beek, P. J. (2011) 'Understanding inconsistent step-length asymmetries across hemiplegic stroke patients: impairments and compensatory gait.' *Neurorehabilitation and neural repair*. United States, 25(3) pp. 253–258.

Rogerson, M., Gladwell, V. F., Gallagher, D. J. and Barton, J. L. (2016) 'Influences of Green Outdoors versus Indoors Environmental Settings on Psychological and Social Outcomes of Controlled Exercise.' *International journal of environmental research and public health*, 13(4) p. 363.

Rosamond, W., Flegal, K., Furie, K., Go, A., Greenlund, K., Haase, N., Hailpern, S. M., Ho, M., Howard, V., Kissela, B., Kittner, S., Lloyd-Jones, D., McDermott, M., Meigs, J., Moy, C., Nichol, G., O'Donnell, C., Roger, V., Sorlie, P., Steinberger, J., Thom, T., Wilson, M. and Hong, Y. (2008) 'Heart Disease and Stroke Statistics—2008 Update.' *Circulation*, 117(4) pp. e25–e146.

Royal College of Nursing Institute (RCNI) (2009) 'Relation between green space and morbidity reinforced.' *Nursing standard (Royal College of Nursing (Great Britain) : 1987) Stand*, 24(12) pp. 16–16.

Rudd, A. G., Bowen, A., Young, G. R. and James, M. A. (2017) 'The latest National clinical guideline for stroke.' *Clinical Medicine, Journal of the Royal College of Physicians of London*, 17(2) pp. 154–155.

Saka, Ö., McGuire, A. and Wolfe, C. (2009) 'Cost of stroke in the United Kingdom.' *Age and Ageing*, 38(1) pp. 27–32.

Sandberg, K., Kleist, M., Falk, L. and Enthoven, P. (2016) 'Effects of Twice-Weekly Intense Aerobic Exercise in Early Subacute Stroke: A Randomized Controlled Trial.' *Archives of physical medicine and rehabilitation*. United States, 97(8) pp. 1244–1253.

Saunders, D. H., Sanderson, M., Hayes, S., Johnson, L., Kramer, S., Carter, D. D., Jarvis, H., Brazzelli, M. and Mead, G. E. (2020) 'Physical fitness training for stroke patients.' *Cochrane Database of Systematic Reviews*. John Wiley & Sons, Ltd, (3).

Saunders, D. H., Sanderson, M., Hayes, S., Kilrane, M., Greig, C. A., Brazzelli, M. and Mead, G. E. (2016) 'Physical fitness training for stroke patients.' *Cochrane Database of Systematic Reviews*, 2016(3) p. CD003316.

Schasberger, M. G., Hussa, C. S., Polgar, M. F., McMonagle, J. A., Burke, S. J. and Gegaris Jr, A. J. (2009) 'Promoting and developing a trail network across suburban, rural, and urban communities.' *American journal of preventive medicine*. Elsevier, 37(6) pp. S336–S344.

Schinkel-Ivy, A., Inness, E. L. and Mansfield, A. (2016) 'Relationships between fear of falling, balance confidence, and control of balance, gait, and reactive stepping in individuals with sub-acute stroke.' *Gait & posture*. Elsevier, 43 pp. 154–159.

Schmid, A., Duncan, P. W., Studenski, S., Lai, S. M., Richards, L., Perera, S. and Wu, S. S. (2007) 'Improvements in speed-based gait classifications are meaningful.' *Stroke*. United States, 38(7) pp. 2096–2100.

Schutt, R. K. (2019) 'Quantitative methods.' *The Wiley Blackwell Companion to Sociology*. Wiley Online Library pp. 39–56.

Schwartz, M. H., Koop, S. E., Bourke, J. L. and Baker, R. (2006) 'A nondimensional normalization scheme for oxygen utilization data.' *Gait & Posture*, 24(1) pp. 14–22.

Selby, S., Hayes, C., O'Sullivan, N., O'Neil, A. and Harmon, D. (2019) 'Facilitators and barriers to green exercise in chronic pain.' *Irish Journal of Medical Science (1971-)*. Springer, 188 pp. 973–978.

Serra, M. C., Treuth, M. S., Hafer-Macko, C. E. and Ryan, A. S. (2016) 'Increased Energy Cost of Mobility in Chronic Stroke.' *Journal of gerontology & geriatric research*, 5(6).

Shipley, J., Luker, J., Thijs, V. and Bernhardt, J. (2018) 'The personal and social experiences of community-dwelling younger adults after stroke in Australia: a qualitative interview study.' *BMJ open*, 8(12) p. e023525.

Shumway-Cook, A. and Woollacott, M. H. (1995) 'Theory and practical applications.' *Motor Control*.

Singleton Jr, R., Straits, B. C., Straits, M. M. and McAllister, R. J. (1988) *Approaches to social research.* Oxford University Press.

Skivington, K., Matthews, L., Simpson, S. A., Craig, P., Baird, J., Blazeby, J. M., Boyd, K. A., Craig, N., French, D. P., McIntosh, E., Petticrew, M., Rycroft-Malone, J., White, M. and Moore, L. (2021) 'A new framework for developing and evaluating complex interventions: update of

Medical Research Council guidance.' *BMJ (Clinical research ed.)*, 374, September, p. n2061.

Slade, S. C., Dionne, C. E., Underwood, M., Buchbinder, R., Beck, B., Bennell, K., Brosseau, L., Costa, L., Cramp, F., Cup, E. H., Feehan, L., Ferreira, M., Forbes, S., Glasziou, P., Habets, B., Harris, S., Hay-Smith, J., Hillier, S., Hinman, R., Holland, A., Honas, M., Kelly, G., Kent, P., Lauret, G. J., Long, A., Maher, C., Morso, L., Osteras, N., Peterson, T., Quinlivan, R., Rees, K., Regnaux, J. P., Rietberg, M., Saunders, D., Skoetz, N., Sogaard, K., Takken, T., Tulder, M. van, Voet, N., Ward, L. and White, C. (2016) 'Consensus on Exercise Reporting Template (CERT): Modified Delphi Study.' *Physical Therapy*, 96(10) pp. 1514–1524.

Smajlović, D. (2015) 'Strokes in young adults: epidemiology and prevention.' *Vascular health and risk management*. Dove Medical Press, 11, February, pp. 157–164.

Snaith, R. P. (2003) 'The Hospital Anxiety And Depression Scale.' *Health and Quality of Life Outcomes*, 1(1) p. 29.

Stanhope, V. A., Knarr, B. A., Reisman, D. S. and Higginson, J. S. (2014) 'Frontal plane compensatory strategies associated with self-selected walking speed in individuals post-stroke.' *Clinical biomechanics (Bristol, Avon)*, 29(5) pp. 518–522.

Stoller, O., de Bruin, E. D., Knols, R. H. and Hunt, K. J. (2012) 'Effects of cardiovascular exercise early after stroke: systematic review and meta-analysis.' *BMC neurology*, 12, June, p. 45.

Suresh, K. (2011) 'An overview of randomization techniques: An unbiased assessment of outcome in clinical research.' *Journal of human reproductive sciences*. Medknow Publications Pvt Ltd, 4(1) pp. 8–11.

Tam, K.-P. (2013) 'Concepts and measures related to connection to nature: Similarities and differences.' *Journal of Environmental Psychology*, 34 pp. 64–78.

Tancredi, L., Martinelli Boneschi, F., Braga, M., Santilli, I., Scaccabarozzi, C., Lattuada, P., Sessa, M., Fumagalli, L., Iurlaro, S., Neromante, I., De Lodovici, M. L., Roccatagliata, D. V, Giacalone, G., Arnaboldi, M., Crespi, V., Agostoni, E., Comi, G. C., Ferrarese, C. and Sterzi, R. (2013) 'Stroke Care in Young Patients.' Baird, A. E. (ed.) *Stroke Research and Treatment*. Hindawi Publishing Corporation, 2013 p. 715380.

Taylor, D., Stretton, C. M., Mudge, S. and Garrett, N. (2006) 'Does clinic-measured gait speed differ from gait speed measured in the community in people with stroke?' *Clin Rehabil*, 20(5) pp. 438–444.

Taylor, L. P. S. and McGruder, J. E. (1996) 'The meaning of sea kayaking for persons with spinal cord injuries.' *The American Journal of Occupational Therapy*. The American Occupational Therapy Association, Inc., 50(1) pp. 39–46.

Teas, J., Hurley, T., Msph, S. G. and Mph, K. O. (2007) 'Walking outside improves mood for healthy postmenopausal women.' *Clinical medicine. Oncology*. SAGE Publications Sage UK: London, England, 1 p. CMO-S343.

Teasell, R. W., McRae, M. P., Foley, N. and Bhardwaj, A. (2001) 'Physical and functional correlations of ankle-foot orthosis use in the rehabilitation of stroke patients.' *Archives of physical medicine and rehabilitation*. United States, 82(8) pp. 1047–1049.

Teixeira-Salmela, L. F., Olney, S. J., Nadeau, S. and Brouwer, B. (1999) 'Muscle strengthening and physical conditioning to reduce impairment and disability in chronic stroke survivors.' *Archives of physical medicine and rehabilitation*. United States, 80(10) pp. 1211–1218.

Terroni, L., Amaro, E., Iosifescu, D. V, Tinone, G., Sato, J. R., Leite, C. C., Sobreiro, M. F. M., Lucia, M. C. S., Scaff, M. and Fráguas, R. (2011) 'Stroke lesion in cortical neural circuits and post-stroke incidence of major depressive episode: a 4-month prospective study.' *The world journal of biological psychiatry : the official journal of the World Federation of Societies of Biological Psychiatry*, 12(7) pp. 539–548.

Thomas, N. and Smith, A. (2008) *Disability, sport and society: An introduction*. Routledge.

Thompson Coon, J., Boddy, K., Stein, K., Whear, R., Barton, J. and Depledge, M. (2011) 'Does participating in physical activity in outdoor natural environments have a greater effect on physical and mental wellbeing than physical activity indoors? A systematic review.' *Journal of Epidemiology and Community Health*, 65(Suppl 2) pp. A38–A38.

Tiemeier, H., van Dijck, W., Hofman, A., Witteman, J. C. M., Stijnen, T. and Breteler, M. M. B. (2004) 'Relationship between atherosclerosis and late-life depression: the Rotterdam Study.' *Archives of general psychiatry*. United States, 61(4) pp. 369–376.

Triguero-Mas, M., Dadvand, P., Cirach, M., Martínez, D., Medina, A., Mompart, A., Basagaña, X., Gražulevičienė, R. and Nieuwenhuijsen, M. J. (2015) 'Natural outdoor environments and mental and physical health: relationships and mechanisms.' *Environment international*, 77 pp. 35–41.

Truelsen, T., Begg, S. and Mathers, C. (2006) 'The global burden of cerebrovascular.' *In Who Int*.

Tyson, S. F., Sadeghi-Demneh, E. and Nester, C. J. (2013) 'A systematic review and meta-analysis of the effect of an ankle-foot orthosis on gait biomechanics after stroke.' *Clinical rehabilitation*. Sage Publications Sage UK: London, England, 27(10) pp. 879–891.

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J. and James, P. (2007) 'Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review.' *Landscape and Urban Planning*, 81(3) pp. 167–178.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A. and Zelson, M. (1991) 'Stress recovery during exposure to natural and urban environments.' *Journal of environmental psychology*. Elsevier, 11(3) pp. 201–230.

Veerbeek, J. M., van Wegen, E., van Peppen, R., van der Wees, P. J., Hendriks, E., Rietberg, M. and Kwakkel, G. (2014) 'What Is the Evidence for Physical Therapy Poststroke? A Systematic Review and Meta-Analysis.' *PLOS ONE*, 9(2) p. e87987.

De Vries, S., Van Dillen, S. M., Groenewegen, P. P. and Spreeuwenberg, P. (2013) 'Streetscape greenery and health: Stress, social cohesion and physical activity as mediators.' *Social science & medicine*. Elsevier, 94 pp. 26–33.

Whear, R., Coon, J. T., Bethel, A., Abbott, R., Stein, K. and Garside, R. (2014) 'What Is the Impact of Using Outdoor Spaces Such as Gardens on the Physical and Mental Well-Being of Those With Dementia? A Systematic Review of Quantitative and Qualitative Evidence.' *Journal of the American Medical Directors Association*, 15(10) pp. 697–705.

White, M. P., Alcock, I., Wheeler, B. W. and Depledge, M. H. (2013) ‘Would you be happier living in a greener urban area? A fixed-effects analysis of panel data.’ *Psychol Sci*, 24(6) pp. 920–928.

White, M. P., Pahl, S., Ashbullby, K. J., Burton, F. and Depledge, M. H. (2015) ‘The Effects of Exercising in Different Natural Environments on Psycho-Physiological Outcomes in Post-Menopausal Women: A Simulation Study.’ *International journal of environmental research and public health*, 12(9) pp. 11929–11953.

Winstein, C. J., Stein, J., Arena, R., Bates, B., Cherney, L. R., Cramer, S. C., Deruyter, F., Eng, J. J., Fisher, B., Harvey, R. L., Lang, C. E., MacKay-Lyons, M., Ottenbacher, K. J., Pugh, S., Reeves, M. J., Richards, L. G., Stiers, W. and Zorowitz, R. D. (2016) ‘Guidelines for Adult Stroke Rehabilitation and Recovery: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association.’ *Stroke*, 47(6) pp. e98–e169.

Winter, D. A. (2009) *Biomechanics and motor control of human movement*. 4th ed., Chichester;Hoboken, N.J; Wiley.

Wonsetler, E. C. and Bowden, M. G. (2017) ‘A systematic review of mechanisms of gait speed change post-stroke. Part 1: spatiotemporal parameters and asymmetry ratios.’ *Topics in stroke rehabilitation*, 24(6) pp. 435–446.

Yavuzer, G., Oken, O., Elhan, A. and Stam, H. J. (2008) ‘Repeatability of lower limb three-dimensional kinematics in patients with stroke.’ *Gait & posture*. England, 27(1) pp. 31–35.

Zelenski, J. M. and Nisbet, E. K. (2012) ‘Happiness and Feeling Connected: The Distinct Role of Nature Relatedness.’ *Environment and Behavior*. SAGE Publications Inc, 46(1) pp. 3–23.

Zukowski, L. A., Feld, J. A., Giuliani, C. A. and Plummer, P. (2019) ‘Relationships between gait variability and ambulatory activity post stroke.’ *Topics in stroke rehabilitation*. England, 26(4) pp. 255–260.

Appendices

NHS and University Ethical Approvals

Appendix 1: Health Research Authority

Ymchwil Iechyd a Gofal Cymru
Health and Care Research Wales

NHS
Health Research Authority

Dr Hannah Jarvis
Department of Life Sciences, Faculty of Science & Engineering
John Dalton Building, Oxford Road
Manchester
M1 5GD

Email: approvals@hra.nhs.uk
HCRW.approvals@wales.nhs.uk

08 September 2020

Dear Dr Jarvis

HRA and Health and Care Research Wales (HCRW) Approval Letter

Study title:	**Stroke in young adults: The influence of an outdoor-walking rehabilitation programme on walking performance and quality of life**
IRAS project ID:	**271699**
Protocol number:	**N/A**
REC reference:	**20/NW/0237**
Sponsor	**Manchester Metropolitan University**

I am pleased to confirm that HRA and Health and Care Research Wales (HCRW) Approval has been given for the above referenced study, on the basis described in the application form, protocol, supporting documentation and any clarifications received. You should not expect to receive anything further relating to this application.

Please now work with participating NHS organisations to confirm capacity and capability, in line with the instructions provided in the "Information to support study set up" section towards the end of this letter.

How should I work with participating NHS/HSC organisations in Northern Ireland and Scotland?
HRA and HCRW Approval does not apply to NHS/HSC organisations within Northern Ireland and Scotland.

If you indicated in your IRAS form that you do have participating organisations in either of these devolved administrations, the final document set and the study wide governance report (including this letter) have been sent to the coordinating centre of each participating nation. The relevant national coordinating function/s will contact you as appropriate.

Please see IRAS Help for information on working with NHS/HSC organisations in Northern Ireland and Scotland.

How should I work with participating non-NHS organisations?
HRA and HCRW Approval does not apply to non-NHS organisations. You should work with your non-NHS organisations to obtain local agreement in accordance with their procedures.

What are my notification responsibilities during the study?

The standard conditions document "*After Ethical Review – guidance for sponsors and investigators*", issued with your REC favourable opinion, gives detailed guidance on reporting expectations for studies, including:

- Registration of research
- Notifying amendments
- Notifying the end of the study

The HRA website also provides guidance on these topics, and is updated in the light of changes in reporting expectations or procedures.

Who should I contact for further information?
Please do not hesitate to contact me for assistance with this application. My contact details are below.

Your IRAS project ID is **271699**. Please quote this on all correspondence.

Yours sincerely,
Matt Rogerson

Approvals Specialist

Email:approvals@hra.nhs.uk

Copy to: *Miss Alison Lloyd*

List of Documents

The final document set assessed and approved by HRA and HCRW Approval is listed below.

Document	*Version*	*Date*
Covering letter on headed paper [Cover Letter]		08 April 2020
Covering letter on headed paper [Response Letter For REC Review]		
Evidence of Sponsor insurance or indemnity (non NHS Sponsors only)		
IRAS Application Form [IRAS_Form_21042020]		21 April 2020
Letter from sponsor [Sponsor Letter Manchester metropolitan University]		07 April 2020
Letters of invitation to participant [Letter of Invitation for participants]	1.0	26 March 2020
Non-validated questionnaire [Three Aims and Three Difficulties Questionnaire]	1.0	26 March 2020
Non-validated questionnaire [Pre-Rehabilitation Questionnaire]	1.0	26 March 2020
Non-validated questionnaire [Post-Rehabilitation Questionnaire]	1.0	30 March 2020
Non-validated questionnaire [1Month Post-Rehabilitation Questionnaire]	1.0	30 March 2020
Other [Risk Assessment Field-Based Data Collection]	1.0	26 February 2020
Other [Risk Assessment Outdoor-walking Programme]	1.0	26 February 2020
Other [Contact Form for Participants]	1.0	26 March 2020
Other [Medical Questionnaire for Participants]	1.0	26 March 2020
Other [Keith Lee Instructor CV]	1.0	15 June 2020
Other [Rebecca Clarke Instructor and Work CV]	1.0	15 June 2020
Other [Keith Lee Current DBS]	1.0	15 June 2020
Other [Keith Lee First Aid Certificate]	1.0	15 June 2020
Other [Keith Lee Mountain Leadership Award Certificate]	1.0	15 June 2020
Other [Keith Lee MLTB Disability Awareness Certificate]	1.0	15 June 2020
Other [Keith Lee Mountain Bike Leadership Award Certificate]	1.0	15 June 2020
Other [Keith Lee Single Pitch Award Certificate]	1.0	15 June 2020
Other [Rebecca Clarke Current DBS]	1.0	15 June 2020
Other [Rebecca Clarke First Aid Certificate]	1.0	15 June 2020
Other [Rebecca Clarke Evidence of Mountain Leadership Training]	1.0	15 June 2020
Other [Rebecca Clarke Sports Leadership Award Level 2 Certificate]	1.0	15 June 2020
Other [Rebecca Clarke Mountain Bike Leadership Award Certificate]	1.0	15 June 2020
Other [Rebecca Clarke Paddlesport Instructor Award Certificate]	1.0	15 June 2020
Participant consent form [Consent Form]	1.0	26 March 2020
Participant information sheet (PIS) [PIS]	1.1	01 June 2020
Research protocol or project proposal [Protocol]	1.1	01 June 2020
Sample diary card/patient card [Intervention Exercise Diary]	1.1	15 June 2020
Sample diary card/patient card [Control Light stretches booklet]	1.1	15 June 2020
Schedule of Events or SoECAT	1	14 May 2020
Summary CV for Chief Investigator (CI) [CV for CI]		08 April 2020
Summary CV for student [CV for student]		08 April 2020
Summary CV for supervisor (student research) [CV for Supervisor]		08 April 2020
Summary, synopsis or diagram (flowchart) of protocol in non technical language [3-Month Outdoor-Walking Rehabilitation	1.1	01 June 2020

Appendix 2: Manchester Metropolitan University Ethical Approval

11/09/2020

Manchester Metropolitan University

Project Title: Stroke in young adults: outdoor-walking rehabilitation programme- a randomised clinical trial

EthOS Reference Number: 25526

Certification

Dear Rebecca Clarke,

The above application was reviewed by the Research Ethics and Governance Team and on the 11/09/2020, was certified. The certification is in place until the end of the project and is based on the documentation submitted with your application.

Application Documents

Document Type	File Name	Date	Version
Additional Documentation	SIYA_CI_InternalAgreement_26March2020_RC_v1.0	26/03/2020	1.0
Additional Documentation	SIYA_MMU_Research_Insurance_Checklist_26March2020_RC_v1.0	26/03/2020	1.0
Additional Documentation	SIYA_LetterOfInvitation_26March2020_RCv1.0	26/03/2020	1.0
Additional Documentation	SIYA_ConsentForm_26March2020_RCv1.0	26/03/2020	1.0
Additional Documentation	SIYA_ContactForm_26March2020_RCv1.0	26/03/2020	1.0
Additional Documentation	SIYA_Medical_Questionnaire_26March2020RCv1.0	26/03/2020	1.0
Additional Documentation	SIYA_CaSM_26March2020_RCv1.0	26/03/2020	1.0
Additional Documentation	SIYA_NR_26March2020_RCv1.0	26/03/2020	1.0
Additional Documentation	SIYA_SAQOL_26March2020_RCv1.0	26/03/2020	1.0
Additional Documentation	SIYA_ScheduleEvents_ABUHB_26march2020_RC_v1.0	26/03/2020	1.0
Additional Documentation	SIYA_ScheduleEvents_CwmTafUHB_26march2020_RC_v1.0	26/03/2020	1.0
Additional Documentation	SIYA_ScheduleEvents_PowysTHB_26march2020_RC_v1.0	26/03/2020	1.0
Additional Documentation	SIYA_ScheduleEvents_SBUHB_26march2020_RC_v1.0	26/03/2020	1.0
Additional Documentation	SIYA_RA_FieldBasedDataCollection_26March2020_RCv1.0	26/03/2020	1.0
Additional Documentation	SIYA_RA_OutdoorWalkingProgramme_26March2020_RCv1.0	26/03/2020	1.0
Additional Documentation	SIYA CV_Clarke (Researcher)	26/03/2020	1.0
Additional Documentation	SIYA_ThreeAims_ThreeDifficulties_30March2020_RCv1.0	30/03/2020	1.0
Additional Documentation	SIYA_PreRehabQuestionnaire_30March2020_RCv1.0	30/03/2020	1.0
Additional	SIYA_PostRehabQuestionnaire_30March2020_RCv1.0	30/03/2020	1.0

Page 1 of 2

Documentation			
Additional Documentation	SIYA_1MFollowUp_PostRehabQuestionnaire_30March2020_RCv1.0	30/03/2020	1.0
Additional Documentation	271699_Stroke in Young Adults_Sponsor Letter_v1.0 07Apr2020_SIGNED	07/04/2020	1.0
Additional Documentation	Evidence_of_ClinicalTrials_Insurance_2020	07/04/2020	1.0
Additional Documentation	Evidence_of_Sponsor_Insurance	07/04/2020	1.0
Additional Documentation	SIYA_Protocol_01June2020_RCv1.1	01/06/2020	1.1
Additional Documentation	SIYA_PIS_01June2020_RCv1.1	01/06/2020	1.1
Additional Documentation	SIYA_3Month_OutdoorWalkingRehbilitationProgramme_01June2020_RCv1.1	01/06/2020	1.1
Additional Documentation	SIYA_Intervention_ExerciseDiary_15June2020_RCv1.1	15/06/2020	1.1
Additional Documentation	SIYA_Control_LightStretchesBooklet_15June2020_RCv1.1	15/06/2020	1.1
Additional Documentation	20-NW-0237 REC_Favourable_opinion_letter_11August2020	11/08/2020	1.0
Additional Documentation	SIYA_OID_GENERIC_12August2020_RC_v1.0	12/08/2020	1.0
Additional Documentation	IRASForm_271699_20August2020	20/08/2020	1.0
Additional Documentation	271699_(Approval)_Letter_of_HRA_Approval	08/09/2020	1.0

Conditions of certification

The Research Ethics and Governance Team would like to highlight the following conditions

Adherence to Manchester Metropolitan University's Policies and procedures

This certification is conditional on adherence to Manchester Metropolitan University's Policies, Procedures, guidance and Standard Operating procedures. These can be found on the Manchester Metropolitan University Research Ethics and Governance webpages.

Amendments

If you wish to make a change to this approved application, you will be required to submit an amendment in accordance with Manchester Metropolitan University guidelines. Please contact the Research Ethics and Governance team for advice around how to do this.

We wish you every success with your project.

Research Ethics and Governance Team

Questionnaires

Appendix 3: Stroke and Aphasia Quality of Life Scale

Stroke Aphasia Quality of Life Scale (SAQOL 49-Item)

Study ID:

Scoring: each item shall be scored with the following key	
Total help – Could not do it at all – Strongly agree	**1**
A lot of help - A lot of trouble - Moderately agree	**2**
Some help - Some trouble - Neither agree nor disagree	**3**
A little help - A little trouble - Moderately disagree	**4**
No help needed - No trouble at all - Strongly disagree	**5**

Energy

1. I fee tired most of the time.	
2. I have to stop and rest during the day.	
3. I am too tired to do what I wanted to do.	

Family Roles

1. I didn't join in activities just for fun with my family.	
2. I feel I am a burden to my family.	
3. My physical condition interfered with my personal life.	

Language

1. Do you have trouble speaking? For example, get stuck, stutter, stammer, or slur your words?	
2. Do you have trouble speaking clearly enough to use the telephone?	
3. Do other people have trouble in understanding what you said?	
4. Do you have trouble finding the word you wanted to say?	
5. Do you have to repeat yourself so others could understand you?	

Mobility

1. Do you have trouble walking?	
2. Do you lose your balance when bending over to or reaching for something?	
3. Do you have trouble climbing stairs?	
4. Do you have to stop and rest more than you would like when walking or using a wheelchair?	

SAQOL 49-item date of issue: **17/06/2021**
SAQOL 49-item version number: **V1.1**
IRAS Project ID: **271699**

5. Do you have trouble with standing?	
6. Do you have trouble getting out of a chair?	

Mood

1. I feel discouraged about my future.	
2. I am not interested in other people or activities.	
3. I feel withdrawn from other people.	
4. I have little confidence in myself.	
5. I am not interested in food.	

Rebecca Clarke (12089492@stu.mmu.ac.uk) is signed in

Personality

1. I am irritable.	
2. I am impatient with others.	
3. My personality has changed.	

Self Care

1. Do you need help preparing food?	
2. Do you need help eating? For example, cutting food or preparing food?	
3. Do you need help getting dressed? For example, putting on socks or shoes, buttoning buttons, or zipping?	
4. Do you need help taking a bath or a shower?	
5. Do you need help to use the toilet?	

Social Roles

1. I don't go out as often as I would like.	
2. I do my hobbies and recreation for shorter periods than I would like.	
3. I don't see as many of my friends as I would like.	
4. I have sex less often than I would like.	
5. My physical condition interfered with my social life.	

Thinking

1. It is hard for me to concentrate.	
2. I have trouble remembering things.	
3. I have to write things down to remember them.	

Upper Extremity Function

1. Do you have trouble writing or typing?	
2. Do you have trouble putting on socks?	
3. Do you have trouble buttoning buttons?	
4. Do you have trouble zipping a zipper?	
5. Do you have trouble opening a jar?	

Vision

1. Do you have trouble seeing the television well enough to enjoy a show?	
2. Do you have trouble reaching things because of poor eyesight?	
3. Do you have trouble seeing things off to one side?	

Work/Productivity

1. Do you have trouble doing daily work around the house?	
2. Do you have trouble finishing jobs that you started?	
3. Do you have trouble doing the work you used to do?	

1. Find it hard to make decisions	
2. Have language problems that affect family life	
3. Have language problems that affect social life	

TOTAL SCORE

SAQOL 49-item date of issue: **17/06/2021**
SAQOL 49-item version number: **V1.1**
IRAS Project ID: **271699**

Appendix 4: Confidence after Stroke Measure

Confidence after Stroke Measure (CaSM 27-Item)

Study ID:

Please rate your level of AGREEMENT with a tick ✓

Self-confidence		Strongly Agree	Agree	Disagree	Strongly Disagree
I feel robbed of my identity	-C1.1	0 ☐	1 ☐	2 ☐	3 ☐
I feel less capable	-C1.2	0 ☐	1 ☐	2 ☐	3 ☐
I feel alone	-C1.3	0 ☐	1 ☐	2 ☐	3 ☐
It is hard for me to achieve my goals	-C1.4	0 ☐	1 ☐	2 ☐	3 ☐
I am able to do things as well as most people	+C1.5	3 ☐	2 ☐	1 ☐	0 ☐
I get frustrated when I can't do as much as I want to	-C1.6	0 ☐	1 ☐	2 ☐	3 ☐
It bothers me that I can't do things like I used to	-C1.7	0 ☐	1 ☐	2 ☐	3 ☐
It is hard to find a hobby that I value	-C1.8	0 ☐	1 ☐	2 ☐	3 ☐
I avoid important everyday tasks	-C1.9	0 ☐	1 ☐	2 ☐	3 ☐

Please rate your level of AGREEMENT with a tick ✓

Positive Attitude		Strongly Agree	Agree	Disagree	Strongly Disagree
I believe I have inner strength	+C2.1	3 ☐	2 ☐	1 ☐	0 ☐
I believe you can do anything if you try hard enough	+C2.2	3 ☐	2 ☐	1 ☐	0 ☐
My attitude helps me to be confident	+C2.3	3 ☐	2 ☐	1 ☐	0 ☐
I manage to solve problems if I try hard enough	+C2.4	3 ☐	2 ☐	1 ☐	0 ☐
I am able to push myself	+C2.5	3 ☐	2 ☐	1 ☐	0 ☐
I believe I can achieve what I want to	+C2.6	3 ☐	2 ☐	1 ☐	0 ☐
I feel comfortable looking in a mirror	+C2.7	3 ☐	2 ☐	1 ☐	0 ☐
I think positively about myself	+C2.8	3 ☐	2 ☐	1 ☐	0 ☐

Please rate your level of AGREEMENT with a tick ✓

Social Confidence		Strongly Agree	Agree	Disagree	Strongly Disagree
I feel other people judge how I look	-C3.1	0 ☐	1 ☐	2 ☐	3 ☐
I am worried about how others see me	-C3.2	0 ☐	1 ☐	2 ☐	3 ☐
I feel terrified meeting people I don't know	-C3.3	0 ☐	1 ☐	2 ☐	3 ☐
I feel home is the only place where I am safe	-C3.4	0 ☐	1 ☐	2 ☐	3 ☐
I feel scared to go out	-C3.5	0 ☐	1 ☐	2 ☐	3 ☐
I do not feel comfortable in public places	-C3.6	0 ☐	1 ☐	2 ☐	3 ☐
I feel people speak down to me	-C3.7	0 ☐	1 ☐	2 ☐	3 ☐
I do not feel able to attend social events	-C3.8	0 ☐	1 ☐	2 ☐	3 ☐
I am confident enough to leave the house	+C3.9	3 ☐	2 ☐	1 ☐	0 ☐
Other people's comments knock my confidence	-C3.10	0 ☐	1 ☐	2 ☐	3 ☐

Appendix 5: Nature-relatedness Scale

Nature-Relatedness Scale (21-Item)

Study ID:

Instructions: For each of the following, please rate the extent to which you agree with each statement, using the scale from 1 to 5 as shown below. Please respond as you really feel, rather than how you think "most people" feel.

1 Disagree strongly	2 Disagree a little	3 Neither agree or disagree	4 Agree a little	5 Agree strongly

1. I enjoy being outdoors, even in unpleasant weather.		12. I am not separate from nature, but a part of nature.	
2. Some species are just meant to die out or become extinct.		13. The thought of being deep in the woods.	
3. Humans have the right to use natural resources any way we want.		14. My feelings about nature do not affect how I live my life.	
4. My ideal vacation spot would be a remote, wilderness area.		15. Animals, birds and plants should have fewer rights than humans.	
5. I always think about how my actions affect the environment.		16. Even in the middle of the city, I notice nature around me.	
6. I enjoy digging in the earth and getting dirt on my hands.		17. My relationship with nature is an important part of who I am.	
7. My connection to nature and the environment is a part of my spirituality.		18. Conservation is unnecessary because nature is strong enough to recover from any human impact.	
8. I am very aware of environmental issues.		19. The state of non-human species is an indicator of the future for humans.	
9. I take notice of wildlife wherever I am.		20. I think a lot about the suffering of animals.	
10. I do not often go out in nature.		21. I feel very connected to all living things and the earth	
11. Nothing I do will change problems in other places on the planet			

NR 21-item date of issue: **17/06/2021**
NR 21-item version number: **V1.1**
IRAS Project ID: **271699**

Appendix 6: Three Aims and Three Difficulties

Three Aims and Three Difficulties

Study ID:

Title of Project: Stroke in young adults: the influence of an outdoor-walking rehabilitation programme on walking performance and quality of life

The purpose of this questionnaire is to ensure that our research is personalised to those who have had a stroke. Therefore, we would like you to, in your own words, write three aims that you hope to achieve and three things that you find difficult (e.g walking or doing the shopping) since you have had a stroke

Aims

1. __________

2. __________

3. __________

Difficulties

1. __________

2. __________

3. __________

SIYA three aims and difficulties date of issue: 17/06/2021
SIYA three aims and difficulties version number: **V1.1**
IRAS Project ID: 271699

Appendix 7: Pre-Rehabilitation Questionnaire

Pre-Rehabilitation Questionnaire

Study ID:

Title of Project: Stroke in young adults: the influence of an outdoor-walking rehabilitation programme on walking performance and quality of life

We have sent this questionnaire to you in order to find out whether you participate in outdoor physical activity and how you feel towards outdoor physical activity.

1. Do you participate in outdoor physical activity? Please explain your answer.

2. How confident do you feel to walk outdoors? Please explain your answer.

3. How do activities of daily living (e.g walking to the shops, completing daily errands) affect you? Please explain your answer.

4. Do you experience any difficulties walking outdoors? Please explain your answer.

SIYA Pre-rehabilitation date of issue: 17/06/2021
SIYA Pre-rehabilitation version number: **V1.1**
IRAS Project ID: 271699

Appendix 8: Post-Rehabilitation Questionnaire

Post-Rehabilitation Questionnaire

Study ID:

Title of Project: Stroke in young adults: the influence of an outdoor-walking rehabilitation programme on walking performance and quality of life

We have sent this questionnaire to you in order to find out whether the outdoor-walking rehabilitation programme has influenced your day-to-day activities, if you engage in outdoor activity, and if so, what it includes.

1. Do you participate in outdoor physical activity? Please explain your answer.

____

____

____

____

2. How confident do you feel to walk outdoors? Please explain your answer.

____

____

____

____

3. How do activities of daily living (e.g walking to the shops, completing daily errands) affect you? Please explain your answer.

____

____

____

____

4. Do you experience any barriers that stop you from taking part in outdoor-walking? Please explain your answer.

____

____

____

____

SIYA Post rehabilitation date of issue: 17/06/2021
SIYA Post rehabilitation version number: **V1.1**
IRAS Project ID: 271699

Intervention and control group diaries

Appendix 9: Intervention diary for the case-controlled study

PARC CENEDLAETHOL BANNAU BRYCHEINIOG
BRECON BEACONS NATIONAL PARK

Manchester Metropolitan University

Stroke in Young Adults: The influence of an outdoor-based rehabilitation programme on walking performance and quality of life

A clinical trial

Intervention Group

Personal Identification Number:..

Study Overview and Rehabilitation Programme

Introduction

This research study is investigating the effects of an outdoor-walking rehabilitation programme on walking performance and quality of life of young adults (18-65years) who have had a stroke. This research project, funded by the Brecon Beacons National Park Authority (BBNPA), also aims to improve and promote participation in the outdoors and use the outdoors as a form of long-term rehabilitation for young adults who have had a stroke after routine NHS care. Most of the research and guidelines are currently based on older adults.

Address for Gilwern Outdoor Education Centre:

Ty Mawr Road, Gilwern, Abergavenny, NP7 0EB

If you need to contact the research team for any reason, contact details are below:

Rebecca Clarke (researcher)
Telephone: 07852739609
Email: Rebecca.clarke8@stu.mmu.ac.uk

Hannah Jarvis (Chief investigator)
Email: Hannah.Jarvis@mmu.ac.uk

The rehabilitation programme

The outdoor-walking rehabilitation programme

Equipment

For each outdoor-walking residentials at Gilwern Outdoor Education Centre, a personal equipment list is provided for you in this exercise diary. The majority of equipment will be provided for you by the outdoor centre and research team such as, rucksacks, maps, compasses and trekking poles. However, if you do have your own equipment and wish to use it, that is fine. It is recommended that you wear sturdy footwear (e.g sensible trainers, walking shoes or boots) for this part of the study.

At home exercise and light stretches programme

As these exercises and light stretches will be completed at home, it is yourself who will need to assess the use of space to perform the stretches correctly and exercises prescribed are routine exercises that have been utilised in a number of previous studies. Furthermore, you must be aware to stay within your capabilities and comfortable when safely performing the stretches prescribed.

Week	Monday	Tuesday	Wednesday	Thursday	Friday
One			Week 1: Intervention delivery of outdoor walking programme at Gilwern OEC		
Two	Home-based exercise programme (intervention and control groups)				
Three	Home-based exercise programme (intervention and control groups)				
Four			Week 2: Intervention delivery of outdoor walking programme at Gilwern OEC		
Five	Home-based exercise programme (intervention and control groups)				
Six	Home-based exercise programme (intervention and control groups)				
Seven			Week 3: Intervention delivery of outdoor walking programme at Gilwern OEC		
Eight	Home-based exercise programme (intervention and control groups)				
Nine	Home-based exercise programme (intervention and control groups)				
Ten			Week 4: Intervention delivery of outdoor walking programme in BBNPA run by Gilwern OEC		

Kit List for Outdoor-Walking Residentials

Walking Clothing	• Footwear: these can be sturdy trainers, walking shoes or boots • Waterproofs: A waterproof/ water resistant jacket and waterproof over trousers (these can be borrowed from Gilwern OEC) • Walking trousers and/ or shorts • Walking socks (or use the socks you normally use) • Tops: these can be fast wicking shirts or normal T-shirts • Midlayers: Please pack a fleece or jumper to throw on when we have a break during the walk
Walking Equipment	• Rucksack: These can be supplied by either the research team (Rebecca Clarke) or Gilwern OEC. • Walking poles: These can be supplied by either the research team or Gilwern OEC • Personal first aid kit: please bring a personal first aid kit (any medication, plasters). The researcher (Rebecca Clarke) and Gilwern instructors will be carrying large group first aid kits • Sun hat/ woolly hat/ scarf/ gloves: these are weather dependent
Personal Clothing	• Clothing that is comfortable and that you can change into after the walking activities • Footwear that is comfortable to wear around the centre (e.g slippers, trainers, sandals) • Nightwear/ Pajamas • Smalls (underwear and socks)
Other	• Please bring with you any necessary medication and/ or equipment (e.g. foot orthoses, walking aids) that you require on a daily basis • Please bring a pillow for your own personal comfort • Wash kit! • Camera and/ or other electronics (e.g. iPad, laptop)

Outdoor-Walking Residentials

WEEK 1	Week 1 will be an introduction into the walking activities due to take place in the following residentials. This residential will include short and easy walking routes e.g. 2-3km in length, with no steep gradients or difficult terrain. Other activities when walking will be introduced and include navigation skills training, which will enable regain to regain your energy and to focus your concentration.
WEEK 2	This week will build on the walking and navigation skills that were introduced in week 1. During residential 2, we will keep the walks at the same length (e.g. 2-3km), however we will increase the difficulty of the walk through steeper and harder terrain (e.g. looser ground, more hazards like tree roots). Navigation will also increase slightly in difficulty, include the teaching of pacings and compass and bearing work
WEEK 3	In week 3, we will aim to increase the difficulty of the walks by the length/ duration of walking activities (e.g. 3-4km walks) and continuing the increased difficulty of gradient and terrain by consolidating the skills learnt during week 2
WEEK 4	This is the last residential of the outdoor walking rehabilitation programme. Walks will be 3-4km (or longer) and include more difficult terrain that was introduced in residentials 2 and 3. Navigation and map reading skills will have also increased in difficulty (e.g. compass bearings, pacings) all skills will be brought together during this residential.

Potential Walking Routes

Route name: The Blorenge	Distance: 3.4-5km Height: 50m

Route name: The Orchard Trail	Distance: 3km Height: N/A

Route Name: Tor-y-Foel	Distance: 3.6km Height: 151m

Route name: Henry Vaughan Trail	Distance: 3.5-5km Height: N/A

Potential Walking Routes

			
Route name: Blaen-y-Glyn	Distance: 2.4km Height: N/A	Route name: Gilwern Wharf and Clydach Gorge	Distance: 3.6km Height: N/A
			
Route Name: Allt yr Esgair	Distance: 5km Height: 200m	Route name: Sugarloaf	Distance: 6km Height: 350m

Home Exercise and Stretches Programme

Home exercises and stretches

The home exercises and stretches that you will be asked to complete are for the upper and lower body. These need to be done two times per week for twelve weeks, with no other changes to your activities of daily living and routine care.

Stretches will be used as a warm-up before completing the home exercises. Each stretch needs to be held for 8-20 seconds and completed once on each side. Support and guidance on how to safely perform each of the eight stretches are detailed on pages 16 and 17 (towards the back of this booklet).

All home exercises and stretches have been adapted so that you can complete each stretch with ease, either using a chair or sitting on the floor and they do not require any specialist equipment.

A member of the research team will be in contact with you once-per-week to ask how you are finding the light stretches programme and whether you are able to perform each stretch.

Reporting Physical Activity

Throughout this exercise diary, there are pages available for you to report what outdoor physical and recreational activities with family/ companions or by yourself each week, such as outdoor-walking, swimming, or cycling. Through this study we hope to encourage you to take part in more outdoor physical activities and to monitor the amount of physical activity you do.

Safety

As the home exercises and stretches will be completed at home, it is yourself who will need to assess the use of space to perform the stretches correctly and stretches prescribed are routine stretches that have been utilised in a number of previous studies. Furthermore, you must be aware to stay within your capabilities and comfortable when safely performing the stretches prescribed.

Report of Physical Activity– Week 1

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your first week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Home Exercise Week 1

Session 1: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Session 2: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Report of Physical Activity– Week 2

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your second week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Home Exercise Week 2

Session 3: Balance exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Heel to toe			
Simple side walk			
Single leg stand			

Session 4: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Report of Physical Activity– Week 3

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your third week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Home Exercise Week 3

Session 5: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Session 6: Balance exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Heel to toe			
Simple side walk			
Single leg stand			

Report of Physical Activity– Week 4

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your fourth week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Home Exercise Week 4

Session 7: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Session 8: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Report of Physical Activity– Week 5

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your fifth week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Home Exercise Week 5

Session 9: Balance exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Heel to toe			
Simple side walk			
Single leg stand			

Session 10: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Report of Physical Activity– Week 6

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your sixth week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Home Exercise Week 6

Session 11: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Session 12: Balance exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Heel to toe			
Simple side walk			
Single leg stand			

Report of Physical Activity– Week 7

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your seventh week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Home Exercise Week 7

Session 13: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Session 14: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Report of Physical Activity– Week 8

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your eighth week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Home Exercise Week 8

Session 15: Balance exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Heel to toe			
Simple side walk			
Single leg stand			

Session 16: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Report of Physical Activity– Week 9

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your nineth week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Home Exercise Week 9

Session 17: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Session 18: Balance exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Heel to toe			
Simple side walk			
Single leg stand			

Report of Physical Activity– Week 10

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your tenth week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Home Exercise Week 10

Session 19: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for warm-up/ cool-down and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Session 20: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 29-35 for warm-up/ cool-down and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Upper Body Stretches

Exercise	How to perform stretch correctly	
Inner arm and wrist stretch	Standing or sitting tall. Extend your arm in front with palm down. Bend wrist, pointing hand toward the floor. With your other hand, gently bend your wrist until you feel a mild to moderate stretch in your forearm.	
Shoulder cross-body stretch	standing or sitting tall. Hold one arm above your elbow with your opposite hand, and pull it across your body toward your chest until you feel a stretch in your shoulder. Make sure to keep your elbow below shoulder height.	
Chest stretch	Sitting tall. Place hands behind yourself, holding on to the chair. Gently squeeze shoulders together and hold as tolerated. Stretch felt in chest.	
Seated torso twist stretch	Sitting tall, with both feet flat on ground, begin to rotate upper body left or right, holding the stretch for a comfortable period.	

Lower Body Stretches

Exercise	How to perform stretch correctly	
Ankle rotation	sitting tall or standing with heel on floor, rotate foot clockwise and anti-clockwise, feeling a stretch in the ankle and calf muscle.	
Seated hamstring stretch	Sitting tall on floor or edge of chair. Sit with one leg extended with other leg at 90degree bend at knee (so that the foot is flat on the floor) and reach toward your ankle of the straight leg without feeling uncomfortable. Repeat on other leg	
Seated quadriceps stretch	Sitting tall on chair, sit facing the side and you are able to hold the back of the chair for support. If possible, holding your foot in your hand, slowly bring the foot furthest away from the back of the chair upwards towards your bottom and hold stretch	
Seated long adductor stretch	Sit with both legs straight in front of you, with your back straight. Slowly work your legs apart without feeling uncomfortable. Hold this position as you slowly bend forward at your hips until you feel more resistance, keeping back straight.	

Upper Body Exercises

Push-up progressions			
1. Sitting position, both hands flat on wall/ counter- bring chest to hands, push to extend and straighten arms	2. Standing, both hands on wall, bring chest to hands, push to extend and straighten arms	3. Kneeling incline position, using edge of sofa to push away from (cushioning for knees)	4. Kneeling prone press-up
			

Side arm raise progressions			
1. Sitting position, single straight arm raise to side	2. Sitting position, both arms raise at same time	3. Sitting position, single straight arm raise to side using resistance bands	4. Sitting or standing position, single or both arms raise to the side
			

Upper Body Exercises (continued)

Tricep kickback progressions			
1. Sitting position, single arm at 90degree bend, push back and extend arm	2. Sitting position, both arms at 90degree bend, push back and extend both arms	3. Sitting position, single arm at 90degree bend, pull with resistance bands	4. Standing position, single or both arms with use of resistance bands
			

Bicep curl progressions			
1. Sitting position, single arm at 90degree bend, curl forearm towards shoulder (weight of arm only)	2. Sitting position, both arms at 90degree bend, curl both forearms towards shoulder	3. Sitting position, single arm at 90degree bend, pull with resistance bands	4. Standing position, single or both arms with use of resistance bands
			

Lower Body Exercises

Sit to stand progressions			
1. Chair to standing- use both arms to push up from chair	2. Chair to standing- use one arm to push up from chair	3. Chair to standing- no use of upper body	4. Bodyweight squat- use counter or back of chair to hold for support
			

Calf-raise progressions			
1. Sitting position- bring both heels off floor	2. Standing position- use counter for balance	3. Standing position with no support– bring both heels off the floor	4. Standing position- use stairs for greater range of movement, have heels hang over edge
			

Lower Body Exercises (continued)

Front single leg raise progressions			
1. Sitting position- bring one foot off the floor and straighten leg	2. Sitting position- use of resistance bands for single leg raise	3. Standing position- use counter for balance, flex at	4. Standing, hands on hips, flex knee
			

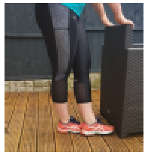
Side single leg raise progressions			
1. Standing position, use counter or wall for balance and support	2. Standing position, use counter or wall for balance, use resistance bands	3. Standing, hands on hips, bring leg to side	4. Use of resistance bands for protocol
			

Balance Exercises

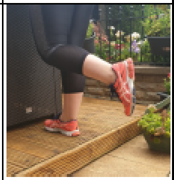
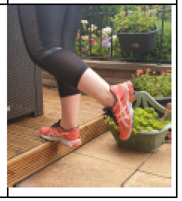
Heel to toe walk progressions

1. Standing stationary, with both hands on wall for support, cross foot over to the other, repeat with other foot	**2.** Standing position, use counter or wall for support, walk heel to toe	**3.** Assistive device, standing position, walk heel to toe	**4.** Standing position, walk heel to toe

Simple side walk progressions

1. Standing stationary, with both hands on wall for support, cross foot over to the other, repeat with other foot	**2.** Standing position, both hands on wall or counter, side step	**3.** Assistive device, standing position, side step	**4.** Standing position, side step
			

Single leg stand progressions

1. Standing stationary, with both hands on wall or counter for support, raise one leg (bend at knee)	**2.** Standing stationary, with one hand on wall for support, raise one leg (bend at knee)	**3.** Standing stationary, hands on hips, raise one leg (bend at knee)	**4.** Standing stationary, use stairs, have heels hang over edge, raise one leg (bend at knee)
			

Appendix 10: Control Diary for the proposed Randomised clinical trial

BRECON BEACONS NATIONAL PARK

Manchester Metropolitan University

Stroke in Young Adults: The influence of an outdoor-based rehabilitation programme on walking performance and quality of life

Light Stretches Booklet

Control group

Personal Identification Number:...

Study Overview

Introduction

This research study is investigating the effects of an outdoor-walking rehabilitation programme on walking performance and quality of life of young adults (18-65years) who have had a stroke. This research project, funded by the Brecon Beacons National Park Authority (BBNPA), also aims to improve and promote participation in the outdoors and use the outdoors as a form of long-term rehabilitation for young adults who have had a stroke after routine NHS care. Most of the research and guidelines are currently based on older adults.

The Study

This study will last ten weeks, which includes an outdoor-walking rehabilitation programme (intervention group) and home exercise and light stretches programme (control group). This booklet includes light stretches for the upper and lower body, for you to follow over the 10-week programme.

If you need to contact the research team for any reason, contact details are below:

Rebecca Clarke (researcher)

Telephone: 07708776874

Email: Rebecca.clarke8@stu.mmu.ac.uk

Hannah Jarvis (co-investigator)

Telephone: 07866033704

Email: Hannah.Jarvis@mmu.ac.uk

Home Exercise and Light Stretches Programme

Home exercises and stretches

The home exercises and stretches that you will be asked to complete are for the upper and lower body. These need to be done two times per week for twelve weeks, with no other changes to your activities of daily living and routine care.

Stretches will be used as a warm-up before completing the home exercises. Each stretch needs to be held for 8-20 seconds and completed once on each side. Support and guidance on how to safely perform each of the eight stretches are detailed on pages 16 and 17 (towards the back of this booklet).

All home exercises and stretches have been adapted so that you can complete each stretch with ease, either using a chair or sitting on the floor and they do not require any specialist equipment.

A member of the research team will be in contact with you once-per-week to ask how you are finding the light stretches programme and whether you are able to perform each stretch.

Reporting Physical Activity

Throughout this exercise diary, there are pages available for you to report what outdoor physical and recreational activities with family/ companions or by yourself each week, such as outdoor-walking, swimming, or cycling.

Safety

As the home exercises and stretches will be completed at home, it is yourself who will need to assess the use of space to perform the stretches correctly and stretches prescribed are routine stretches that have been utilised in a number of previous studies. Furthermore, you must be aware to stay within your capabilities and comfortable when safely performing the stretches prescribed.

Report of Physical Activity– Week 1

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your first week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 1

Session 1: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Session 2: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Report of Physical Activity– Week 2

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your second week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 2

Session 3: Balance exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Heel to toe			
Simple side walk			
Single leg stand			

Session 4: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Report of Physical Activity– Week 3

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your third week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 3

Session 5: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Session 6: Balance exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Heel to toe			
Simple side walk			
Single leg stand			

Report of Physical Activity– Week 4

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your fourth week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 4

Session 7: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Session 8: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Report of Physical Activity– Week 5

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your fifth week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 5

Session 9: Balance exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Heel to toe			
Simple side walk			
Single leg stand			

Session 10: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Report of Physical Activity– Week 6

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your sixth week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 6

Session 11: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Session 12: Balance exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Heel to toe			
Simple side walk			
Single leg stand			

Report of Physical Activity– Week 7

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your seventh week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 7

Session 13: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Session 14: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Report of Physical Activity– Week 8

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your eighth week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 8

Session 15: Balance exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Heel to toe			
Simple side walk			
Single leg stand			

Session 16: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Report of Physical Activity– Week 9

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your nineth week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 9

Session 17: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Session 18: Balance exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 16-22 for stretches and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Heel to toe			
Simple side walk			
Single leg stand			

Report of Physical Activity– Week 10

In the table below, please write down any physical activities you have taken part in and how long you participated in these activities during your tenth week of the outdoor-walking programme.

Weekday	Activity	Duration
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Week 10

Session 19: Upper body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 28-34 for warm-up/ cool-down and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Push-up			
Side arm raise			
Tricep kickback			
Bicep curl			

Session 20: Lower body exercises

Progression level for exercises: 1 2 3 4

Please complete the stretches before completing any exercise

Please see pages 28-34 for warm-up/ cool-down and exercise guidelines

Exercise	Sets	Repetitions	Completed?
Sit to stand			
Calf raise			
Front single leg stand			
Side single leg stand			

Upper Body Stretches

Exercise	How to perform stretch correctly	
Inner arm and wrist stretch	Standing or sitting tall. Extend your arm in front with palm down. Bend wrist, pointing hand toward the floor. With your other hand, gently bend your wrist until you feel a mild to moderate stretch in your forearm.	
Shoulder cross-body stretch	standing or sitting tall. Hold one arm above your elbow with your opposite hand, and pull it across your body toward your chest until you feel a stretch in your shoulder. Make sure to keep your elbow below shoulder height.	
Chest stretch	Sitting tall. Place hands behind yourself, holding on to the chair. Gently squeeze shoulders together and hold as tolerated. Stretch felt in chest.	
Seated torso twist stretch	Sitting tall, with both feet flat on ground, begin to rotate upper body left or right, holding the stretch for a comfortable period.	

Lower Body Stretches

Exercise	How to perform stretch correctly	
Ankle rotation	sitting tall or standing with heel on floor, rotate foot clockwise and anti-clockwise, feeling a stretch in the ankle and calf muscle.	
Seated hamstring stretch	Sitting tall on floor or edge of chair. Sit with one leg extended with other leg at 90degree bend at knee (so that the foot is flat on the floor) and reach toward your ankle of the straight leg without feeling uncomfortable. Repeat on other leg	
Seated quadriceps stretch	Sitting tall on chair, sit facing the side and you are able to hold the back of the chair for support. If possible, holding your foot in your hand, slowly bring the foot furthest away from the back of the chair upwards towards your bottom and hold stretch	
Seated long adductor stretch	Sit with both legs straight in front of you, with your back straight. Slowly work your legs apart without feeling uncomfortable. Hold this position as you slowly bend forward at your hips until you feel more resistance, keeping back straight.	

Upper Body Exercises

Push-up progressions			
1. Sitting position, both hands flat on wall/ counter- bring chest to hands, push to extend and straighten arms	2. Standing, both hands on wall, bring chest to hands, push to extend and straighten arms	3. Kneeling incline position, using edge of sofa to push away from (cushioning for knees)	4. Kneeling prone press-up
			

Side arm raise progressions			
1. Sitting position, single straight arm raise to side	2. Sitting position, both arms raise at same time	3. Sitting position, single straight arm raise to side using resistance bands	4. Standing position, single or both arms raise to the side
			

Upper Body Exercises (Continued)

Tricep kickback progressions			
1. Sitting position, single arm at 90degree bend, push back and extend arm	**2.** Sitting position, both arms at 90degree bend, push back and extend both arms	**3.** Sitting position, single arm at 90degree bend, pull with resistance bands	**4.** Standing position, single or both arms with use of resistance bands
			

Bicep curl progressions			
1. Sitting position, single arm at 90degree bend, curl forearm towards shoulder (weight of arm only)	**2.** Sitting position, both arms at 90degree bend, curl both forearms towards shoulder	**3.** Sitting position, single arm at 90degree bend, pull with resistance bands	**4.** Standing position, single or both arms with use of resistance bands
			

Lower Body Exercises

Sit to stand progressions			
1. Chair to standing- use both arms to push up from chair	**2.** Chair to standing- use one arm to push up from chair	**3.** Chair to standing- no use of upper body	**4.** Bodyweight squat- use counter or back of chair to hold for support
			

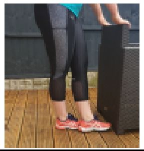
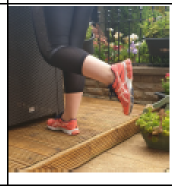
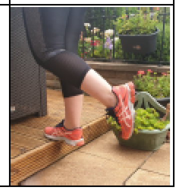
Calf-raise progressions			
1. Sitting position- bring both heels off floor	**2.** Standing position- use counter for balance	**3.** Standing position with no support– bring both heels off the floor	**4.** Standing position- use stairs for greater range of movement, have heels hang over edge
			

Lower Body Exercises (Continued)

Front single leg raise progressions			
1. Sitting position- bring one foot off the floor and straighten leg	2. Sitting position- use of resistance bands for single leg raise	3. Standing position- use counter for balance, flex at	4. Standing, hands on hips, flex knee
			

Side single leg raise progressions			
1. Standing position, use counter or wall for balance and support	2. Standing position, use counter or wall for balance, use resistance bands	3. Standing, hands on hips, bring leg to side	4. Use of resistance bands for protocol
			

Balance Exercises

Heel to toe walk progressions			
1. Standing stationary, with both hands on wall for support, cross foot over to the other, repeat with other foot	2. Standing position, use counter or wall for support, walk heel to toe	3. Assistive device, standing position, walk heel to toe	4. Standing position, walk heel to toe
Simple side walk progressions			
1. Standing stationary, with both hands on wall for support, cross foot over to the other, repeat with other foot	2. Standing position, both hands on wall or counter, side step	3. Assistive device, standing position, side step	4. Standing position, side step
			
Single leg stand progressions			
1. Standing stationary, with both hands on wall or counter for support, raise one leg (bend at knee)	2. Standing stationary, with one hand on wall for support, raise one leg (bend at knee)	3. Standing stationary, hands on hips, raise one leg (bend at knee)	4. Standing stationary, use stairs, have heels hang over edge, raise one leg (bend at knee)
			

Three-month Follow-up Responses

Appendix 11: Participant Testimonies

Participant 4

Being able to have participated on the walking research project was an enjoyable, rewarding, valued and greatly appreciated opportunity having suffered my stroke in January 2020 with resultant left side weakness to my upper and lower limbs my recovery period coincided with the coronavirus pandemic. This therefore did not enable me to receive the routine expected & planned course of post stroke physiotherapy rehab. Being able to participate on the research project therefore provided me with an alternative course of rehab both with the experience and guidance of outdoor walking and the program of home based exercises. Pre study I had been able to re mobilise to some limited extent using a quad stick and with the benefit of an AFO purchased and supplied by the London orthotic company. My walking ability was however hampered by problems of anxiety, balance problems and loss of walking confidence. By following the research study program and walking with other stroke survivors of varying walking ability, I was able to restore my confidence in walking dispense to some extent with using a walking stick and increase my walking distance By following the walking program I am now able to confidently leave the house alone and go walking on various terrain types without any fear of falling over . The program of selected walks of varying degrees of difficulty and terrains enabled me to re establish and re gain my confidence of balance and stamina which has increased my overall walking distance. The camaraderie that developed between stroke survivors (the participant's) the Gilwern walking guides/ instructors & research co-ordinator during the programme & walks also benefited-in providing self determination & goals to complete each individual walk and complete the research program. The Gilwern instructors also provided and added points of great interest during walks and of beneficial relevance to out door walking in terms of walking safety & safely . During walks the instructors also pointed out Features of local historical & geographical interest so much so that I wish to return to the Brecon Beacons national park to further explore & enjoy the natural beauty of the area has to offer.

The program of home based exercises also provided me with a course of extra physio rehab which had been lacking in provision from the health service due to the pandemic . Although I found these difficult initially with perseverance I was able to follow some of the exercises and found the upper limb exercises particularly useful and by following the program by the end of the period I was able to slightly flex my effected left arm where pre program I had no observable movement at all.

The selected base for the study at Gilwern out door education centre was in my opinion an appropriate and ideal location. Being so close to the Brecon Beacons national park and Wye valley it provided an abundance of varied walks and terrains/ gradients to re familiarise- stroke survivors with varying conditions for walking and re testing balance abilities and quickly re establishing walking confidence. The Gilwern out door education centre also provided level step free easy access which was suitable for people with walking difficulties.and all facilities were clean and in efficient working order. Which helped to make accommodation away from home pleasing& comfortable.The Gilwern team were highly motivated to assist and support participants at all times and when any difficulties or individual requests for help were noted or when it was considered that improvements could be made these were quickly and efficiently dealt with without any further need to follow up or question.All staff members on the Gilwern team from catering team / walking instructors were also very welcoming & supportive which made each visit & stay very enjoyable.

Overall being able to participate on the outdoor research project provided me with a very unique opportunity to receive monitored & assessed rehabilitation outside the usual health care setting of a hospital or clinic and has significantly assisted in improving & sustaining my overall wellbeing including my mental well-being which had faltered in my post stroke rehabilitation period & prior to being a participant on the project
The group based structure of the study and being able to converse freely & openly with other stroke survivors both on walks and whilst during social time at the centre also provided a valuable networking opportunity with other stroke survivors this enabled me to gain greater understanding of the varied impacts of strokes and how participants developed their own techniques and acquired support aids to assist with their own rehab and had adapted their lives post stroke .

This ability to network with other stroke survivors I considered to be a considerable positive and extremely valuable gain from being able to participate.

I would welcome and be an interested and willing participant on any further outdoor based research for stroke survivors to possibly further establish how initial participants have progressed post study or to possibly establish whether any other outdoor activity could possibly assist with the rehabilitation of upper limb /lower limb use post stroke.

Participant 1

Twelve like minded people took part in this fantastic research, who were brought together with only one thing in common, and that is STROKE.

We all have the same fears, concerns and worries, but it is lovely to think others, who do not know us, are willing to put in time and effort to help with our recovery, and to give us all a much needed boost. It is humbling to think that we are not forgotten or abandoned, and that our lives still matter.

This type of study, outdoors in beautiful country side, promotes awareness, of not just ourselves, but others and nature. It wakes up part of the brain, to say, " hey, all is not lost, this is a major setback in your life, but LOOK around you, you are definitely not alone "

With this in mind, your attitude changes from, "what’s the point", to " sod it, IAM going to fight this "
For me, it got me to do something I had talked about before the STROKE, but never got round to it. It was just the push I needed, and others can benefit from this, only if more studies are put forward.

We now have a," group chat " where we can have a laugh and a moan, but most importantly, we support each other. This must help take the strain off the health system, because we can ask a question, without bothering our GP, from others going through the same. This is just one of the many bonuses, that can come from this type of study.

This was a well run, well thought out, and a MUCH needed study.

Participant 3

I really enjoyed the daily activities and the interaction with people in a similar position to myself. It's really good to talk about our individual challenges and also receive and offer up advice so that we can all benefit from our individual experiences. The days were challenging but I enjoyed rising to the challenges and really did feel good when we reflected back each day on what we had achieved. It was also good to be helping other people as I am more able bodied than some of the group. My walking speed has most defiantly improved and I have also found that my stamina is also better making me able to walk further and longer. I have also enjoyed making many new friends and we are still all part of the what's app group and chat frequently.

I have gained confidence as I feel more able to be out and about on my own due to the improved fitness level. I also feel more confident to explain my disabilities when out and about when I require help/assistance.

I really enjoyed the group based side of programme and hopefully covered this off in my first answer.

Definitely would like to see more future opportunities, I really enjoyed the programme and have benefited from it in many ways.

Participant 5

Can I first thank **you** and everyone involved in Gilwern OEC and the Brecon Beacons National Park project for the positive experience I got in my efforts to recover from the effects of the Stroke I suffered March 2021.

It helped me in so many ways.

Because the group was at different stages of their rehabilitation, I was able to see where I had been and what was possible with time and effort. By talking and getting to know the group I received encouragement and that helped to motivate me. I felt as part of a team and this has continued after the project as we are all in contact via What's App and still helping each other. The physical aspect was demanding but was made easier by the support of each other and our fantastic support team. We had **fun** and I welcomed that with open arms.

I hope that this project can continue so that it can help Stroke survivor's like us. If there is any opportunity in future for me to attend any more projects like this, please put me at the top of the list.

Participant 11

When I was asked to go on the walking assessment, by my physiotherapist, I was a bit apprehensive, as I was only 8 months after having my stroke. The stroke left me with no sensation in my right leg and arm and I was unable to walk any distance at all, so thought it would be beneficial to go on the course.

I really enjoyed the experience of getting to know other people with the same condition as myself, getting help and tips to build up my confidence, and making friends forever.

The course gave me tremendous amount of confidence, as for the 8 months previous I was at home with my wife for 24/7 and this course gave me the opportunity to be able to be independent for those 3 days, which really built up my confidence.

The walking part of the course was very challenging, but I done it with the help of the guides and the group of people I was with.

I would like to mention Rebecca for her hard work and assistance, also the guides and the staff at Gilwern outdoor centre, who were amazing and very helpful which made the course easier for myself.

Participant 9

This is my thoughts and opinion on THE OUTDOOR REHABILITATION RESEARCH PROJECT, held at the Gilwern Outdoor Centre

Having been on a variety of Stroke Rehabilitation Projects, including the National Exercise Referral Scheme NERS, and Well-being Outdoors, which were all very good in their own way.

The Outdoor Rehabilitation Research Project held at the Gilwern Outdoor Centre was on a different level for the following reasons:- I have broken down the benefit under the three headings associated with fatigue

PHYSICAL: The walking was both rewarding and challenging in such a way that all levels and abilities of physical capability after having strokes was catered for conducted on an individual personal basis.

Even though I hold a Joint Services Expedition Leaders certificate there was no pressure placed on myself to achieve the things I was capable of participating prior to my strokes, which allowed me to set realistic goals.

It was good the way in which the rehabilitation programme allowed me to push my own physical abilities without any pressure and assist others with moral suport when needed.

The walks, weather and underfoot terrain were often challenging yet the sense of achievement was immense.

MENTAL: Being with other stroke survivors who dont necessarily have any physical disabilities associated with stroke, yet understood the mental impact as the stroke has on our well-being was invalueable knowing they also suffer with the mental aspects of stroke, its not just you its common .

EMOTIONAL: The emotional support given by the staff and other participants was second to none.

Even small things have the most adverse affect on a stroke surviors emotional feelings which was something most of the participants had experienced.

I think the Physical, Mental well-being and Emotional support given throughout this project should be available to all stroke survivors who have the ability to walk after their stroke , even if it only very limited, because this project allowed all particianpts to improve thier quality of like after stroke.

My recommendation would be that all Stroke associations and health boards give maximum support to this and other such project in the future.

Participant 7

Hi Rebecca, I would like to give you some feedback on the rehabilitation programme and study run in Gilwern recently, firstly like everyone I did not know what to expect , but during the initial measurement process everything was explained fully as to how the programme would run and what to expect etc.

My lasting impression from the course is the camaraderie that quickly evolved amongst everyone involved , and although we had never met before a willingness to share experiences of our strokes, how we deal with things and what support we get came through clearly and everyone was ready to help wherever they could with any advice , physical help and encouragement when needed. I personally felt that my confidence both mentally and physically was not an issue on joining the group, but I could clearly see in many other members of the group a growing confidence amongst everyone and a clear improvement in ability by the end of the programme, to me this was a massive plus to see this and personally thinking how lucky I had been when suffering my stroke in comparison to others in the group physically, the effect the whole programme had on me was the good feeling when seeing these improvements amongst the group, and the efforts they were putting in to make improvements to their lives.

All of the staff at the Gilwern centre were really good and very understanding and of course yourself and your study group had plenty of patience and were always on hand when needed. I feel that many more people would benefit greatly from attending courses like this in the future and can only praise everything from start to finish, and when I say finish of course it doesn’t end there as we set up a what’s app group to continue to share our experiences and continue to support each other and maybe arrange to meet up for walks or a cuppa!

I would like to thank you all for everything you have done and are currently doing to help people who have suffered strokes at a relatively young age, only good can come from this!

Being out in the fresh air and walking at whatever pace suits you ,either by yourself or even better in company is a great tonic for everyone and any encouragement to people to enable them to do this this should be fully supported in any way it can.

Appendix 12: Testimonies from Family members:

Family member of Participant 4

I attended the research study to support my Husband who was a participant. During my attendance I was able to speak to and observe other stroke survivors. This gave me a greater understanding of the complexities of strokes and the way others have had to adapt their lives to live with the effects. I was able to observe a great camaraderie which developed amongst the group and each were enthused by each other's determination to complete the walks which were very well organised by competent and knowledgeable instructors which included the coordinator.

Following the study my husband has made a noticeable improvement of his walking and also his approach to dealing with the effects of his stroke.

It was a big commitment to attend , but would do it again and encourage anyone who may be given an opportunity to attend any similar study.

Family member of Participant 6

My husband, was invited to join the research study after having had two strokes at the age of… due to a genetic condition.

He was always a very active person, always on the go, whether it be in his full time job as a mechanic, renovating our house or spending time with our children & dogs, he was happiest when busy & being able to do practical things.

Obviously after his first stroke things changed drastically & he was no longer able to do any of the things that he could do previously, after lots of hard work & dedication, being able to mostly regain the use of his right side, fatigue was still a massive issue, he then suffered a 2nd, smaller stroke, which although didn't cause as many physical problems, his fatigue was overwhelming, so he was extremely limited to what he could do.

When he was invited to join the study he was extremely apprehensive, not only about his abilities, but about meeting other stroke survivors too.

Right from the first visit to Gilwern I saw a change in him, he was surprised by what he could achieve, even down to it being the first time he'd been away from me since his strokes, as the visits continued I could tell how much he was enjoying the independence & sense of achievement he felt with every activity, no matter how small.

He met other people who knew how things were for him, especially as due to covid he hadn't had any access to the support that stroke survivors usually are. They understood the fatigue, the cognitive issues, the difficulties with day to day things, that seem so small to the rest of us, but are massive after you've had a stroke!

For me seeing their confidence grow after each visit was wonderful, not only did he know that he wasn't alone, he also began to know & test his own abilities, but not in a gym or at home on a treadmill, in the countryside, visiting different places, walking different terrains, with the company of people who knew what it was like!

He really enjoyed spending time with the other participants of the study, but he also really enjoyed exploring areas that even as fairly 'outdoorsy' people we probably wouldn't have visited as we'd have decided they were 'too much' for him.

He is now back at work & although fatigue is still an issue, he & I recognise the importance of getting outdoors, even if just for a short stroll with the dogs and children.

Having a stroke changes not only the survivors life, but the people around them, it's not the obvious physical issues that are necessarily the most challenging, it's much 'bigger' than that, the research study benefitted our lives as a family & I don't say that lightly, it was about so much more than exercise, it was about realising your abilities, companionship & understanding, those things are priceless. It gave us a little bit of 'Jon' back, although his genetic condition will continue to change our lives, knowing that the experiences he had whilst at Gilwern gave him the confidence to do things he didn't think he could, means he'll continue to have the confidence to try things he doesn't think he can do!

Publications

Appendix 13: Published Abstract 1

Clarke R, Reeves N, Tzoulas K, Cavan G, Griffiths A, Walker L, Rees N, Jackson K, Jarvis H. (2022) Stroke in Young Adults: The feasibility of an outdoor rehabilitation programme investigating walking performance and quality of life [Abstract]. In: European Stroke Organisation Conference.; 4-6 May 2022; Lyon. Accepted

Background

Exercising in natural outdoor natural environments have been associated with better physical and mental health. No rehabilitation programmes exist for young adults who have had a stroke using “outdoor natural environments” to improve health and wellbeing. The aim of this study was to determine the feasibility of conducting a case controlled study testing the effectiveness of an outdoor rehabilitation programme for young adults who have had a stroke.

Methodology

Participants who have had a stroke (n=4) were recruited to participate in a 3-week outdoor-based rehabilitation programme, involving walking, archery and canoeing. Participant and outdoor instructor feedback (enjoyment, delivery and improvements) was captured pre, weekly and post rehabilitation programme using guidelines. Feedback was investigated using thematic analysis by inductive coding. Quality of life was assessed using EuroQol.

Results

Participant feedback (Figure1) suggested that the outdoor rehabilitation programme was enjoyable and motivational due to participating in a stroke specific group with similar impairments. Feedback of the home-based exercises suggested that they disliked completing the planned exercises at home, as it was not group based. Quality of life improved from 70 to 87.5 (EQ-VAS). Instructor feedback suggested archery and canoeing were not feasible to deliver routinely for a larger cohort.

Conclusion

The activities as part of this feasibility study seemed to be well-tolerated and were feasible to deliver with participants who had mild-moderate motor impairments caused by stroke. The group-based design of the intervention was well received.

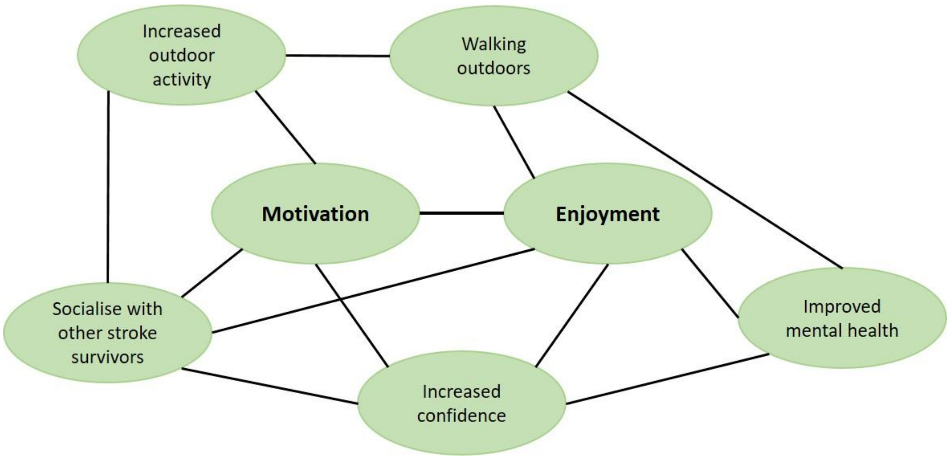


Figure 1. Key themes identified from participant feedback of feasibility study

Appendix 14: Published Abstract 2

Clarke R, Reeves N, Tzoulas K, Cavan G, Griffiths A, Walker L, Rees N, Jackson K, Jarvis H. (2022) Stroke in Young Adults: The influence of an outdoor-walking rehabilitation programme on walking speed, energy cost and quality of life [Abstract]. In: European Stroke Organisation Conference.; 4-6 May 2022; Lyon. Accepted

Background

Twenty-six percent of adults who have had a stroke in the United Kingdom are under 65years of age (defined as young adults). Most are unable to return to employment or participate in social/leisure activities due to difficulties walking. No rehabilitation programmes exist using "outdoor natural environments" for young stroke survivors. Previous research reported exercising outdoors improves physical function for other health conditions. The aim of this study is to investigate if an outdoor-walking rehabilitation programme can improve walking speed and energy cost of young adults who have had a stroke.

Methodology

Participants who had experienced a stroke (18-65years: n=12) were recruited from three health boards in Wales, UK to participate in a ten-week outdoor-walking and home exercise rehabilitation programme. Walking speed and energy cost (using the physiological cost index) was measured during three minutes of walking in indoor and outdoor environments at baseline and post-rehabilitation. Quality of life was assessed using SAQOL.

Results

Stroke participants walked quicker indoors (pre: 0.82m/s, post: 0.91m/s post-intervention (p=0.01)), outdoors (pre: 0.79m/s, post: 0.89m/s (p=0.005)) and more efficiently (indoor, pre: 0.75 beats/m, post: 0.57 beats/m (p=0.56), outdoor, pre: 0.83 beats/m, post: 0.60 beats/m (p=0.168). Overall quality of life improved from 2.76 to 3.21 (p=0.024).

Conclusion

This study highlights the positive role of exercising in outdoor natural environments to promote recovery, improve walking ability and quality of life, following stroke in young adults and the need for natural outdoor environments to be used as settings for an alternative form of rehabilitation.