Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

Assessing the gait, physical activity and quality of life benefits of mobility assistance dogs for children with physical and neurological impairments

Heather Kennedy-Curtin B.Sc. Physio

09826955

Supervisors: Prof. Ciaran Simms

Dr. Michelle Spirtos

Prof. Richard Reilly

Department of Mechanical, Manufacturing and Biomedical Engineering

Trinity College Dublin

A thesis submitted to the University of Dublin in partial fulfilment of the requirements for the Degree of Doctor of Philosophy

Submitted January 2025

Declaration

I, Heather Curtin, hereby declare that this dissertation is entirely my own work and that it has not been submitted as an exercise for a degree at this or any other university.

I have read and I understand the plagiarism provisions in the General Regulations of the University Calendar for the current year, found at http://www.tcd.ie/calendar.

I agree to deposit this thesis in the University's open access institutional repository or allow the library to do so on my behalf, subject to Irish Copyright Legislation and Trinity College Library conditions of use and acknowledgement.

I consent to the examiner retaining a copy of the thesis beyond the examining period, should they so wish (EU GDPR May 2018).

Signed : Heather Curtin

Heather Curtin

Date : September 2024

Abstract

Children with physical and neurological impairments such as cerebral palsy often have difficulty walking. Reduced activity levels and participation restrictions in these children may lead to reduced quality of life, compared to their typically developing peers. A charity in Ireland trains and provides mobility assistance dogs to children aged 6-12 with impaired walking, to help with their balance, gait and mobility. Approximately ten to fifteen mobility assistance dogs are provided per year.

There is literature on the social and psychological benefits of assistance dogs, but the specific benefits of mobility assistance dogs for children and in particular any biomechanical benefits to gait, posture and balance are unknown. This study has been designed to provide qualitative and quantitative assessment of the benefits of the mobility assistance dogs provided.

This study monitored physical activity, gait and quality of life of ten children with physical and neurological impairments aged 6-12 years, during and up to a six-month period. Children's activity levels, gait and quality of life were measured prior to dog placement as a baseline. Following dog placement, activity levels and quality of life were measured after one month, three months and six months. Physical activity was measured using the Stepwatch activity monitor over seven consecutive days. Quality of life was measured using the Cerebral Palsy Quality of Life (CPQoL) outcome measurement tool. Semi-structured qualitative interviews were completed at each of these time points. Children had gait analysis at the Central Remedial Clinic gait laboratory prior to placement of the dog and at six months post dog placement.

In the qualitative interviews, parents perceive substantial benefits for their children in areas including social facilitation, motivation to be active and positive effects on family life. Parents perceive improvement in gait, balance and endurance in children with milder impairment. On assessment of quality of life, the group of ten children showed positive change in the domains: social-wellbeing and acceptance, feelings about functioning and emotional-wellbeing after six months. Children with more impairment showed no change in any domain measured. The group of ten children showed no change to their gait quality, measured by GDI or gait parameters speed, cadence or time in double support from baseline to six month follow up. The group showed a positive change in abdominal and left quadriceps strength, but those with more impairment (Gross Motor Function Classification Scale level III-IV) showed no change in strength measures at follow up. Children who completed a gait analysis while walking with their dog, showed little overall change at follow up. Individual clinically significant change was seen for some children. The group of ten children showed no significant change in physical activity outcomes from pre-dog to six month follow up. Children with milder impairment (GMFCS I-II) spent more time at a higher intensity of physical activity ($p<0.05$) at six month follow up. Children with more impairment (GMFCS III-IV) did not show change in any domain of physical activity measured. Results were highly individual and participant case studies do reflect clinically important positive change for some children, however the weather may have affected physical activity levels.

Dog assisted gait training for children with physical or neurological impairments aged 6-12 leads to measurable benefits in quality of life after six months but does not lead to measurable change in gait or physical activity.

Acknowledgements

I would like to thank the children and families who participated in the study. It was a pleasure meeting this group, I enjoyed our interactions and appreciate the time given to the project. I hope they are all getting on well with their doggies.

To Jennifer Dowler and all of The Dogs for Disabled team. Thank you so much for pursuing and seeking funding for this important research. Jennifer's passion and energy for the children and dogs she works with is admirable. Without Jennifer's drive, none of this research would exist.

To my supervisors, I feel very lucky to have a wonderful team of supervisors and I certainly wouldn't have made it this far without their guidance! Professor Ciaran Simms has been a joy to work with, Ciaran's excellent communication and vision has helped me organise myself (big task) along the way and has lined up the project to be such a nice piece of work. Dr Michelle Spirtos has been so generous with her time and knowledge. I'm delighted to have worked with Michelle on this project. Both Ciaran and Michelle are brilliant communicators and are always so personable, even when personal circumstances came up, there was never a scary professor on the end of the line! I'd also like to thank Mr Richard Reilly for setting up the project and for his support.

To Damien Kiernan, clinical adviser on the project, I wouldn't have got this far without Damien's support. Damien's own work ethic is inspiring, and I hope I can carry over some of his attention skills to hone my own ability to sit still at a desk and write for a bit longer!

I'd like to thank the wider team in the Gaitlab and CRC for all their support throughout this project, Colm for his practical support and ideas, Rory for pointing in me in the direction of 'some research about dogs', Carla, Niamh, Jasmine and all the team for their time and support throughout.

I'd like to thank my own family for their support throughout my meandering and lengthy education. To my wonderful husband Richard, for supporting me in taking on a research project with a young family, Richie has endlessly 'listened' to me talk about the project and could probably write the thesis at this stage. Thank you for your time and patience.

To my gorgeous children Pearse and Amber, who have both known me to be a very busy mum. I'll make sure to share more downtime with you now and less time with a laptop open at the weekend. I hope this work may at some point inspire you to be open minded, curious and give some thought to how you might help those who are less able.

Table of Contents

List of Tables

List of Figures

Publications

1. This study was published in September 2024 in the journal Physical and Occupational Therapy in Pediatrics https://doi.org/10.1080/01942638.2024.2400344.

"The Effect of Mobility Assistance Dogs on Quality of Life in Children with Physical and Neurological Impairments".

2. This abstract was accepted for presentation at European Society of Movement of Analysis Conference (ESMAC) in September 2022 and published in Gait and Posture. https://doi.org/10.1016/j.gaitpost.2022.07.206

''The impact of the training effect of stability dogs on gait in children with neurological or physical impairment using 3D gait analysis''.

3. This study was presented as a poster presentation at The European Academy of Childhood Disability Conference (EACD) 2024 (www.eacd2024.org).

"The impact of mobility assistance dogs on physical mobility, activity levels and social inclusion in children with physical and neurological impairments: A qualitative study of parental perceptions."

4. The following paper is under review in the journal Physical Therapy Reviews, it was submitted to the journal in February 2024.

"The impact of mobility assistance dogs on physical mobility, activity levels and social inclusion in children with physical and neurological impairments: A qualitative study of parental perceptions".

5. This abstract was presented at the Association of Occupational Therapists in Ireland (AOTI) Conference in September 2024 as an oral presentation.

"Mobility assistance dogs for children with cerebral palsy (CP) and neurological impairments: Impact on social participation and family life."

6. The following paper is under review in the Journal of Pediatric Rehabilitation Medicine, submitted in December 2024.

"The effect of mobility assistance dogs on physical activity levels in children with physical and neurological impairments".

List of Abbreviations

MAD	Mobility Assistance Dog
QOL	Quality of Life
AD	Assistance Dog
PA	Physical Activity
GMFCS	Gross Motor Function Classification Scale
GMFM	Gross Motor Function Measure
CP	Cerebral Palsy
CRC	Central Remedial Clinic
TCD	Trinity College Dublin
SDR	Selective Dorsal Rhizotomy
AFO	Ankle Foot Orthotic
IDFD	Irish Dogs for Disabled
3DGA	Three Dimensional Gait Analysis

1. Introduction

1.1. Introduction

This chapter will introduce the background and rationale for this research. Children with physical and neurological impairments are described. Associated reduced walking capacity and physical activity levels are outlined. It will also introduce assistance dogs and how they are to date involved with children with impairments. This chapter will introduce the overall study design and aims of the overall project.

1.2. Background and Rationale

Children with physical and neurological impairments such as cerebral palsy (CP) often have difficulty walking. A child is considered disabled if they have a 'physical or mental impairment which has a substantial and long-term effect on their ability to carry out normal day to day activities' (Disability Discrimination Act 2018) (Aliyu, 2019). CP is a clinical diagnosis which describes a range of disorders due to injury to the developing brain often manifesting as difficulties with movement and posture (Rosenbaum, 2007). It is the most common cause of motor impairment in young children and is reported to occur in 2.1 per 1000 live births (Oskoui et al., 2013). Motor impairments such as CP often lead to difficulties during gait, due to muscle weakness, tightness and impaired motor control (Oskoui et al., 2013).

Children with motor impairments participate in significantly lower levels of habitual physical activity than their peers and less than recommended guidelines (Carlon et al., 2013). Typically, in chronic neurological impairments such as CP, physical activity levels are related to gross motor function (Bjornson et al., 2007) and this level of activity decreases as adulthood approaches (Maher et al., 2007), alongside the Gross Motor Function Measure (GMFM) curve (Rosenbaum et al., 2002).

Reduced activity levels and participation restrictions in children with physical and neurological impairments may lead to a reduced quality of life (QoL) compared to their typically developing peers (Rosenbaum, 2007). It has been shown that QoL is not always directly related to level of function in children with CP (Shelly et al., 2008), as although physical functioning may play a role in QoL, there are other influential domains such as a person's feelings of well-being across many domains including physical, social, emotional and spiritual aspects of life. The social inclusion of children with disabilities is crucial to their development and wellbeing (Odom & Buysse, 2011).

Assistance dogs (ADs) are dogs that are specially trained to undertake a variety of tasks to help mitigate an individual's disabilities. Their role is to allow people to achieve an optimal level of functional independence (Assistance Dogs International[1]). The three most common types of assistance dogs are guide dogs, hearing dogs and mobility assistance dogs (MADs). MADs offer greater independence to people with mobility impairments through practical support, performing tasks such as opening doors, turning on lights and retrieving objects and to provide counterbalance for transitional movements (Assistance Dogs International[1]).

There is evidence to show that ADs can improve social inclusion and perceived QoL in children with disabilities (Bibbo et al., 2019; Crowe et al., 2019). The benefits of animal assisted therapies have been long understood in people with visual impairment (Whitmarsh, 2009). There is an increasing body of literature developing in the area of human – animal interaction in recent years and a growth in the knowledge of expanding roles for service animals and their therapeutic effects (McCune et al., 2014). Although there is evidence of the benefits of ADs on psychosocial factors in families of children with disabilities, the need for further exploration of animal assisted interventions (AAI) and the expanding roles of dogs in therapy has been highlighted as an area for future research (Audrestch et al., 2015).

The charity Irish Dogs for Disabled (IDFD) trains specially bred dogs to assist children and adults with physical and neurological impairments, aiming to help them achieve greater independence. The charity was established in 2007 and has supplied approximately 30 dogs a year since. They train and provide MADs for children who are ambulant, task dogs for wheelchair users and therapy dogs. The charity provides approximately 10 to 15 MADs to families annually to help children aged 6-12 with physical and neurological impairments with their balance, gait and mobility. Approximately 150 MADs have been trained and provided to children in Ireland since the charity was established. This study has been designed to provide qualitative and quantitative investigation of the benefits of the MADs provided. There is literature on the general and psychological benefits of animal therapy which will be covered in the literature review, but the specific benefits of MADs for children and in particular any biomechanical benefits to gait, posture and balance appear to be unknown.

[1] www.assistancedogsinternational.com

1.3. Overview of Methodology

This is an exploratory mixed methods study. This study measured physical activity (PA) and wellbeing of 10 children with physical and neurological impairments aged 6-12 years, during and up to a six-month period. Children's activity levels, gait and QoL were measured prior to dog placement as a baseline, as shown in Figure 1-1.

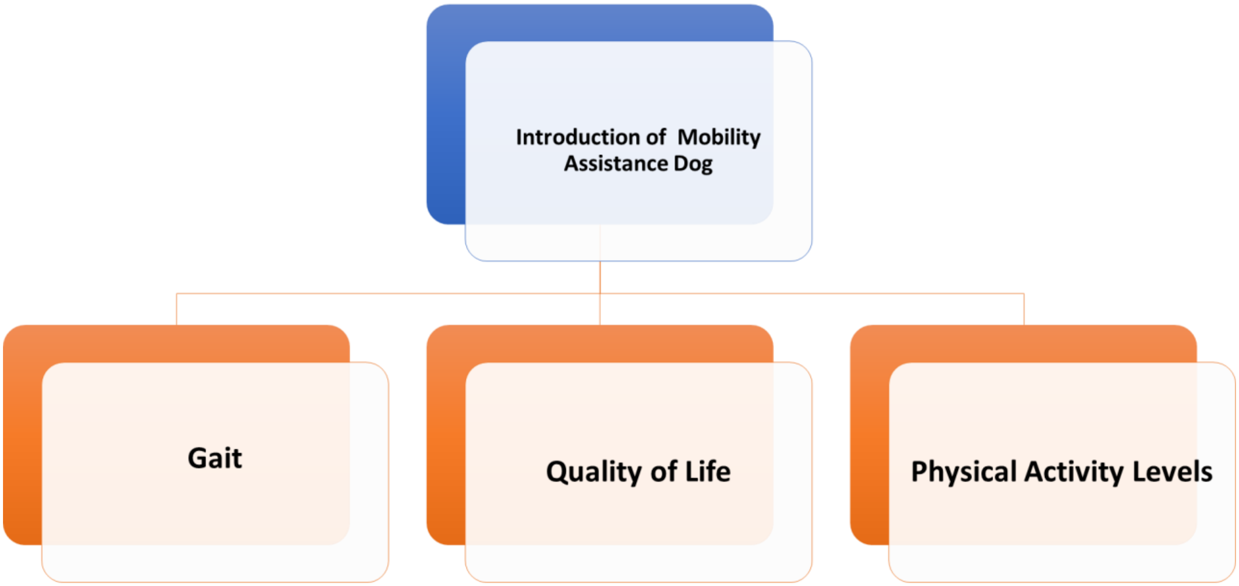


Figure 1-1: Overview of objective data measurement

Following dog placement, activity levels and QoL were measured after one month, three months and six months. PA was measured using a wearable activity monitor over a one-week period. QoL was measured using a validated QoL outcome measurement tool. Semi structured qualitative interviews were completed at each of these time points. Children had gait analysis at the Central Remedial Clinic (CRC) gait laboratory prior to placement of the dog and at six months post dog placement. The charity IDFD were responsible for (i) recruiting the children / families to take part in the project and (ii) for placing and supplying the MADs to the families.

1.4. Aims of the study

Considering the background, this study aimed to analyse if introducing a mobility assistance dog to children with physical or neurological impairments aged 6-12 led to measurable benefits in gait, activity levels and quality of life. Parental perceptions of the impact of the dog will also be measured. Detailed aims are described in Section 2.9.1. Study Aims.

1.5. Overview of the Thesis

Chapter one has provided an introduction to the overall background, need for, and methodology of the study. Chapter two will provide a literature review of the study's relevant areas of interest. Chapter three will give an overview of the study design and the general methods used in all components of the mixed methods study. Chapter four is the qualitative component, a study outlining the parent interviews which were conducted at each time point. Chapter five is a published study on QoL, measured using the Cerebral Palsy Quality of Life questionnaire for children (CPQoL). Chapter six is a study on the gait analysis conducted prior to the children getting a dog and repeated at the six month time point. Chapter seven will cover physical activity monitoring of the ten children over the six month period with their dogs. Chapter eight will give individual case studies for each child from each type of data collection method. Finally, chapter nine will provide a discussion of the overall mixed methods study.

2. Literature Review

2.1. Introduction

This chapter provides a review of the literature in the study's areas of interest. Firstly, an overview of published studies in the use of ADs in disability is presented. This is followed by studies using the data collection methodologies employed in the study: clinical gait analysis and the use of gait analysis in measuring walking with an AD; measuring PA levels in children with impaired walking; an evaluation of the most suitable activity monitors to use to measure PA in this cohort; studies in the area of measuring QoL in paediatric disability and finally qualitative research methodology and relevant studies using thematic analysis data collection techniques will also be covered. Finally, the International Classification of Functioning (ICF) Framework for paediatric therapies are outlined. A summary of the five studies, deemed most relevant to MADs and children with walking impairment, are described in Table 2-1.

2.2. Assistance Dogs

2.2.1. Background of Assistance Dogs

ADs are specially bred and trained to undertake a variety of tasks to help people achieve an optimal level of functional independence (Audrestch et al., 2015). The first ADs described in the literature were trained to assist adults with visual impairment (Fishman, 2003). Dogs have been known to provide assistance to people with visual impairments since the 13th century (Fishman, 2003). In 1819, it was proposed that guide dogs for adults with visual impairments should be trained by sighted instructors. In the 1930's in a dog training program, 'The Seeing Eye', a rigid U-shaped handle was introduced, attached to a guide dog's harness, as it would provide a more accurate sense of the dog's movement than a flexible leash (Fishman, 2003). Adults who were deemed suitable to benefit from a dog went through a month-long training program with their guide dog, during which time they live at 'The Seeing Eye' facilities. They received a specially bred dog which itself has completed a four-month training course, beginning at about 18 months to 2 years of age, for a life's work that will last about 8–10 years. The greatest barrier for improved mobility for people with visual impairment was reportedly the attitude of the public towards them. Attributed to the idea that disability should be unnoticeable, however, qualitative studies have shown that a person with an impairment walking with their dog, brings admiration, not pity (Fishman, 2003). It is assumed, generally, that in animal assisted therapies with children, the children perceive their therapy/assistance dogs as non-judgemental participants who are outside of the complications and expectations of human relationships (Friesen, 2010).

2.2.2. The Benefits of Assistance Dogs

There is an increasing body of literature developing in the area of human-animal interaction and a growth in the knowledge of the expanding roles for service animals and their therapeutic effects (McCune et al., 2014). ADs can be trained to assist individuals with mobility impairments in their daily occupations such as propelling wheelchairs, retrieving objects, opening doors, and providing counter-balance (Herlache-Pretzer et al., 2017). There is evidence of the general benefits of ADs on psychosocial factors in adults (Audrestch et al., 2015; Rodriguez et al., 2020) and families of children with disabilities (Bibbo et al., 2019). Despite the lack of a strong evidence base, animal assisted interventions are popularly used as a tool in therapy in children with disabilities. Strategies for improving the evidence base of these animal assisted interventions in special populations are encouraged (McCune et al., 2017). The need for further exploration of animal assisted interventions and the expanding roles of dogs in therapy has been highlighted as an area for future research (Audrestch et al., 2015).

2.2.3. Mobility Assistance Dogs

MADs offer greater independence to people with mobility impairments through practical support performing tasks such as providing counterbalance for movement. Additionally, MADS can provide companionship and emotional support, with owners reporting increased happiness, well-being, and enhanced self-esteem (Crowe et al., 2019). Studies have shown that beyond the trained tasks the AD performs, the AD’s companionship and emotional support and social facilitation in public may also improve the QoL in people with disabilities (Modlin, 2001; Sachs-Ericsson et al., 2002; Winkle et al., 2012). A systematic review in 2020 analysed the benefits of ADs (including guide dogs, hearing dogs and MADs) on psychosocial health and wellbeing (Rodriguez et al., 2020). Of 27 studies, the majority of which used qualitative data, outcomes included significant positive effects on psychological well-being, emotional functioning, self-esteem and general energy or vitality. It has been seen that an adult handling a dog as an assistive device experiences less negative stigma than has been associated with other assistive devices (Whitmarsh, 2009). However, there was a lack of objective investigation into the effect on physical outcomes such as gait and physical functioning in these studies.

There is a small amount of literature documenting the effect of ADs in chronic conditions and mobility disorders. Longitudinal and cross-sectional studies have found positive correlations overall on the effects ADs can have on improving the QoL for individuals with mobility disorders. Individuals with a variety of disabilities including physical impairments, functional disabilities, CP, multiple sclerosis and post-stroke benefit from an AD specifically trained to assist with mobility impairments (Crowe et al., 2019; Herlache-Pretzer et al., 2017; Rondeau et al., 2010).

Blanchet et al (2013) conducted a study analysing walking function in 34 ambulant adults with physical disabilities, with and without a MAD (Blanchet et al., 2013). All participants completed a Timed up and Go (TUG), ascend/descend stairs test and 10 Metre Walk Test (10 MWT) while holding a MAD by a harness. Results showed that 72% walked faster ($p=0.015^{*}$) over a 10-meter distance with a MAD (15.7 ± 8.5 s); 70% performed the TUG test faster ($p=0.005^{*}$) with a MAD; 75% performed the stair ascent test faster ($p = 0.001^{*}$) with a MAD; Stair descent test showed no significant effect of the MAD. However, there was some discrepancy in the data collection methodology and the description of participants was quite generalised. The study lacked a description of the profile of the dogs involved.

Rintala et al (2008) completed a pre and post intervention study in 42 participants who received or were waiting for an assistance (hearing or mobility) dog (Rintala et al., 2008). They completed 'Pre-Dog' and 'Post-Dog' questionnaires. Functional and QoL outcome measures were completed. A control group was formed from those on a waiting list for a dog, six of the experimental group had mobility impairments. Results showed that 39% (n=7) of ADs gave mobility support, 28% (n=5) helped maintain posture, 5% (n=1) were used to position the participant for transfers. There was no significant change in the functional independence motor score.

While these studies have analysed the effects of an AD on mobility in adults, there have been no studies to date analysing the specific effect of a MAD on gait in children with physical impairment.

2.2.4. Assistance Dogs and Children

Although the evidence suggests ADs benefit adults with disabilities in psychosocial domains and QoL, there have been fewer studies supporting the use of ADs in children with physical impairments. Bibbo et al (2019) found that trained ADs had a significant positive impact on paediatric QoL in children and youths with chronic conditions (Bibbo et al., 2019). There have also been several studies which show the positive impact of trained AD in QoL in children with autism spectrum disorder (ASD). The benefits included parents perceiving that their child was safer, that the public acted more respectfully towards their child, reduction of anxiety behaviours in public places and increased social participation (Bibbo et al., 2019; Burgoyne et al., 2014; Crowe et al., 2019). There is research which has demonstrated that partnering ADs with children with developmental disabilities and their families results in positive effects, including improved mood and reduced anxiety in these children (Smyth & Slevin, 2010; Viau et al., 2010). They report increased social interactions, such as positive community acknowledgements for both the child and the entire family, and reduced parental stress (Smyth & Slevin, 2010; Viau et al., 2010).

Benefits of ADs for children with a variety of impairments and their families were found in a review of 29 studies (Lindsay & Thiyagarajah, 2021). Similarly, from this review, it is clear that there are benefits to psychosocial aspects of life and to social wellbeing, not only to the recipient of the dog but to their family (Lindsay & Thiyagarajah, 2021). There were clear benefits found in improved QoL, behaviour and stress management. Four studies in the review showed improved child mobility, however two of these were particularly focussing on guide dogs for visual impairment. A qualitative study by Davis et al showed that ADs enhanced a child's ability to perform functional tasks such as turning on lights or retrieving objects, this facilitated independence from relying on others for daily tasks (Davis et al., 2015). The seven previously published studies deemed most closely related to this study are described in Table 2-1 below.

Table 2-1: Most relevant studies summarised

Study objectives/research design	Cohort	Intervention description	Outcome measures	Results
Blanchet et al (2013) Effects of a Mobility Assistance Dog on the Performance of Functional Mobility Tests Among Ambulatory Individuals with Physical Impairments and Functional Disabilities . Cross sectional experimental design	34 adults - varied physical disabilities; assistance dogs primarily for mobility.	Participants performed at least one of the functional tests in their home environment both with and without their assistance dog.	10 metre walk test (10MWT); Timed Up and Go (TUG); Stair ascent and descent; Recorded in clients home environment; The time taken to complete each item was recorded	72.2% were faster performing 10 MWT with their dog. 70.4% were faster performing TUG test with their dog. 75% performed stair ascent with their dog. There was no change in stair descent with their dog
Altman (2021) Impacts of Mobility Dogs on Kinematics during Ambulation: A Quantitative Study. Descriptive study	16 adults with typical gait	Participants walked in a gait laboratory with no device; using a cane on the left; using a mobility dog on the left.	Differences between joint angles were analysed for each condition	Differences were found in left shoulder abduction cane versus mobility dog, mobility dog versus no device, and left hip extension when comparing mobility dog versus no device, and mobility dog versus a cane.
Zabihaylo et al (2005) Analysing the postural and gait behaviour of a person with retinitis pigmentosa travelling with a guide dog. Pilot study using quantitative and qualitative data	Four adults with visual impairment	Participants walked along familiar and unfamiliar routes with an AD, sagittal and coronal plane videos were analysed. The subjects then walked in a gait laboratory.	Video observation analysed for quality of walking. Laboratory measures included gait speed, head rotation and time in double stance	Dog increased gait speed: With a guide dog, the amplitude of up and down head rotation diminished, while left and right amplitude increased, regardless of lighting conditions. The presence of a guide dog has a positive impact on locomotion

Rondeau et al (2010) Effectiveness of a rehabilitation dog in fostering gait retraining for adults with a recent stroke: A multiple single-case study	Four participants post recent stroke, with hemiparesis	A 3-week training period focused on gait retraining using a MAD. For each session, walking speed and the gait pattern with both the rehabilitation dog and a cane was documented.	Walking speed over 10 metres was measured alongside gait pattern using Los Ranchos Observational Gait Analysis.	All 4 participants walked faster during training at post with the dog than their walking cane. The gait pattern appeared to have less deviations with the dog than the cane
Bibbo et al (2019) Impact of Service Dogs on Family Members' Psychosocial Functioning Cross sectional study with single time point assessment	50 family members (46 parents and 4 partners) living with an assistance dog and a control group from a wait list (n=76)	Data were collected via a self-report survey completed online, over the phone or by post.	Pediatric Quality of Life Inventory (Peds QL); Patient - Reported Outcomes Measurement Information System (PROMIS); Anger Short Form ; Companionship Short Form; Sleep Disturbance Form; Monash Dog Owner Relationship Scale (MDORS)	Living with a service dog was most closely associated with less health-related worry and better overall psychosocial health and emotional functioning, less total family impact from the chronic condition, and better emotional QoL
Crowe et al (2019). Effects of Partnerships between Adolescents with Developmental Effects of Partnerships between Adolescents with Developmental Disabilities and Service Dogs Single subject alternating treatment design	Three participant dyads: an adolescent and their parent who had received service dogs	Under two conditions (service dog present or not present), adolescents' anxiety behaviours during transitions and during grocery store shopping, for social interactions during grocery store shopping, and for parents' reported levels of stress were examined	Transitional Behaviours Outcome Measure (TBOM), the Store Social Interaction and Behaviours Outcome Measure (SSIBOM), and the Parent Stress Measure (PSM)	Service dog partnerships reduced the presence of anxiety behaviours during transitions for one of the three adolescents; reduced the presence of anxiety behaviours during grocery store visits for two of the three adolescents; increased social interactions for all three of the participant dyads; and had no meaningful impact on self-reported parental stress level.

Rintala et al (2008) To examine the functional assistance of service dogs and the satisfaction and problems of owning a service dog for adults with disabilities. Pre-post, wait list, non-randomized control group study	33 participants, sample of convenience, adults with mobility impairments • 18 with service dogs • 15 on wait list, • 2 participants in both service dog and wait list	18 participants received an assistance dog to help with mobility Training with dog not described	Pre-dog Task Checklist, Post-dog Task Checklist, Dog Performance, Short-Form Health Survey, Functional Independence Measure Motor Subscale, Craig Handicap Assessment and Reporting Technique, Satisfaction with Life Scale)	Participants satisfied with ADs, ADs have positive impact on their lives. Activities dogs most often assisted with: retrieving items (89%); carrying items (79%); barking in emergency (78%); opening/closing doors (56%), pushing automatic doors (56%). Reported decreased dependence on other persons with reduced hours of paid assistance

2.3. Children with Physical and Neurological Impairments

CP is a clinical diagnosis which describes a range of disorders due to injury to the developing brain often manifesting as difficulties with movement and posture (Rosenbaum et al 2007). It is the most common cause of motor deficiency in young children and is reported to occur in 2.1 per 1000 live births (Oskoui et al 2013). Motor impairment is the predominant feature in CP. Motor impairments in CP are multifactorial and include spasticity, reduced motor selectivity, impaired coordination, and reduced muscle strength. The physical function of children with CP can be classified using The Gross Motor Function Classification Scale (GMFCS) (Rosenbaum, 2007) as described in Figure 2-1:

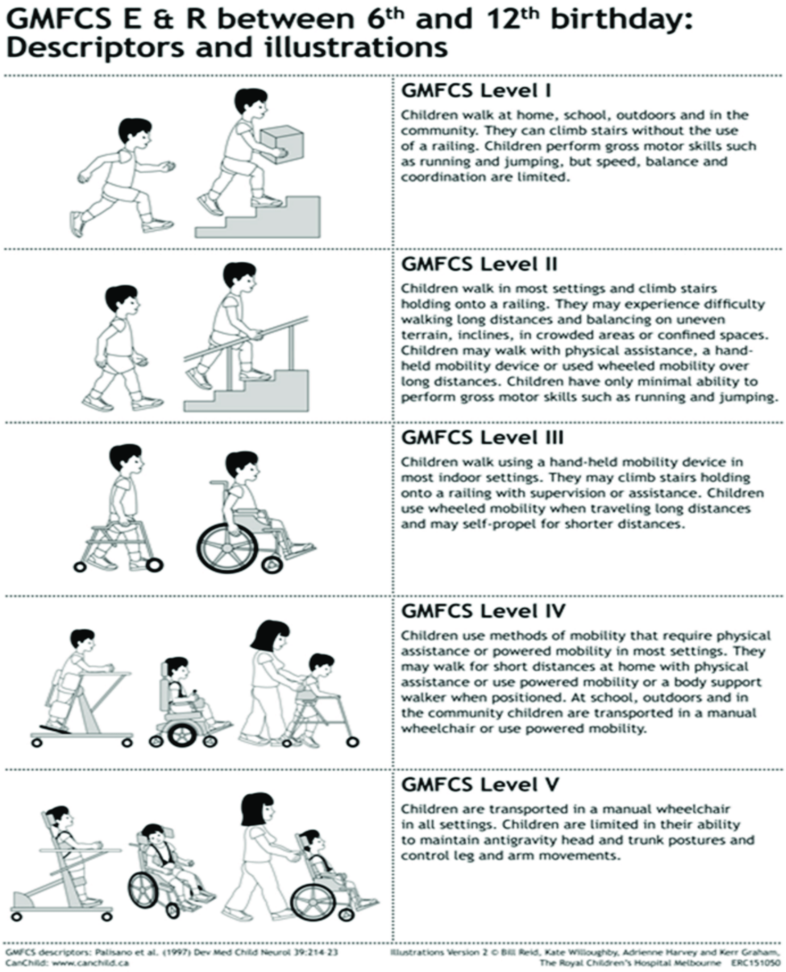


Figure 2-1: Gross Motor Function Classification Scale (Rosenbaum et al., 2002)

The GMFCS was developed as a method to classify the severity of CP, using a five-level system, formally assessed with The Gross Motor Function Measure (GMFM) (Harvey, 2017, Hanna et al., 2009). This gives families and clinicians an evidenced based and meaningful way to predict their child's functional outcome level to help devise appropriate goals and to gather meaningful data. Typically, in CP, PA levels are related to gross motor function as per their GMFCS level (Bjornson et al 2007). This level of activity decreases as adulthood approaches (Maher et al 2007), alongside the Gross Motor Function Measure (GMFM) curve. Figure 2-2: shows the GMFM curve across GMFCS levels up to age 21.

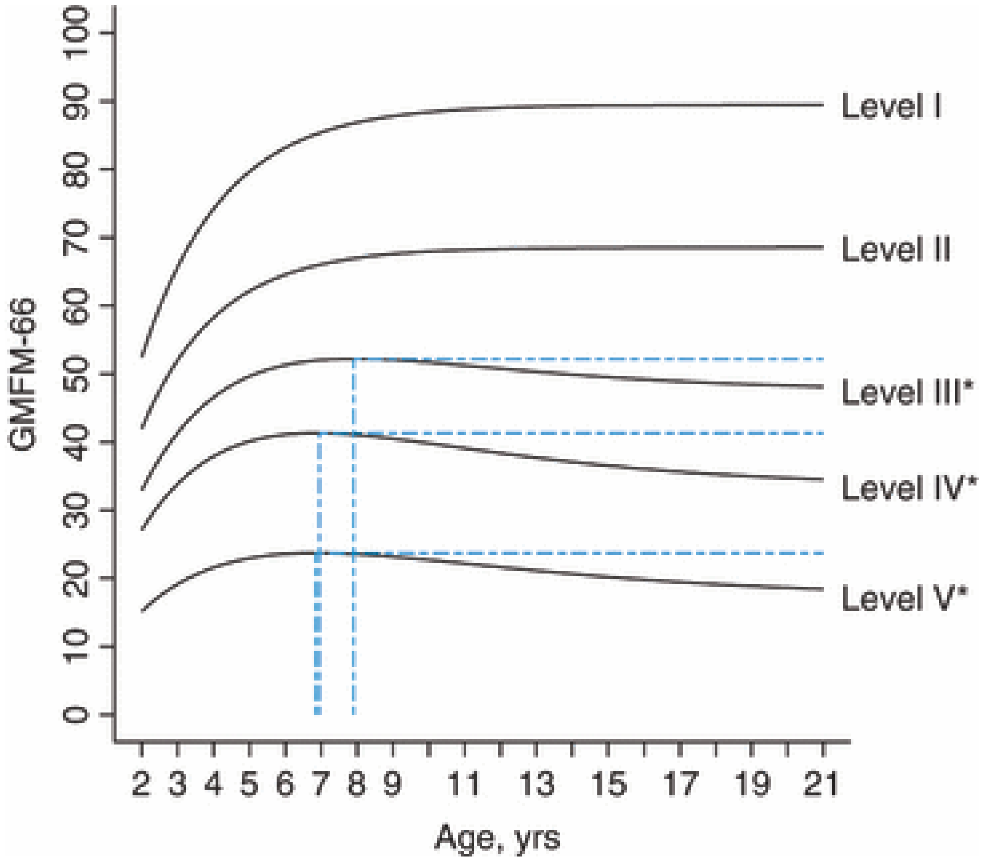


Figure 2-2: Gross Motor Function Measure Curve (Hanna et al. 2009)

The GMFM curve above shows that children with CP, across GMFCS levels improve in gross motor function up to the age of five or six and then, this motor function levels off by age seven. In children of GMFCS III-V, motor function tends to decline through adolescence. Studies show that PA levels fall approximately in line with this curve in children with CP (Bania et al., 2014; Lee, 2017).

2.4. Clinical Gait Analysis

Clinical gait analysis is a systematic way to objectively measure and describe walking (Gage et al., 1995; Perry & Burnfield, 2024; Whittle, 2014). Walking or bipedal gait is the mechanism of transport of the body using coordinated movements of the lower limbs. This requires coordination of the neurological and musculoskeletal systems to convert the vertical movements of the alternate lower limbs to a smooth forward trajectory of the head and trunk, to allow the eyes to remain steady and to conserve energy (O'Brien, 2001; Perry

& Burnfield, 2024). Physical and neurological impairments such as CP interfere with typical gait, making it difficult to participate in normal activities. Clinical gait analysis was developed to measure and define these gait impairments, to measure change and to suggest intervention and to objectively quantify the effects of an intervention (Bell et al., 2002; Gage et al., 2009; O'Brien, 2001). Clinical gait analysis uses five components to obtain a thorough picture of a person's gait pattern. These components are kinematics, kinetics, electromyography, clinical examination and video. Methodology of collection and interpretation will be covered in Study Three (Chapter 6). It has been shown that gait parameters measured during gait analysis, such as cadence and gait speed, correlate with gross motor function in CP (Damiano & Abel, 1996).

2.4.1. Gait Analysis and Assistance Dogs

The use of ADs to provide mobility support and guidance has been long standing in people with visual impairment. People with visual impairment have associated difficulty with balance, spatial awareness and negotiating obstacles, as is similar to those with physical impairments (Rutkowska et al., 2015). Zabihaylo et al (2005) analysed the effect of a guide dog on walking kinematics in adults with visual impairment, using 3-dimensional gait analysis (3DGA). The effect of walking with the dog on head and neck position was measured alongside gait speed and time in single and double support. The guide dog was shown to improve all of these gait parameters. The visually impaired adult was shown to have more walking confidence while walking with the dog (Zabihaylo et al., 2005).

Few studies have reported the benefits of MADs on performance-based measures such as gait. Video motion analysis of the adult upper limb has been completed while walking with an AD in a more recent study (Altman et al., 2021). Video footage was used to measure upper limb and trunk joint angles in 16 adults who walked both with and without MAD. Significant differences were found in left elbow flexion, shoulder abduction and left hip extension angles when walking with their dog on their left side. They recommend that providers monitor potential impacts of a MAD on asymmetry of the gait pattern (Altman et al., 2021). The effect of a MAD in adults without disability was assessed biomechanically using a G-walk triaxial accelerometer (Bradley, 2022). The gait analysis found varied individual differences, but the group showed a shortened stride length and reduced gait speed in gait laboratory setting. It was suggested that these adults were unaccustomed to walking with the dog (Bradley, 2022). The novel idea of gait retraining with an AD post stroke in four adults was analysed in a study using both 3DGA and observational gait analysis (Rondeau et al., 2010). All four adults walked faster with the dog than with a walking cane and were recorded to have less deviations from a typical gait pattern after eight weeks of gait training with the dog. An assistance dog was used as a therapeutic walking aid in a case report in adults with ataxia (Abbud et al., 2014). The dog allowed the participant to pull or push on the harness after balance disruptions. Positive change was recorded in the linear trajectory of walking, a narrower base of support, arms held closer to the body, improved cadence and more independence on stairs with the dog than with a walking aid.

Gait kinematic analysis in children with CP has been analysed with different walking aids (Krautwurst et al., 2016). Using 3DGA, it was shown that in 26 children with bilateral spastic CP, (GMFCS) levels II-III, there is a clear pattern of increased hip and trunk flexion and reduced flexion at the knee when using a walking aid, regardless of the type of aid. Reduced knee flexion would be an overall positive effect to prevent increased force acting at the knee (O'Sullivan et al., 2021). However, increased trunk and hip flexion would be an overall negative effect, increasing lumbar force (Kiernan et al., 2017). This may be important when considering gait kinematics when walking with an AD in place of a walking aid. There have been no studies to date examining the gait of children with physical and neurological impairments using a MAD.

2.5. Physical Activity Levels in Children with Neurological or Physical Impairments

Habitual physical activity (HPA) has been defined as "*any bodily movement produced by skeletal muscles which results in energy expenditure in daily life*" (Caspersen et al., 1985). Typically, in people with CP, PA levels are related to gross motor function (Bjornson et al., 2007) and this level of activity decreases with increasing age (Maher et al., 2007), alongside the GMFM curve (Harvey, 2017) (Figure 2-2:). The curve shows that children with CP improve in gross motor function up to the age of 5 or 6 and then this motor function levels off by age 7, regardless of GMFCS level. A previous study reported that marginally-ambulant (GMFCS III) and non-ambulant (GMFCS IV–V) children with CP, aged 4–5 years had significantly lower HPA levels and were less likely to meet PA guidelines compared to independently-ambulant children with CP (GMFCS I–II) (Keawutan et al., 2017).

Interventions for children with CP have shifted from a focus on improved attainment of developmental milestones for motor skills to include improved HPA (Damiano, 2006). More recently, PA guidelines for people with CP were launched to promote healthy lifestyles and prevent the risk of cardiovascular and metabolic diseases (Verschuren et al., 2016). In typically developing children, The World Health Organisation (WHO) guidelines state that 60 minutes of moderate to vigorous PA per day is recommended and that sedentary behaviour is limited to no more than two hours (Chaput et al., 2020). It is recommended that children with CP aim to meet these guidelines. According to existing studies in CP, exercise prescription should include a minimum frequency of two-three times per week, between 60%-95% peak heart rate of a minimum of 20 minutes per session for at least eight consecutive weeks and to include a warm-up and cool-down. Specification of exercise prescription for children with CP to frequency, duration, intensity and volume of muscle strengthening should all be gradually increased and aim to reach that of the typical guidelines. Healthcare providers can therefore play an instrumental role in the promotion of PA by encouraging people with CP and their families to integrate it into daily life. Studies in children with typical development indicated that PA levels in early childhood were sustained until young adulthood (Jones et al., 2013). There is also moderate evidence that has shown that PA can improve mental health including self-esteem, and reduce depression and anxiety (Biddle & Asare, 2011). No studies to date have analysed the effects of MADs on PA levels in children with physical impairments. Too much time spent sedentary is detrimental to cardiometabolic health. It has been suggested that reducing sedentary behaviour in people with CP should be targeted to reduce cardiovascular complications. Evidence suggests that frequent interruptions of sedentary time are beneficial to metabolic and cardiovascular health (Verschuren et al., 2016). Studies have shown that children with CP (levels I-III) spend 76%-99% of their waking hours being sedentary. The effect of a MAD on the sedentary activity of children with physical and neurological impairments has yet to be investigated. Innovative ways to improve PA levels in children with CP are welcomed (Bjornson et al 2007).

2.5.1. Monitoring Physical Activity in children with neurological or physical impairments

Knowledge of patterns of PA in children with impairments such as CP may help healthcare professionals involved in their care monitor activity levels across GMFCS levels (Bjornson et al., 2007). A number of activity monitors are available for measuring PA with many validated for use in a pathological population. The use of wearable sensors to monitor activity levels has been described in several studies in children with walking impairments including CP.

In a study by Bjornson et al (2007), they monitored 81 children with CP, levels I-III alongside a typically developing control group (Bjornson et al., 2007). They used the Modus Healthcare Stepwatch (www.modushealth.com) for seven days and documented average daily total steps, percentage time active/inactive, and the ratio of low, medium and high activity levels. The children with CP had lower steps and activity levels than those with typical development. GMFCS level predicted level of activity.

2.5.2. Choosing a suitable activity monitor

For the purpose of measuring PA levels in children with impaired walking in this study, it was necessary to analyse available and suitable activity monitors. Four activity monitors were considered for use in the project.

The ActivPAL (PAL Technologies Glasgow, UK) uni-axial accelerometer contains a microprocessor and connects to a host PC. It has shown criterion validity in measuring time sitting, standing and stepping in children with CP (O'Sullivan et al., 2021). The device is applied to the thigh via its adhesive backing and is worn over seven consecutive days. On testing, it was found that when the ActivPAL was compared to Modus Healthcare's Stepwatch, the Stepwatch was superior in accuracy of step count in impaired walking (McCullagh et al., 2017). The ActivPal was reported to have been less user friendly for children to wear in comparison with the Stepwatch (direct communication with Rory O'Sullivan and Ruth McCullagh, authors of above studies).

The Shimmer3 and Verisense monitors from the Irish based company Shimmersensing were considered for use in the project. These have been used in clinical trials in adults and frail elderly populations but haven't yet been validated in a paediatric population. The Shimmer 3 is worn on the low back or wrist and measures gait parameters including step length and gait speed.

The Modus Healthcare Stepwatch is an ankle worn dual axis accelerometer. It is worn on a watch-like strap on the distal ankle. It is waterproof and has a battery life of up to one month. It measures step count, activity levels and gait parameters such as cadence, average gait speed, peak gait speed and time inactive. It has been used in over 360 peer reviewed publications including in research in children with ambulant CP and has been shown to be valid in measuring step count in children with CP levels I-III when worn over seven consecutive days (Bjornson et al 2007). It is worn on the lower limb and thus may be more accurate in detecting steps in impaired walking (McCullagh et al., 2017).

The Modus Healthcare Stepwatch had clear advantages over the other activity monitors when considered with regard to the needs of this particular study, given its sensitivity to capture step count in children with ambulant CP and impaired walking, validation in this cohort, wearability, the specific aforementioned outputs and reported ease of data download.

In a study with 209 children with ambulant CP (GMFCS level I-III) it was shown that a wearable sensor should be worn for seven consecutive days to accurately show PA in this cohort (Ishikawa et al., 2013).

Table 2-2: Activity monitor properties

Sensor	ActivePAL	Shimmer3	Verisense	Stepwatch
Measures	Steps, time in sitting, lying, standing	Gait parameters: step length, speed	Activity levels: high, medium, low, idle, sleep	Steps, activity levels
Wearability	Applied to leg (upper thigh) using adhesive tape	Wearable (wrist or low back), advised on low back for gait parameters	Wrist wearable	Lower-limb wearable. (strap around ankle)
Cost (x10 units)	€2833 + Consumables to add	€4152 including software	€10,000 including base and software	€3650 Software not included (~€1000) Requires IPAD to program (~€850)
Research/ clinical use	Used in 2500 published studies in various cohorts	Clinical trials, elderly cohorts, falls	Clinical trials, Adults	Used in over 360 peer-reviewed publications including ambulant CP. Validated in treadmill walking in CP
Image of monitor in situ				

2.6. Quality of Life

Reduced activity levels and participation restrictions in children with physical and neurological impairments may lead to a reduced QoL, compared to their typically developing peers (Rosenbaum, 2007). The WHO defines QoL as “an individual’s perception of their position in life in the context of the culture and value systems in which they live, and in relation to their goals, expectations, standards and concerns” (www.who.int) (WHOQoL, 1994). QoL is also defined as a person’s feelings of well-being across many domains including physical, social, emotional and spiritual aspects of life. Participation is defined by The WHO as involvement in life situations or being involved in everyday activities. Communication, mobility, education, domestic life, leisure and social relationships comprise some of the areas of participation and are indicators of the extent to which an individual functions in their environment (www.who.int).

Outcome measures that evaluate QoL should take a broad approach to measuring well-being and not just measure on the functional domain (Davis et al., 2006; Shelly et al., 2008). It has been shown that QoL is not always directly related to level of function in children with CP (Shelly et al., 2008) and it is important to assess individual domains impacting QoL. QoL assessment has been described as a mandatory component of clinical trial research (Davis et al., 2010). The effect of ADs on QoL has been measured in several studies to date (Bibbo et al., 2019; Burgoyne et al., 2014; Crowe et al., 2019). These studies all found that a trained AD had a positive effect on QoL in children with varied disabilities.

As part of the mixed methodology of data collection, it was decided to use a QoL Outcome Measure as a quantitative descriptor of the effect of the introduction of a trained MAD in children with physical and neurological impairments. To choose a suitable QoL tool, several available outcome measures were analysed (Table 2-3).

To choose an appropriate tool, several components were considered (Figure 2-3), as described in a study by Lemmon et al (2020). Health related QoL domains of interest were identified (Lemmon et al., 2020). Logistics of administration were considered, validation of tools in the target cohort were assessed and then the most appropriate measures were selected and compared (Figure 2-3).

Table 2-3: Quality of Life Outcome Measures

Name	Peds QL	CP QOL	PEDI	CP Child	GOAL Questionnaire	PODCI
Full Title	The Pediatric Quality of Life Inventory	Cerebral Palsy Quality of Life Inventory	Pediatric Evaluation of Disability Inventory	Caregiver Priorities and Child Health Index of Life with Disabilities	The Gait Outcomes Assessment List	Paediatric Outcomes Data Collection Instrument
Suitable for	All disability where cognitive and communication ability will allow them to answer child section	Children with CP. Parent report and child report where cognition and communication allows them to answer	All paediatric disability	Moderate to severe CP	Ambulant CP	Generic paediatric disability
Measures	Subjective/perception of family and friends, school, participation, communication, health, equipment, pain, access to services, happiness, confidence	As Peds QL, includes 3 questions specific to limb involvement	All functional domains: Self-care, Mobility, social function, scored as per level of ability, equates to GMFCS level for mobility.	Functional ability and QOL	Measures gait priorities for parents and functional mobility. Measures all domains of ICF	Measures functional health status and functional outcomes Parent-reported- assesses mobility, physical function, comfort, happiness and expectations of the healthcare interventions in children with musculoskeletal health issues.

Validity	Good construct validity, interrater and intrarater reliability	Good construct validity, interrater and intrarater reliability	Good	Not in this population	Valid assessment of gait function in ambulant children with CP	Good reliability and validity
Summary	Generic Disability. Measures QOL	Validated in Ambulant CP. Specific to QOL	Generic disability. Requires trained professional to administer	Mod to severe CP. Measures function and QOL	Measures gait outcomes, function and parent's priorities. Does not measure QOL	Modest sensitivity to detect change of walking function in children with CP following orthopaedic surgery ; scoring system is considered too expansive to detect subtle changes. Not QOL

Carlon et al. (2010) conducted a systematic review of QoL measures for school-aged children with CP, including: the Caregiver Priorities and Child Health Index of Life with Disabilities (CPCHILD) (Narayanan, 2006), CP QoL-Child (Waters et al., 2007), DISABKIDS (Baars et al., 2005; Peterson et al., 2005; Schmidt et al., 2006) and PedsQL 3.0 CP Module (Varni et al., 2006). Following assessment of quality, validity and reliability, the authors concluded that CPCHILD and the CP QoL-Child demonstrated the strongest psychometric properties and considered the DISABKIDS and PedsQL 3.0 as being moderately constructed.

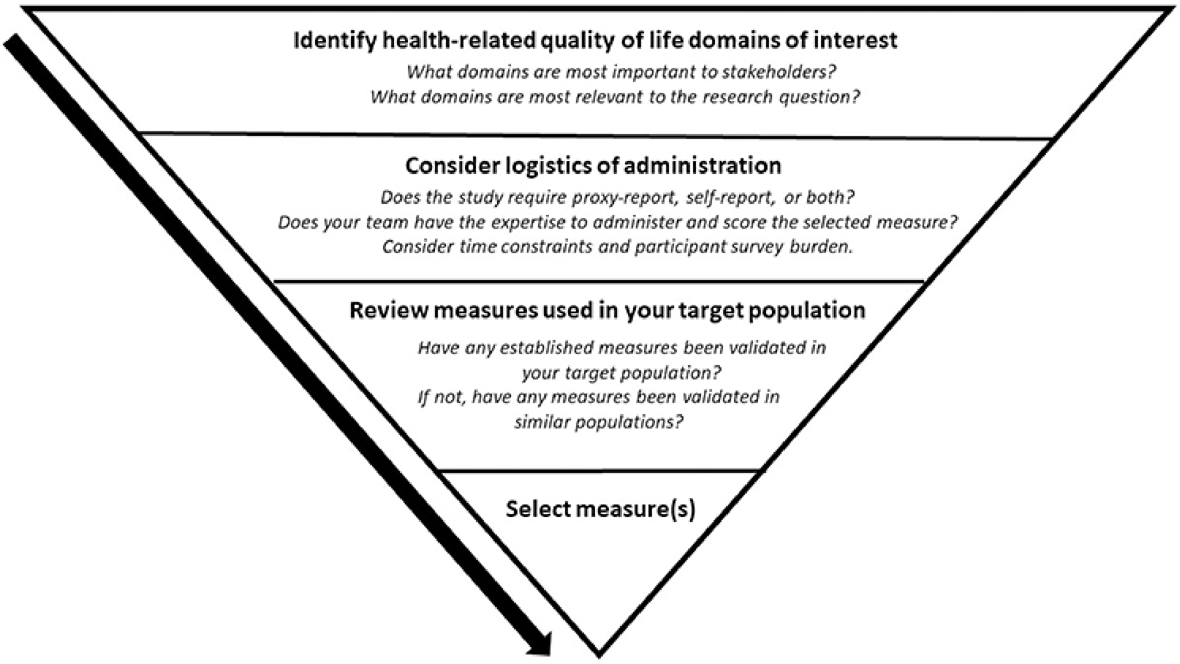


Figure 2-3: Choosing a suitable Outcome Measure (Lemmon et al., 2020)

Based on evaluation of the most suitable tool to measure QoL in this cohort, The CPQoL (Waters et al 2013) was chosen to measure QoL.

2.7. International Classification of Function, Disability and Health Framework for paediatric therapies

The International Classification of Function (ICF) is the WHO's framework for measuring health and disability at both individual and population levels. The ICF has shifted the focus from the impairments in children with CP such as restriction in joint ROM or abnormal muscle tone to the evaluation of function by assessing the quantitative and qualitative aspects of a child’s Activities of Daily Living (ADLs). It states that the focus of rehabilitation should be shifted from identifying a person’s disability to focusing on enhancing a person’s function, ability and performance quality, for each individual in a contextual manner, based on their own goals. The ICF identified domains that should be evaluated in children with

CP to include body function and structure, activity and participation. A consensus-based survey of clinicians, parents and youth with CP supported these domains as relevant to the evaluation of all health care interventions in children with CP.

The “F-words in childhood disability” (function, family, fitness, fun, friends, and future) were introduced in 2012 (Rosenbaum & Gorter, 2012). This is a relatively new concept and framework to help bring therapists and families together to an operational level to utilise the WHO’s 2001 (ICF) framework (www.who.int). The F-words framework encourages innovative ways to engage children, families and therapists to incorporate the F-words as part of therapy in paediatric disability. The F-words framework will be referenced again in discussing the outcomes of the study and although not an intended objective of the study from the outset, may be incorporated at the outcome stage.

2.8. The Mixed Methods Approach

Mixed methodologies involve the use of both quantitative and qualitative approaches of data collection and analysis, warranted by the breadth of the aims and the complexity of the experience of a new technique (Clark & Creswell, 2008), such as the introduction of a MAD. Mixed methods research purports that the combination of methodological approaches facilitates a greater understanding than with quantitative or qualitative methodologies alone (Clark & Creswell, 2008). In this approach, the investigator collects and analyses data, integrates the findings, and draws inferences using both qualitative and quantitative methods in a single program of inquiry (Tashakkori & Creswell, 2007).

2.8.1. Qualitative Interviews

Developing an in-depth understanding of the experiences of participants and their families, over the time points and over the process, is central to this research and requires a research design that addresses this. A social process is defined as a series of events or actions involving human interaction that occur over time. It involves change, and has a beginning, an end and a series of events and actions and interactions in between.

Originating from a naturalistic enquiry perspective, qualitative research is underpinned by a desire to understand a phenomenon, event or process from the point of view of those experiencing it (Pistrang & Barker, 2012). Qualitative description enables the researcher to provide clear, recognisable accounts of the varied, overlapping and shared experiences and processes involved in the research. In this study, this will be achieved by clustering together common ideas from participants to form themes and subthemes occurring across participants and timepoints. The methodology and use of thematic analysis has been previously described (Braun & Clarke, 2006).

Qualitative research has been used to look at the psychological and physical effects of human and animal interaction previously in a study quantifying the experience of children with CP who attended hippotherapy (Debuse et al., 2009). Although the physical outcomes from hippotherapy have been previously described (Debuse et al., 2009), the overall experience of the user can be described by a qualitative interviewing technique. This study found that there were physical effects of hippotherapy including normalisation of muscle tone, improved trunk control and improved walking ability. The study also analysed the overall experience and the psychosocial effects and carryover effects of hippotherapy to activities of daily living, increased self-efficacy, confidence, and self-esteem (Debuse et al., 2009). This study showed a novel insight into the context of hippotherapy, as well as its effects on impairment, activity, participation, and QoL in people with CP.

There have been no studies to date using a qualitative enquiry or mixed methods approach to understand the experience of the user when a MAD is introduced to a family of a child with a physical or neurological impairment.

2.9. Summary of the literature and detailed thesis aims and objectives.

In summary, there is evidence of the benefits of ADs in people with varied disabilities to improve social interaction and QoL. There is low level evidence describing benefits of a MAD on gait speed and walking confidence in adults. Research shows that clinical gait analysis is a validated method of quantifying gait changes in children with walking impairments. There is clear evidence that children with physical and neurological impairments such as CP have lower levels of PA than their typically developing peers. Knowledge of these PA levels is important to understand how an intervention may alter their level of activity. Activity should be monitored over seven consecutive days to appropriately represent PA levels in this population. The Modus Healthcare Stepwatch™ is a suitable wearable sensor used to measure PA levels in impaired walking, The research has shown that we should aim to improve QoL in children with walking impairments by improving their participation. There is evidence to show that animal assisted interventions may be favourable for children with disabilities as they incorporate the ICF's Five F's framework.

There is a paucity of evidence regarding the benefits of MADs as a walking aid or gait training intervention in children with physical or neurological impairments. This is the first study of its kind analysing the effects of MADs in children using this novel approach The available literature leaves this study well placed to initiate the analysis of the benefits of MADs in children with impaired walking ability.

2.9.1. Study Aims

Therefore, the aims of this study are as outlined below:

To investigate if the introduction of a trained mobility assistance dog leads to measurable changes in gait in children aged 6-12 with physical or neurological impairment.

To investigate if the introduction of a trained mobility assistance dog leads to measurable change in the physical activity levels in children aged 6-12 with physical or neurological impairment.

To investigate if a trained mobility assistance dog leads to changes in quality of life domains, both measured and perceived, in children aged 6-12 with physical or neurological impairment.

The following chapter, chapter three, will give an overview of the study design, based on rationale from reviewing the literature. The general methods which apply to all studies within the project are also described.

3. Study Design and General Methods

3.1. Introduction

This chapter will introduce the design of the study and the methods which apply to all parts of the larger mixed methods study.

3.2. Study Design/Theoretical Framework of The Project

The study design is created by review of the literature, methodology selection and presentation of objectives. A mixed methodology, quasi-experimental study design was chosen to address the objectives of the study (Cresswell, 2013). The specific mixed methods design chosen involves a single study with quantitative and qualitative data gathered, informing each other across multiple stages of data collection (Creswell et al., 2004). In order to determine the effect of mobility dog introduction, the study will gather a set of measures in gait, PA, quality of life and qualitative interviews. Data collection was completed pre dog introduction, post dog introduction and at two follow up points (Portney, 2009).

3.3. Ethics

Research ethical approval to measure gait, activity and involve families in interviews was obtained from both the Trinity College Faculty of Health Sciences Research Ethics Committee and the Central Remedial Clinic Research Ethics Committee prior to commencement of the project. The Ethical approval letter from TCD and the CRC ethics application are available in the appendices Appendix C and Appendix D.

3.4. Recruitment

3.4.1. Recruitment procedure

Children with neurological or physical impairments aged between 6 and 12 years who were on a waiting list to receive a mobility assistance dog were recruited to the research project. All parents of children on a waiting list (n=33) to receive a MAD with the charity and were suitable for the study were invited to participate. Recruitment was via a gatekeeper within the charity. Potential participating families were provided with the study information. Recruitment was via invitation by IDFD, who provided an information leaflet explaining the details of the project. This participant information leaflet was created (Appendix A) alongside a child friendly version of this information leaflet (Appendix B).

Children and their families who volunteered to be part of the project contacted directly and expressed their interest. Parents or guardians signed and returned written consent forms (Appendix E). Each participant kept a copy of this form, and copies of all signed consent forms were kept in a locked cabinet in the office of the Principal Investigator. The study cohort consisted of ten children (aged 6-12 years) with neurological or physical impairments and their parents.

3.4.2. Inclusion criteria

Children were eligible for inclusion if they had a neurological or physical impairment and impaired walking. Children were not eligible for inclusion if they had undergone orthopaedic surgery (within six-months) or travelled abroad for a period of more than six weeks during the course of the study. Sixteen suitable families came forward to participate, thirteen of these began the study and met all inclusion criteria. Three children did not complete the study: one had orthopaedic surgery during the course of the study and two children went abroad for extended periods of rehabilitation during the course of the study. All parents signed informed consent and children completed informed assent.

Stage 1

Review Previous Work (Literature Review) and Develop Framework

Review Theory, Data Sharing, Identify Research Questions and Context. Ethical Consideration

Develop Conceptual Framework for Data Collection Methodologies and Selection of data types

Mixed Methods including Quantitative and Qualitative methodologies incorporating a repeat measures design

Ethics application

Stage 2: Data Collection Framework

AIM	Research Questions	Study Design	Sample	Setting	Data Collection Method	Data Analysis	Rigour
To measure gait pattern pre and post 6 months of MAD training	Does MAD training alter the gait in a child with impaired walking from a 6-month baseline? Does walking with a dog versus walking with a typical aid change the gait parameters and kinematics?	Pre and Post Intervention, Quantitative data	10 children/as able	Gait Laboratory	Clinical Gait Analysis: standardised instrumented motion analysis	Statistical analysis of the group pre to post.	Validity, reliability, standardisation
To measure physical activity levels	Does the introduction of a mobility assistance dog increase physical activity levels in children with impaired walking over 6 months?	Repeat measures Quantitative data	10 children	In the child's typical environment	Physical Activity monitor to be worn over 1 week	Statistical analysis of the group pre to post.	Validity, reliability, standardisation
To quantify the effect of a MAD on quality of life	Does the introduction of a mobility assistance dog have measurable effects on quality of life in a child with impaired walking over 6 months?	Repeat measures, Quantitative data	10 parents	In their home environment, posted back	QOL Outcome Measure.	Statistical analysis of the group pre to post.	Validity, reliability, standardisation
To understand the experience of when a MAD is introduced	What are parent's perceptions of the introduction of a MAD? What are the parent's perceptions of the dog on their child's gait, physical activity and QOL?	Qualitative Interviews: Pre-Intervention and Repeat Measure at 1, 3 and 6 months	10 parents	Location convenient to the family	Qualitative Semi-structured Interviews.	Thematic Analysis	Anonymity; credibility; reflexivity, two researchers

Stage 3: Data Evaluation and Mixed Methods Analysis

Figure 3-1: Theoretical data collection framework.

3.4.3. Participants

Ten children met all inclusion criteria and completed the study. Eight children had a diagnosis of CP and two had another diagnosis which was a permanent neurological impairment with associated walking pathology. Those without a CP diagnosis[2] walked independently but required handheld support for crowds, steps and stairs and functioned at a level equivalent to GMFCS I. All children and their families were white Irish, from a mix of suburban and rural areas across Ireland with good access to green space and parks for walking. Participant characteristics are presented in

Table 3-1. The children in the study ranged from GMFCS I-IV. Those who were level IV (n=2) use a powered wheelchair for longer distances but did walk for therapy daily and did their walking practice using the MAD and thus would have impaired walking ability. Children were then grouped into those with less physical impairment (group A- GMFCS I-II) and those with more physical impairment (group B- GMFCS III-IV) for further analysis.

Table 3-1: Participant Characteristics - children (diagnoses not disclosed to protect identity)

Participant Number	Age	Gender	GMFCS (or equivalent)	Group	Typical walking aid
01	12	M	III	B	handheld/PW
02	9	M	IV	B	PW/powered wheelchair
03	9	M	I	A	handheld/supervision
04	8	F	III	B	walker or tripods
05	9	M	I	A	supervision/handheld/PW
06	8	M	II	A	supervision/handheld/PW
07	9	F	IV	B	PW/powered wheelchair
08	8	F	III	B	PW/tripods
09	11	M	II	A	handheld/supervision
10	6	M	II	A	handheld/supervision/PW

PW: Posterior Walker; GMFCS : Gross Motor Function Classification Scale. GMFCS levels: Level I: Walks without limitations; Level II: Walks with limitations; Level III: Walks using a hand-held mobility device; Level IV: Self mobility with Limitations; May use Powered Mobility; Level V: Transported in a Manual Wheelchair (Palisano et al 2008)

[2] Diagnoses not described to protect participant anonymity.

3.5. Data Collection Timeline

Children’s activity levels prior to MAD placement were recorded using the activity monitor over a one-week period as a baseline. Parents completed an activity diary to accompany the activity monitor at each time point. Following MAD placement, activity levels were monitored after one month, three months and six months. Qualitative interviews were completed at each of these time points alongside the QoL outcome measure. Children had gait analysis at the CRC Gait laboratory prior to placement of the MAD and at 6 months post MAD placement (Figure 3-2).

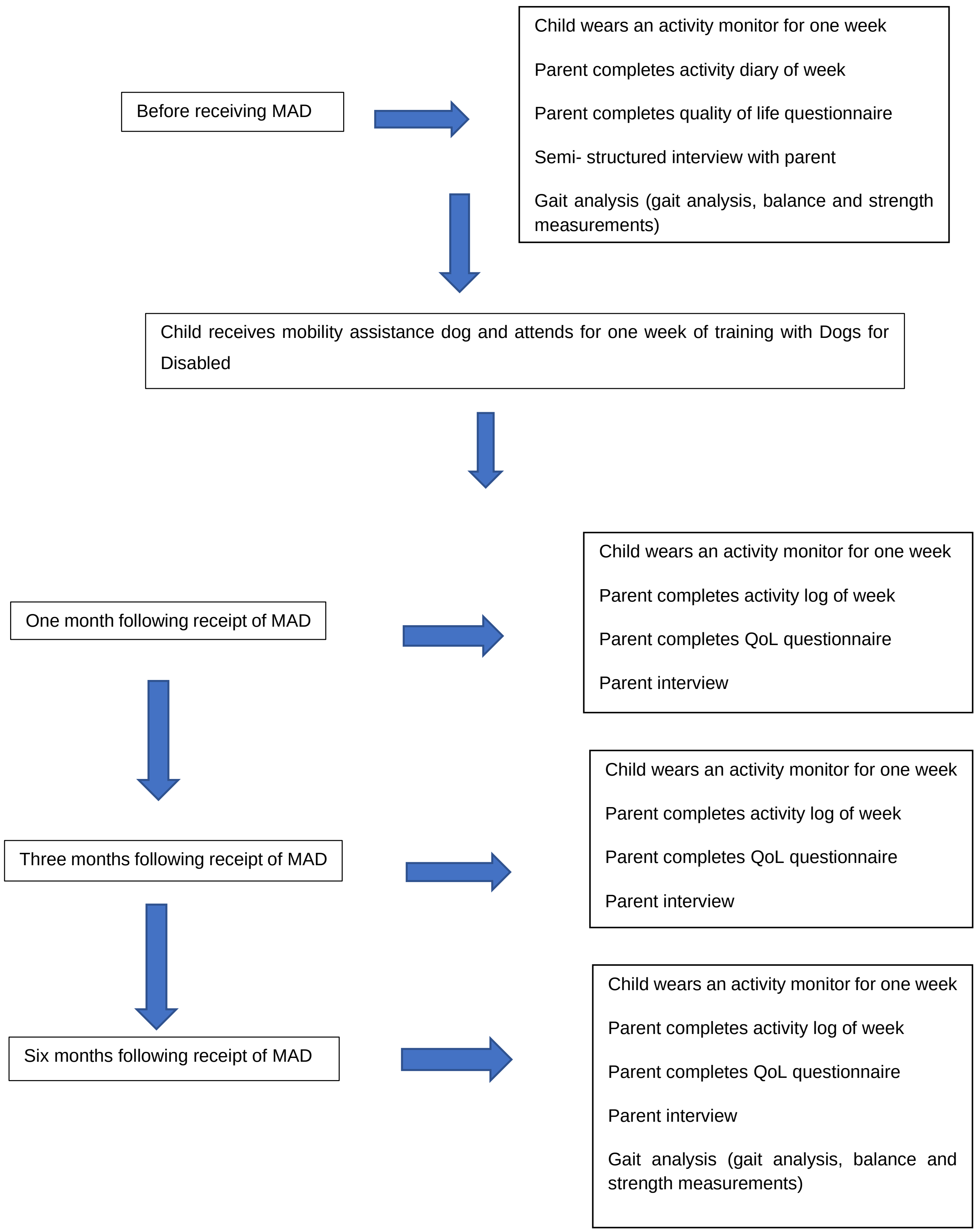


Figure 3-2: Timeline of data collection.

3.6. COVID 19

This research project began in March 2021 and data collection began in May 2021. Data collection continued until August 2022. All data collection was completed during the COVID-19 pandemic. All COVID-19 restrictions were adhered to throughout the course of the study. Updates and changes to these restrictions guided the timeline of data collection at times due to a child or parent having COVID-19 or the researcher having COVID-19. Qualitative interviews were conducted outside where possible. Questions relating to the impact of COVID 19 on the PA levels of the children were included in the qualitative interviews.

3.7. Matching with dogs

All children attended IDFD prior to receiving their dog. An assessment was completed by the IDFD trainer to analyse the child's walking ability and their suitability to a particular dog, as per their protocol. Each dog is individually trained to meet the needs of their intended client. MADs are aged two years or more and may be Labrador, Labrador Retriever or Standard Poodle breeds. These dogs are specifically bred for the purpose of being ADs. They undergo training to obey specific commands for turning left and right, to go and to stop alongside basic commands such as 'sit' and 'stay'. Each child's walking speed is considered when being matched with their prospective dog as there is interbreed variation of walking speed such as a Labrador would typically have a larger body mass and tends to have a slower walking speed than a Standard Poodle who may be more suited to a child with a faster walking speed. Personality type is also taken into consideration when dogs are matched with children: a more excitable dog may be given to a quieter child to encourage more interaction, and a more placid dog may help to provide sensory input and a calming effect to a more excitable child. The dog trainer meets each family and completes an assessment including medical background and evaluation of their home environment prior to matching their AD.

3.8. Walking Training with IDFD

According to Assistance Dogs International, a trained, effective, MAD must have the following attributes:

- ability to follow basic commands, such as stopping, sitting or lying down, from an owner

- ability to memorise and follow hand signals or commands, or be able to respond to the tone of an individual's voice
- knowledge to understand that he or she is working, and the ability to maintain decorum
- ability to focus on the needs of an owner, as opposed to distractions

For a trained dog to qualify as a MAD, they must perform three specific tasks (Assistance Dogs International):

- provide a stable base and forward motion for the client
- negotiate environmental objects such as people, steps, or kerbs
- regulate the speed of walking by the client. The dog may be trained to dictate the pace of the gait.

The child and parent complete up to five days of training to learn the commands to control the dog and how to use the harness. The harness is fitted around the chest of the dog with a metal, rigid handle, similar to a guide dog harness but with a shorter handle. The length of the handle is adjusted as the child grows. The child pulls on the handle to rebalance when need. The handle has been adapted from a traditional guide dog handle to have a shorter handle so that the child walks beside rather than behind the dog (Figure 3-3**).** The rigid side fitting metal handle moves freely as the dog and child move together, replacing the need for the parent's hand. The dog trainer in IDFD has designed the handle for this reason. The parent controls the dog with a lead from the opposite side. Walking practice takes place firstly in a controlled spacious environment such as a quiet park followed by encountering environments including shopping centres, crowds of people, traffic lights and steps. As the parent and child become confident in controlling the dog and giving commands in various settings, the trainer signs off that they have completed their training. The trainer provides continued support to the family by home visits as required.

All children attended IDFD with one parent or guardian to meet their dog and for training. Families stayed at residential accommodation close to the charity. Families were educated about animal husbandry and how to care for their dog.

Figure 3-3: Child walking with mobility assistance dog. The parent controls the dog. Road crossing is part of the training.

Figure 3-4:The metal handle, attached to a sturdy leather harness.

The handle is oriented to the side the child will walk on, in this case to the left of the dog with the harness held in the child's right hand as shown in Figure 3-4. The child walks beside the dog, just behind the front legs.

The side of the dog the child walks on will be dependent on their individual needs but typically if there is no asymmetry in their gait they will walk on the left of the dog. The parent is taught the commands to initiate forward motion and to turn left and right. The child is encouraged to give these instructions as they become more confident. To handle an assistant dog, an individual must be able to (Assistance Dogs International):

- Follow the dog's lead to negotiate obstacles
- Understand and implement training techniques
- Understand dog health, and retain medical services (including vaccinations)
- Know and adhere to local laws, understand rights.

Figure 3-5: (Left) Child walking with tripods and parental supervision; (Right) Child walking with dog and one tripod and two adults

For children with more impaired walking, such as those who have CP GMFCS level III-IV who are dependent on a walking aid to mobilise, two adults are required (Figure 3-5). The dog may be used as a motivation to practice walking with their walking aid. The children also practice their routine physiotherapy exercise programme with their dog, such as sit to stand practice and standing balance, again using the dog with the harness to provide light support and counterbalance. For children with mild walking impairment and reduced visual-spatial awareness, the dog is trained to regulate the speed of walking and encourages the child to negotiate obstacles safely with increased care and to counterbalance when they lack dynamic balance on turns and when changing direction.

3.9. Pilot data collection

Prior to commencement of data collection, the activity monitor protocol, CPQoL-parent report and qualitative interview data collection techniques were piloted, and protocols were refined in a pilot episode with a child who had previously received a MAD. Parental consent and child assent were obtained to be part of the study. The child was a 12 year old girl with CP, GMFCS III who walked using a posterior walker or her MAD.

Feedback from the pilot data collection was as follows: Initially the activity monitor was piloted with a family member of one of the researchers. However, it was found that this child was very active and engaged in activities such as football, sprinting and trampolining. This level of activity may not have been representative of the type of data to be collected as settings required on the activity monitor differ to those for a child with impaired walking. Additionally, the activity monitor was validated as reliable for measuring step count in the population in overground walking, see Appendix G.

Ideally the interview should be completed with one parent, without the child present. The interview should be conducted where possible in the participant's home to allow freedom to talk and good quality audio.

3.10. General Data Collection Methods

3.10.1. Quality of Life Outcome Measure

Each parent or guardian was given a printed copy of the CP QoL-Child Parent report to complete at baseline and at each timepoint. They were asked to complete this and return the printed copy with the activity monitor at the end of the week. The copies were returned by stamped self-addressed envelopes or were collected.

Scores were collated as per the documented protocol. Raw scores were recoded into a range of 0–100, with higher scores indicating better QoL except in pain and impact of disability domain, where lower scores indicate better QoL (Waters et al., 2013). Scores were then uploaded to a database and coded for each domain across participants and time points. Domain specific scores were analysed, and a summary score was used to portray overall trends of QoL.

3.11. Qualitative Interviews

A qualitative method was used to analyse the perceptions of the participants and their families of the experience of receiving a MAD. Data were gathered from parent interviews and separate child interviews before they received their MAD and at one month, three months and six months after they received their dog using a semi-structured interview format. This was analysed to form a detailed understanding of the families' experience of the process (Mason, 2002). Data analysis was then carried out using thematic analysis (Braun & Clarke, 2013).

Developing an in-depth understanding of the experiences of participants and their families, over the time points throughout the process, is central to this research and requires a research design that addresses this. A social process is defined as a series of events or actions involving human interaction that occur over time. It involves change, and has a beginning, an end and a series of events and actions and interactions in between. Families were interviewed using a predetermined set of semi-structured open-ended questions at each time point. Questions related to the families' experiences related to the introduction of the dog, including the parents' perceptions of the dog's effect on their child's gait, PA levels and QoL, see Appendix I. Interviews were conducted at a place of convenience for the participants. The interview data was recorded on a software application otter.ai (Otter.ai 2021) and to increase audio quality a 2-way blue tooth speaker was used with the iPad. The Otter.ai programme is an artificial intelligence (AI) speech-to-text software (Otter.ai, 2021c). The software live streams text transcription from audio and shows the real-time transcripts streaming. The draft is then saved as a text document, and it can be further refined and edited by the researcher by checking it with the playback recording. Live Transcription was used during an interview, this shows the real-time transcripts streaming . The draft transcription was then saved along with the audio file. The file was then uploaded into an MS Word document and the playback recording was used to edit any inaccuracies. The file was then edited to remove all identifying data such as names and place names.

All interview transcripts were uploaded to the qualitative data analysis software programme Nvivo (Version 12; QSR International, Doncaster, Victoria Australia). This programme is designed to assist in the management of qualitative data. Nvivo is useful for storing and visualising data, but the researcher remains in control of the analysis and interpretation. Formal online training was undertaken to understand the use of this software package.

Thematic analysis was used to find patterns and themes across participants (Braun and Clarke 2013). Initial themes occurring were formed in the early baseline interviews. Points of potential interest were initially noted and highlighted on paper copies of transcripts. Within the Nvivo programme, codes were initiated as concise labels to identify data groups. Themes occurring were labelled and text containing quotes alluding to these themes were highlighted. A theme represents a coherent and meaningful pattern in the data, relevant to the research question and is actively created by those coding (Braun and Clarke, 2013).

As these themes are constructed, relationships between themes are constructed and linked together to meaningfully address the research questions (Braun & Clarke, 2012). Themes are rigorously reviewed throughout the research process to ensure that they coherently represented the entire data set.

3.12. Storage and analysis of data

All data were stored on a password protected TCD registered laptop. All participant data were anonymised. All quantitative data were uploaded to Microsoft Excel for preliminary analysis. All data were uploaded to IBM SPSS Statistics Version 28 (Armonk, NY: IBM Corp) SPSS statistics package for further analysis of quantitative data.

3.13 Schedule

Table 3-2: Research project timeline

	January	February	March	April	May	June	July	August	September	October	November	December
2021	Literature review and clinical practice review. Ethics application and completion.			Pilot testing. Acquiring data collection techniques and developing protocols. Cohort recruitment. Sensor choice, testing and calibration			Launch activity monitoring and gait analysis	Data collection – activity monitoring, gait analysis, QoL and qualitative interviews, 1, 3 and 6 month follow up.				
2022	6 month data collection (*some delays due to COVID 19). Data analysis					Data cleaning. Data analysis			Gait data presented at ESMAC	Qualitative data analysis. Transfer report writing and viva.		
2023	Qualitative data analysis		QoL data analysis		**OFF BOOKS**						Activity Monitor data analysis	
2024	Gait data analysis Cluster data analysis		Research paper submissions		Final report writing. Research paper reviews. Qualitative data presented at EACD 2024				Quality of Life paper published Thesis submitted Contingency			

* 2 participants did not begin data collection until January 2022 due to (i) not aged 6 until January 2022 and (ii) had to go under investigation for allergies to dogs prior to commencing. * 4 week delay in data collection in February and March 2022 due to COVID-19 surge among participants .

4. Study One. The impact of mobility assistance dogs on physical mobility, activity levels and social inclusion in children with physical and neurological impairments: A qualitative study of parental perceptions

This chapter is a modified version of the article which is currently under review in the journal *Physical Therapy Reviews*. This study includes the analysis of the qualitative interview data obtained from the parents of the children who received mobility assistance dogs, before they got their dog, one month after they got their dog and at two follow up time points.

4.1. Introduction

Children with physical and neurological impairments such as cerebral palsy (CP) often have difficulty with walking, due to muscle weakness, tightness and impaired motor control (Oskoui et al., 2013). Children with motor impairments participate in lower levels of physical activity (PA) than their peers and less than recommended guidelines (Carlon et al., 2013). Reduced activity levels in these children may lead to a reduced QoL (Rosenbaum, 2007).

Assistance dogs are trained to undertake tasks to help mitigate an individual's disabilities (Audrestch et al., 2015). The three most common types of assistance dogs are guide, hearing and mobility assistance dogs (MADs). MADs offer greater independence to people with mobility impairments through practical support, performing such tasks as opening doors, retrieving objects and providing counterbalance for transitional movements (www. assistancedogsinternational.org).

In Ireland, the charity Irish Dogs for the Disabled provides dogs trained as a walking aid for children with impaired walking ability. The dogs are trained to provide forward momentum and counterbalance for the child while walking. Approximately 30 dogs are being provided to children each year.

For children with more impaired walking, such as those who have cerebral palsy GMFCS level III-IV who are dependent on a walking aid to mobilise, the dog may be used as a motivation to practice walking with their walking aid. The children also practice their routine physiotherapy exercise programme with their dog, such as sit-to-stand practice and standing balance, again using the dog with the harness to provide light support and counterbalance.

For children with mild walking impairment and reduced visual-spatial awareness, the dog is trained to regulate walking speed and encourages the child to negotiate obstacles safely and to counterbalance on turns and when changing direction (direct communication with Dogs for the Disabled).

Assistance dogs can improve social inclusion and perceived QoL in children with disabilities (Bibbo et al., 2019; Crowe et al., 2019). MADs have been shown to have positive outcomes in adults with physical disabilities on psychosocial wellbeing, self-esteem and general energy (Rodriguez et al., 2020). Beyond the trained tasks the assistance dog performs, their companionship, emotional support and social facilitation in public may also improve QoL in people with physical disabilities (Winkle et al., 2012) and across varied disabilities (Sachs-Ericsson et al., 2002).

However, few studies have assessed the impact of any type of assistance dogs on mobility, activity levels or quality of life in children with limited walking ability. Bibbo et al found that assistance dogs had a significant positive impact on pediatric QoL in children with diagnoses such as CP, muscular dystrophy and seizures (Bibbo et al., 2019). Several studies have shown the positive impact of trained assistance dogs on QoL in children with autism spectrum disorder with benefits including parents perceiving their child to be safer, members of the public acting more respectfully towards their child, reduced anxiety behaviours and increased social participation (Crowe et al., 2019), (Bibbo et al., 2019; Burgoyne et al., 2014). However, the specific effects of MADs in children with physical and neurological impairments remain unknown.

The Irish Dogs for the Disabled has been operational since 2007, but so far there has been no scientific evaluation of this practice. Accordingly, this study is part of a larger mixed methods study examining the effects of introducing trained MADs on gait, balance, activity levels and QoL in children with CP and neurological impairments over a six-month period. The aims of this qualitative study were to understand parental perspectives of the impact of MADs on their children’s walking ability, activity levels, social impact and the overall effect of the introduction of the dog on family life.

4.2. Methods

4.2.1. Research Ethical Approval

Research ethical approval was obtained as outlined in the general methods section here 3.3 Ethics**.**

4.2.2. Study Design

A qualitative description methodology (Sandelowski, 2010) was used to explore parental perceptions of the experience of receiving a MAD for their child. Data were gathered from parent interviews prior to receipt of their dog and at one month, three month and six month intervals after they received their dog. Semi-structured qualitative interviews were devised and conducted with one parent of each child. Interviews were designed based on the research questions. These interview questionnaires have been supplied in Appendix I. The Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist was completed to ensure rigor of qualitative research (Tong et al., 2007).

4.2.3. Recruitment

See previous section as described in general methods here 3.4 Recruitment.

4.2.4. Procedure: Training

See previously described section on walking training with the dog in general methods here 3.8 Walking Training with IDFD**.**

4.2.5. Procedure: Data Collection

I completed all components of the data collection. I had no prior knowledge of the families involved in the study and was not involved in their care and have no prior affiliation with the charity providing the dogs. I interviewed one parent of each child using a predetermined set of semi-structured, open-ended questions at each time point. Interview guides are provided (Appendix I). Interviews (19-55 minutes) were typically conducted at the participant's home and were recorded using audio recording and transcription software Otter.ai (Otter.ai,2021c). Transcriptions were manually edited using playback to correct any inaccuracies. Files were then pseudo-anonymised by removing identifying data and audio files destroyed. While data were collected at a pre-dog time point with specific questions around goals and expectations, the data presented here relates to post dog interviews and relates to the impact of the dog.

4.2.6. Data analysis

Data analysis was carried out using reflexive thematic analysis to find patterns and themes across participants (Braun & Clarke, 2014). Points of potential interest were initially noted and highlighted on paper copies of transcripts. Interview transcripts were uploaded to the qualitative data analysis software Nvivo (Version 12; QSR International). Within Nvivo, codes were inputted as concise labels to identify data groups. Inductive coding was completed and both latent and semantic coding approcahes were used to ensure that aims of the study were discussed and that important findings, not necessarily anticipated, were not missed (Braun & Clarke, 2006). Codes were created and categories were classified into higher-order themes. As themes were constructed, relationships between themes were considered (Braun & Clarke, 2014). Themes were reviewed throughout the process to ensure representation of the entire dataset. Coding and theme development continued in iterative cycles until clear repeated themes were constructed and variant and typical cases were evident. This process included a second author (MS), professor in Occupational Therapy, experienced in qualitative research. Representative quotations of each sub-theme were selected to illustrate meaning (Braun & Clarke, 2014).

4.3. Findings

Thirteen children and their parents were recruited. Three children did not complete the study: one had unscheduled surgery following the first time point and two went abroad for periods of extended therapy during the study. Ten of those initially recruited completed the study. Participants were allocated a number to maintain anonymity, and this is represented in the quotes. All children and their families were white Irish, from a mix of suburban and rural areas across Ireland with good access to green space and parks for walking. Eight children had a diagnosis of CP and two had another diagnosis which was a permanent neurological impairment with associated walking pathology. Those without a CP diagnosis walked independently but required handheld support for crowds, steps and stairs and functioned at a level equivalent to GMFCS I. Diagnoses are not disclosed to protect anonymity. Table 4-1 describes participant (child) characteristics, repeated to include the parent involved in the interviews. Table 4-2 describes participant/interviewee (parent) characteristics. These findings relate to data collected at the one, three and six month time points, after the children received their dog.

Table 4-1: Participant Characteristics: children (diagnoses not disclosed to protect identity)

Participant Number	Age at start of study	Gender	GMFCS (or equivalent)	Typical walking aid	Parent who completed interview
01	12	M	III	handheld/PKW	Father
02	9	M	IV	PKW/powered wheelchair	Mother
03	9	M	I	handheld/supervision	Mother
04	8	F	III	walker or tripods	Mother
05	9	M	I	supervision/handheld/PKW	Mother
06	8	M	II	supervision/handheld/PKW	Mother
07	9	F	IV	PKW/powered wheelchair	Mother
08	8	F	III	PKW/tripods	Father
09	11	M	II	handheld/supervision	Mother
10	6	M	II	handheld/supervision/PKW	Mother

PKW: Posterior Kaye Walker; GMFCS : Gross Motor Function Classification Scale. GMFCS levels: Level I: Walks without limitations; Level II: Walks with limitations; Level III: Walks using a handheld mobility device; Level IV: Self mobility with Limitations; May use Powered Mobility; Level V: Transported in a Manual Wheelchair (Palisano et al 2008)

Table 4-2: Participant characteristics: parent

Participant Number	Who completed interview	Previous experience with dogs	Other children	Home environment
01	Father	Yes	One other child	Housing estate
02	Mother	No	Two other children	Housing estate
03	Mother	Yes	One other child	Housing estate
04	Mother	No	Two other children	Countryside
05	Mother	No	Two other children	Countryside
06	Mother	Yes	Two other children	Housing estate
07	Mother	No	One other child	Small village
08	Father	No	No	Housing estate
09	Mother	Yes, dog in home	One other child	Housing estate
10	Mother	No	One other child	Countryside

There were five themes which relate to the impact of the introduction of the MADs with the children: (1) The impact on physical mobility; (2) Social facilitation; (3) The dog as a motivator (4) Personal growth for the child and (5) The impact on the family.

4.3.1. The impact of the dog on physical mobility

All of the participating parents perceived that walking with the dog had a positive effect on their child's physical mobility. This included the perception that the child walked for longer periods, had improved quality of walking and was safer. Improved endurance was described by all parents. Some parents felt that their child was walking longer distances with the dog than with their typical walking aid:

"We can just get longer out and about …. before it was probably a kilometre before he'd say he has pains or 'I'm tired'... … it's helping him so much with his endurance and his ability just to enjoy a walk ..." (9)

This was deemed by parents to be due to a combination of the children being motivated to walk with the dog and the frequency of structured walking increasing their ability to walk for longer.

"….he could probably go twice as long (with the dog) as with our hand. I don't know if it's in his mind or whatever.. he seems to be able to walk better and for longer with her (the dog) than if he had our hands, he might have been saying 'pick me up' whereas now you wouldn't hear that.'' (10).

All parents perceived that their child's overall walking pattern, steadiness and balance had improved since starting walking training with the dog.

"… definitely more stable, definitely more upright… looking forward better as well and obviously not ploughing along which would have been a huge concern before''. (5)

In eight participants, parents described the dog enabling the child to negotiate different surfaces including walking on the beach, through woods and walking on rough terrain or stones. For three of the children, the parents report a reduction in the number of trips and falls they have since using the dog as a walking aid, with one parent reporting a 'huge difference' in the number of falls.

"Walking with (dog), he doesn't really fall anymore… When realistically if we were doing the walks we're doing now he would have fallen maybe four or five times per walk. So it's a huge difference''. (9)

Most (seven) parents perceived their child was more active since the dog arrived, due to more structured walking, walking further distances and increased frequency of walking.

“…we're not just walking to the bus. We're walking to the bus and we're practicing crossing the road and back and we're walking a bit further because the dog needs a few steps extra… there's definitely more activity on a daily basis”. (9)

Three parents report that their children are less sedentary, and more active while playing with the dog.

“…he's out now all the time playing with (dog) in the garden”. (3)

and they are less likely to be using devices or watching television. However, three other parents didn’t feel that the dog had any impact on their child’s activity levels yet.

“Not changed hugely…outdoor activities would be the same… I suppose we go out for a bit more walks….but he’d more in his wheelchair than his walker…But overall his activity levels are probably the same”. (2)

These children had more impaired walking ability and are still very dependent on their parents to do their walking or therapy.

Although all parents described improved mobility, there were perceived challenges in relation to walking training. Four parents identified that walking with the dog was tiring or hard work for the child. These were children with more impaired walking (GMFCS III and IV):

“… at the start it’s going to be more energy consuming. Doing his normal walking he's holding your hand… he's probably putting a bit more weight on you… so it's more work, so he's gonna get more tired so it's gonna take a while to build up that stability.’’ (1)

Some parents talk about their child not wanting to do the walking training due to the physical challenge. For the children who typically use a Kaye Walker, two adults were required to do the walking training safely with the dog. This was described as time consuming and at times, parents found it hard to fit this into their day. Most parents report that walking training with the dog requires practice and that there is a process to adjust to walking with the dog, including navigating both child and dog in public places being a challenge for the parent.

''The challenges I think are for me mainly, in that you're trying to drive the two of them… It's trying to manage the two of them ...''. (3)

All families reported in the one and three month interviews that the walking training was still progressing, and most families felt the child's physical walking ability and activity levels had improved by the six-month time point. However, the four children with more impaired walking still found walking training with the dog challenging after six months.

4.3.2. Social facilitation

All parents perceived the dog to impact their child's social interactions in a positive way, facilitating them to interact with the public and their peers. In many cases people would stop and talk to the child with their dog. One mother described how another child's parent approached the child and interacted with the child in a manner that would never have happened previously.

"… this never happened before, a car actually pulled in, and it was a friend from school and the mother was like, 'Oh, I hope you don't mind, my child wants to say hello to the dog'… that was lovely ...they never stopped before… it was nice that maybe they see (dog) and they thought 'oh, we'll stop and say hi' ''. (10)

Many parents described their child engaging with others, as the dog gave them a topic of conversation and this helped to initiate interactions.

"it's an icebreaker I think for people that don't know the whole disability side of things''. (1)

"…if we meet somebody on the street, they'll say 'oh, this is your dog'… he'll be more open and chatty, certainly about the dog…it's brought him out of himself a little bit.'' (2)

The dog was perceived as bringing a positive emphasis to the child rather than a negative difference, effecting positively on the child's social confidence.

"it's a great way for (child) to integrate with conversations ….. when people see a person with a dog, it looks a lot more normal to them than when they see a person in a walker or a wheelchair… (child) has definitely increased in confidence… I think a lot of that has been to do with (dog) and opening up a different way for her talk to people ''(8).

Most parents reported that the dog brought positive social attention from peers and this facilitated their inclusion in their school and with friends. This mother talks about other children wanting to pet the dog, prior to this she felt they stared at him:

"…before we would be going for walks and kids would have kind of queried him or stared at him or wondered what was wrong with him. Whereas now kids are stopping and saying 'I like your dog', 'What's her name?' ..it's actually lovely, because other kids do want to say hello or pet the dog''. (10)

One parent described how making their child's physical challenges visible through the dog was a positive and that people gave her child more space in public places stating *"people move out of his way now''. (3)*

4.3.3. The dog as a motivator

The influence of the dog on the child's motivation to either be more active, get outside more or to do their therapy is described in all post dog interviews. The dog had a positive impact in motivating some children to get outdoors more, this was described by five parents:

"He's definitely getting outside more since we got (dog) …now because we're going out for more walks, he's getting more fresh air." (1)

Two parents describe how their child is motivated to go places because the dog is going. This included the child wanting to do daily errands like go to the shops or help their parent with chores and this is not something that the child would previously have done:

"Certainly the motivation even to go places would be huge. There's a huge desire to go because (dog) is going and I don't know whether that's because suddenly there is a dog there or it's just the confidence that it gives him … I do think it's probably a confidence thing more than anything else''. (3)

All of the parents described the motivational impact the dog had on getting the child to go walking, both doing walking training and going out for walks with the family using their typical walking aid. Some parents added that the dog distracted the child from walking difficulties, such as feeling tired. Other parents described how their child is more willing to go out walking due to the responsibility of having to exercise the dog:

"There's a huge difference… we can see it already that he's more he's willing to go out and go walking a lot more, because he knows he is his dog and he has to bring him out…'' (6)

Two parents talked about how the dog is incorporated into their child's routine physiotherapy programme and the dog motivates them to put in extra effort, makes therapy less laborious and adds a fun factor to their exercise programme. The children were motivated by having the goal of being able to walk with the dog:

“It brings more ...fun into the exercises (doing exercises with dog)”. (7)

“He might not necessarily be doing anything at the time (dog), but he's in the room and its motivation, ‘yeah we're gonna get going there now and get moving with dog, at some point’”. (2)

Most (seven) parents perceived their child was more active since the dog arrived, due to more structured walking, walking further distances and increased frequency of walking:

“…we're not just walking to the bus. We're walking to the bus and we're practicing crossing the road and back and we're walking a bit further because the dog needs a few steps extra… there's definitely more activity on a daily basis”. (9)

“…he's out now all the time playing with (dog) in the garden”. (3)

However, three parents didn’t feel that the dog had any impact on their child’s activity levels yet. These children had more impaired walking ability and are still very dependent on their parents to do their walking or therapy:

“Not hugely…outdoor activities would be the same… I suppose we go out for a bit more walks….but he’d more in his wheelchair than his walker…But overall his activity levels are probably the same”. (2)

Another three parents describe how their child is less sedentary and up on their feet more even within the house due to the dog and they are less likely to be using devices or watching tv:

“I just noticed overall (child) has wanted to be up more on her feet than before , she loves watching YouTube videos, but she would have just sat on the couch and done that but now she'll stand by the coffee table and watch them and be moving more”. (8)

4.3.4. The child’s personal growth

All parents describe how their child’s confidence and self-belief had grown since the dog arrived. This may be a combined effect of the confidence their child gets from increased social engagement, increasing self-esteem or increased physical ability thus gaining the benefits of exercise from increased activity levels:

“…but I think it's more do with his confidence in himself. And his growing confidence in handling (dog) is very good. I can see him when we're crossing roads now. He's got a greater awareness of the dangers of cars and things like that”. (9)

Some parents talk about how their child is very proud of their dog and the positive impact this brings through a sense of wellbeing and happiness while walking with the dog:

“People are inclined to talk and smile and (child) is very proud when he’s with (dog)”. (5)

The introduction of the dogs provided some of the children with responsibilities. Caring for their own dog gave them a duty and they had a sense of achievement from this:

“... And to see the responsibility and the interaction, … like he gets his feed and he gets his water.”(5)

All parents describe how the child and dog developed a bond and that their child now has a close companion. This includes some children having a friend:

“…she just really loves having the dog… she's really her friend, they really are just buddies… (dog) always comes over and plonks herself beside her and (child) loves giving her rubs and stuff”. (8)

One parent described how she feels the dog will help the child to deal with getting over any surgery he may need, including motivating him to physically rehabilitate post-operatively:

“…it'll be a great help for (child) if he ever does need surgery…to get him back on his feet again and mobile, because you have a crutch there. You know, it is going to be a reason to move again. So it's all so positive”. (9)

Some parents explained the dog’s calming effect on their child, reducing anxiety and meltdowns and helping them to get over triggering moments more easily:

“…so there are less tantrums now…if she goes into a tantrum, she's a lot faster ...getting out of them. She’ll go over and she’ll rub (dog) , and then it's easier for me then to actually suggest let's go do a bit of exercise or we’ll do something with (dog) or with her walker. And she’ll do it”. (7)

Having the dog also facilitated an easier experience with hospital appointments, making it more of a positive experience for one child:

“We've had a few appointments, where she's come with us now, that's a huge thing… we had an EEG recently… she just did this, she just lay down and he let us do the whole thing. She was amazing. And it was just lovely’’.(3)

The perception of increased child confidence and pride was seen clearly at the six-month time point, while at the one month time point most children had not yet accrued these benefits.

4.3.5. Impact on the family

All parents described how the family benefitted overall from the introduction of a mobility assistance dog and this was present throughout the interviews. The dogs were perceived to bring a positive energy and happiness to the home.

“A very positive addition to the family, not just to (child). It's made a big difference. … he brings a kind of positive energy into the house”. (1)

This was attributed to the dogs having wonderful temperaments, being well trained and settling in easily to family life:

“You couldn't ask for an easier dog to care for, she's a big softy… she tells you everything that she needs, she puts her head on your lap and you know something's up!”. (8)

Most parents were getting more exercise since the arrival of the dog, due to the responsibility of having to exercise the dog. Some families went for more walks together and described this as a positive:

“... He needs a big walk every day. I mean it's extra work but it's a positive thing… we're getting more walks, (dad) and I will do it”.(1)

“… it's definitely got us out more, walking with (dog), as a family”. (9)

Some parents talk about the positive effect the dog brought to their other children. One mother describes how a sibling also benefits from the positive attention the dog brings from his own peers:

“I thought its lovely for him (sibling) that we have the dog as well… a lot of the time other kids probably would have been staring at (child) too…it's nearly an outlet for him to talk about… that even though his brother has a walking problem, they have this cool dog and that’s this positive thing to talk about”. (10)

Introducing the dog to the family and child was a process. This involved training with the dog trainer, training in care of the dog and subsequent periods of adjustment for both the family and the child using the dog as a walking aid. Attending the charity for training was a challenging but rewarding experience for all participants:

"I found it quite challenging ...at the start, trying to manage the two of them, but (trainer) was very reassuring … you realise the amount of obstacles that there are, people as well as things that are actually in the way….and it was actually quite enjoyable doing it, I learned an awful lot actually''. (3)

Bringing the dog home brought a change to the household with all families commenting on the change of having the responsibility of minding a dog:

".. it's been a challenge minding him because we didn't have a dog and now we do and someone has to mind him everyday… it's just another being to manage in the house. So… responsibility''.(4)

There was a period of adjustment for the family, for the most part the other children bonded with the dog before the child with the impairment:

"…but (child) has a slightly different relationship with him… it's more of a working relationship. Even though the dog is his and he likes that it's his dog and he's very proud that he has this assistance dog, it's probably taken him a bit longer to connect with the dog, more so than (the other child) or myself, or dad". (1)

There were challenges for all families. Dog ownership brought additional work and required effort on the parents' part with careful consideration prior to getting a MAD recommended. The overall sentiment, however, was that the benefits of the dog outweigh the challenges:

" …a dog is a big responsibility… it might not be for everyone... you have to think about what you're taking on". (1)

All families wanted a dog and were prepared to take a dog into their home. Although each family described challenges, the overall feeling was a positive impact on the household.

4.4. Discussion

The findings highlight that although a MAD is trained to aid with mobility, the experience of these families is that there are a variety of positive outcomes for the children and their families, including perceived change in mobility, socialisation and personal development of the child. Previous studies in adults have similarly identified that beyond the trained tasks of the dog, such as providing assistance to walk, the dogs may also provide companionship and facilitate social interaction for people with disabilities (Sachs-Ericsson et al., 2002; Winkle et al., 2012).

In this study of ten children, all parents highlighted improved perceived general mobility in their children. The physical benefits are clearly described in children with less impaired walking (such as child 3,5,6 and 9). Parents describe perceived benefits to their gait, balance and posture. This aspect will benefit from follow-up quantitative measurement of gait and balance to compare perceptions to measurable changes. There is little research in this area in pediatrics although (Zabihaylo et al., 2005) showed that gait rehabilitation with a dog following stroke showed measurable improvement in gait parameters and head control in one adult. It is not yet clear if this is directly due to the training effect of the dog, or the overall effect of the dog on increased activity and confidence. All parents report that their child is more motivated to walk and be active. Increasing PA has been shown to have subsequent health benefits in children with CP (Carlon et al., 2013). It is known that there is difficulty maintaining PA levels in children with impaired walking as they reach teenage years and as they go through growth spurts (Carlon et al., 2013). These findings may suggest that the addition of a MAD may facilitate motivation to stay active.

Most parents describe how the dog allowed their child to negotiate terrain and obstacles with more ease than with their typical walking aid. This may be due to the nature of the child feeling more confident while walking with their dog or due to the dog being more manoeuvrable. The training effect of the dog may include the child's increased need for postural control when they rebalance using the dog via a handle. Using a walking aid or holding a parent's hand, they may put more force through the aid and be less reliant on their own dynamic balance. Some children were described as more aware of obstacles when they are not reliant on holding a parent's hand and they were more aware of their environment. This has not previously been described. Quantitative data on gait and balance parameters analysing the training effect of walking with the dog and while using the dog as a walking aid may help to explain this further. Blanchet et al (2013) found that adults with a disability who used a MAD walked faster and ascended stairs more quickly with a dog (Blanchet et al., 2013), but there are no similar studies reported in children to date.

Although families widely report a positive impact on their child's mobility, some parents report that walking training with the dog is effortful and tiring. Although the mobility dog may be useful for building strength and endurance in these children, retaining a walking aid that aided energy conservation may be beneficial for functional mobility for some children of GMFCS level III and IV, given the underlying impact of fatigue associated with physical impairments such as CP (Joyner, 2022). All children in our study were described as being motivated to be more active through structured walking and unstructured activities. The motivation to be physically active using animal interventions was suggested by parents in a previous qualitative study in children with CP (Shimmell et al., 2013). In our study, these children are clearly perceived to be motivated by their MAD, however perceived improved mobility and activity levels were clearly seen in those children GMFCS level I-III only, after 6 months.

Families perceive that the dog had a positive impact on family life, encouraging the family to get more exercise, to go walking as a family and bringing a positive emphasis to the child's disability. These findings are consistent with previous literature on the benefits of assistance dogs on families (Bibbo et al., 2019). However, the families described a process of change in introducing a new routine of using the dog as a walking aid and caring for the dog. Nonetheless, overall parents explained that the positive impact of the dog far outweighed any negative impact. All families in this study had the resources to take a dog into their homes, having adequate access to green space and at least one parent working in the home or at home throughout the day. Not all children may have these resources available.

Assistance dogs are increasingly provided to improve functional independence in children with pervasive disorders (Berry et al., 2013). Many children with physical impairments such as CP also have needs in their social-emotional regulation (Colver et al., 2015) and an assistance dog may provide support as a coping mechanism, regardless of the training effect of walking with the dog. The perceived positive effect on the child's social inclusion was clear and this is consistent with previous studies (Sachs-Ericsson et al., 2002; Winkle et al., 2012). The social inclusion of children with disabilities is crucial to their development and wellbeing (Odom & Buysse, 2011) and the introduction of a trained dog may facilitate that inclusion in children with walking impairments.

The study is limited in that it is in a small group of children with varied walking ability. Data collection and follow up was over a 6-month period with each child and therefore, longer term perceptions of outcomes are yet unknown. All children had received a dog from the same assistance dog charity and there is also a possibility that families may have felt indebted to positive reporting due to their commitment to their own decision to get a dog, although all families were given ample opportunity to express challenges with the experience.

4.5. Conclusion

Parents perceive substantial benefits of mobility assistance dogs for their children with walking impairments. There are clearly perceived benefits in social facilitation, motivation to be active and positive effects on family life across levels of impairment. Parents perceive improvement in gait, balance and endurance in children with less impairment. Changes in social inclusion appeared after one month however physical benefits and personal growth for the child was seen after six months. Understanding parents' perceptions around this novel training method for children with walking challenges and how an assistance dog may benefit a child, is of clinical relevance for paediatric therapists involved in their care. Future comparison with quantitative gait, activity and quality of life data will shed light on measurable change alongside parents' perceptions. The use of assistance dogs for children with physical and neurological impairments would benefit from medium to long term follow-up to analyse how these children fare with their dogs over a longer period.

The following chapter, Chapter five, will analyse the QoL changes of the ten participants who received a MAD at each of the aforementioned timepoints, using the standardised QoL tool, the Cerebral Palsy Quality of Life Inventory (CPQoL).

5. Study Two. The Effect of Mobility Assistance Dogs on Quality of Life in Children with Physical and Neurological Impairments

This chapter is a modified version of the article published in the journal *Physical and Occupational Therapy in Pediatrics:* https://doi.org/10.1080/01942638.2024.2400344.

Heather Curtin[1,2] , Ciaran Simms[1], Damien Kiernan[2], Richard.B.Reilly[3] and Michelle Spirtos[4]

[1] Discipline of Mechanical, Manufacturing and Biomedical Engineering and Centre for Biomedical Engineering, Trinity College Dublin, Ireland.

[2] The Motion Analysis Laboratory, Central Remedial Clinic, Dublin, Ireland.

[3] Centre for Biomedical Engineering, School of Medicine, Trinity College Dublin, Ireland.

[4] Discipline of Occupational Therapy, School of Medicine, Trinity College Dublin, Ireland.

5.1. Introduction

Reduced physical activity (PA) and participation restrictions in children with physical and neurological impairments such as cerebral palsy (CP) may lead to a reduced quality of life (QoL) compared to their typically developing peers (Rosenbaum, 2007). The World Health Organization (WHO) defines QoL as “an individual’s perception of their position in life in the context of the culture and value systems in which they live, and in relation to their goals, expectations, standards and concerns” (www.who.int). QoL in children with CP has been defined as feelings of well-being across domains including physical, social, emotional and spiritual aspects of life (Bjornson & McLaughlin, 2001). QoL is not always related to the level of function in children with CP (Makris et al., 2021; Shelly et al., 2008). Factors such as pain, parental stress and psychological factors can predict QoL in some domains (Rapp et al., 2017) and therefore QoL assessment of children with CP should assess individual domains impacting QoL which include psychological and social aspects and not just functional ability (Makris et al., 2021). Current recommendations for effective therapies on motor skills and pain in CP include animal assisted intervention (AAI) (Novak et al., 2020), where they also highlight that motor based therapies should include mobility training, strength training and general physical activity to target improved community participation. There is some evidence that AAI can improve QoL in children with CP by improving mood and decreasing the psychosocial burden of their impairment (Deutz et al., 2018; Elmaci & Cevizci, 2015).

Assistance dogs are trained to undertake tasks to help mitigate an individual's impairments. (Audrestch et al., 2015). The three most common types of assistance dogs are guide, hearing and mobility assistance dogs (MADs). MADs offer greater independence to people with mobility impairments through practical support; performing such tasks as opening doors, retrieving objects and providing counterbalance for transitional movements (Assistance Dogs International Summary of Standards 2024).

In Ireland, a charity provides dogs trained as a walking-aid for children with impaired walking ability [https://dogsfordisabled.ie/]. The dogs are trained to provide forward momentum and counterbalance for the child while walking. For children with mild walking impairment such as those of Gross Motor Function Classification System (GMFCS) levels I-II (Palisano R, 1997), the dog is trained to regulate walking speed and encourages the child to negotiate obstacles safely and to counterbalance on turns and when changing direction. For children with more impaired walking, such as those who have CP GMFCS levels III-IV and are dependent on a walking aid to mobilise, the dog may be used as a motivation to practice walking with their walking aid. The children also practice their routine physiotherapy exercise programme with their dog, such as sit-to-stand practice and standing balance, again using the dog with the harness to provide light support and counterbalance.

Several studies to date found that a trained assistance dog, including those who help with functional tasks and those who provide emotional support, had a positive effect on social inclusion and perceived QoL in children with disabilities (Bibbo et al., 2019; Burgoyne et al., 2014; Crowe et al., 2019). MADs have had positive outcomes in adults with physical disabilities when considering psychosocial wellbeing, self-esteem and energy levels (Rodriguez et al., 2020). Beyond the trained tasks that the dog performs: their companionship, emotional support and social facilitation in public may improve QoL in people with physical disabilities (Winkle et al., 2012). A systematic review investigating the impact of assistance dogs in children with a wide range of disabilities found that 23 out of 29 studies showed improvements in physical health, psychological health, social well-being and companionship, using a variety of QoL outcome measures (Lindsay & Thiyagarajah, 2021). Little is presently known about the impact of a MAD for children with physical and neurological impairment. In particular, no studies have used a validated tool to investigate the specific effect on QoL of a MAD provided to help children with walking impairment.

To better understand the QoL outcomes following receiving a MAD, this study followed ten children with data pre-dog, at one-month post receiving their dog and at three-month and six-month follow-up using a standardised QoL measure. We also sought to determine if there is a difference in the change in QoL domains based on the functional (GMFCS) level. This is one component of a larger mixed methods study assessing the effects of a MAD on gait, activity levels and QoL in children with impaired walking.

5.2. Methods

5.2.1. Ethical considerations

Research ethical approval was obtained from both the Trinity College Dublin Faculty of Health Sciences Research Ethics Committee and the Central Remedial Clinic Research Ethics Committee prior to commencing this study.

5.2.2. Participants

This prospective repeat measures study is part of a larger mixed methods study. Recruitment procedure and participant characteristics are described as in general methods 3.4 Recruitment.

5.2.3. Procedure: Training

Children were matched and trained to walk with their dogs as previously described here 3.7 Matching with dogs and 3.8 Walking Training with IDFD.

5.2.4. Outcome Measure Selection

Based on evaluation of the most suitable tool to measure QoL in this cohort as outlined in the literature review**,** Section 2.6. The CPQoL (Waters et al 2013) was chosen to measure QoL. The Cerebral Palsy Quality of Life questionnaire for children (CP QoL-Child) is a condition-specific measure developed and validated to assess QoL for children with CP aged 4–12 years (Waters et al., 2013). It has the strongest evidence of measurement properties among condition-specific QOL measures for children with CP (Carlon et al., 2010). The CPQoL has been shown to have good internal consistency and reliability (Waters, 2007), (Carlon et al., 2010). Its framework is based on the International Classification of Functioning (ICF). The CPQoL-Child measures the following seven areas of a child's life: *social wellbeing and acceptance; participation and physical health; feelings about functioning; emotional wellbeing and self-esteem; pain and impact of disability; access to services* and *family health*. The primary caregiver-proxy form contains 66 items and the child self-report form contains 52 items. The child self-report (age 9-12) was not used in the study, as those aged over 9 included in the study (n=6) may have had some communication difficulties and the primary caregiver proxy-report was deemed the most suitable to use with all participants (completion time for both ranged from 15–25min). The CP QoL Child was designed to be used by researchers, clinicians, health professionals and educators for a variety of purposes, including conducting research to determine whether an intervention has increased a child's QoL; and as an assessment to gain insight into several aspects of children's lives. The handbook on administration and scoring of the CPQoL is available here [3]. The CPQoL child is available here[4].

The World Health Organization (WHO) defines quality of life (QoL) as "an individuals' perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns" (WHO, 2001). This is multidimensional and can be assessed using either generic or condition-specific measures (Gilson, Davis, Reddihough, Graham, & Waters, 2014).

Although not all participants in the study have a diagnosis of cerebral palsy, (eight participants have a CP diagnosis (two have other diagnoses[5]), all children have a permanent neurological disorder and impaired walking and the CP QoL-Child parent proxy version was deemed the most appropriate QoL outcome measurement tool and was used for all children.

This tool has been shown to have good measurement properties: internal consistency ranged from 0.74 to 0.92, and test-retest reliability ranged from 0.76 to 0.89 (intraclass correlation coefficient) (Carlon et al., 2010; Davis, Shelly, Waters, & Davern, 2010; Waters et al., 2007). The questions of the first five domains begin with "How do you think your child feels about…?". The questions on pain and impact of disability domain are 'yes/no' questions and 'how' questions such as "Is your child bothered by hospital visits?" and "How much pain does your child have?". The family health domain starts questions with "How do you feel about…?". The questionnaire is scored on nine-point scales from 1 = very unhappy to 9 = very happy except for one item in the pain and impact of disability domain. This item, "Does your child worry about who will take care of them in the future?" is scored on a five-point scales from 1 = never to 5 = always.

Each parent or guardian was given a printed copy of the CP QoL-Child Parent report to complete at baseline and at each timepoint. They were asked to complete this and return

[3] CPQOL-Child-manual.pdf (ausacpdm.org.au)[3]
[4] CPQOL-Child-primary-caregiver-4-12-1.pdf (ausacpdm.org.au)
[5] Diagnoses not described to protect participant anonymity.

the printed copy with the activity monitor at the end of the week. The copies were returned by stamped self-addressed envelopes to me or were collected.

Scores were collated as per the documented protocol. Raw scores were recoded into a range of 0–100 scores, with higher scores indicating better QoL except in pain and impact of disability domain, where lower scores indicate better QoL (Waters et al., 2013). For the interest of looking at an average QoL score, the pain and impact of disability domain score was inverted to create a summary score. Scores were then uploaded to a database and coded for each domain across participants and time points. Domain specific scores were analysed and a summary score was used to portray overall trends of QoL.

To date, no standardised method has been found to substantiate an individual change threshold for intra-individual scores in the CPQoL (Wyrwich & Warinski, 2000). Sensitivity of the CPQoL to measure intra-individual change has yet to be established and for the purpose of analysing individual participant results, we will refer to greater than 10 point change for intra-individual scores as previously reported, where a 10% cut off was employed to classify participants as having improved or worsened in QoL outcome measures (Osoba et al., 2005).

5.2.5. Data Collection

Each parent or guardian was given a printed copy of the CPQoL to complete at baseline (before they received their dog) and this was repeated a month after they received their dog, at three-months and at six-months follow-up. Although the data were collected at four timepoints, the three-month timepoint data were not deemed necessary for inclusion in the QoL analysis. These data were included in collection to ensure adequate data timepoints were collected in the case of missing data.

Scores were collated as per the documented protocol, previously described (Waters, 2007). Raw scores were re-coded into a score ranging from 0–100, with higher scores indicating better QoL, except in pain and impact of disability domain, where lower scores indicate better QoL. Domain specific scores were analysed. To graphically show domains in the same trajectory, the pain and impact of disability domain score was therefore inverted prior to inclusion in the analysis. Data were then grouped into those with less physical impairment (group A- GMFCS I-II) and those with more physical impairment (group B- GMFCS III-IV) for further analysis.

5.2.6. Statistical Analysis

Data were uploaded to IBM SPSS Statistics Version 28 (Armonk, NY: IBM Corp) for analysis. Due to the small group size, non-parametric tests were used to assess differences in groups across timepoints. The Wilcoxon Signed Rank test was used where pre and post data had a similar distribution (distribution available in Appendix L), and the Sign Test was used if the data were not similar in distribution around the median (King & Eckersley, 2019). Statistical significance for the group was set at $p<0.05$.

5.3. Results

All parents completed the outcome measure for their child at each timepoint with the exception of participant 1. They did not complete at one-month and three-months as the child was not walking for a period due to an injury. The parents did not feel it would be a fair reflection of the child's progress with their dog.

The domain *access to services* has been excluded from the analysis. This domain may have been affected by the ongoing COVID-19 pandemic at the time of data collection and additionally was deemed as having no expected relation to the child receiving a dog.

5.3.1. Results by Participant

Domain specific scores for each child (participants 1-10) are presented in Figure 5-1.

<u>Participant 1 (GMFCS III):</u>

This child uses hand-held assistance to walk at baseline, they hold a parent's hand for outdoor mobility and hold an assistant's hand in school. They tend to walk holding on to furniture around the house. A clinically significant change (>10 point change) in QoL scores was observed in the domains *social wellbeing and acceptance* and *emotional wellbeing and self-esteem* at 6 months.

<u>Participant 2 (GMFCS IV):</u>

This child uses a posterior walker for daily walking therapy only. They typically mobilise using a powered wheelchair. They require full assistance for all transfers. No change (>10 point) was seen in any domain from pre-dog to one-month or from pre-dog to six-month follow-up.

<u>Participant 3 (GMFCS I):</u>

This child typically walks with parental supervision and at times with hand-held assistance, particularly in crowded areas. They have some difficulty with visual-spatial awareness, low muscle tone and endurance. Change (>10 point) was seen from pre-dog to one-month in domains *social wellbeing and acceptance* (positive) and *pain and impact of disability* (negative). From pre-dog to six-month follow-up there is positive change (>10 point) in domains: *social wellbeing and acceptance*, *feelings about functioning*, *participation and physical health* and *emotional wellbeing and self-esteem*.

<u>Participant 4 (GMFCS III):</u>

This participant walks quite independently using a posterior walker and transfers independently. They use two crutches for walking therapy and a manual wheelchair for longer distances. They showed negative change (>10 point) at the one-month timepoint in domains *emotional wellbeing and self-esteem*, *participation and physical health* and *emotional wellbeing and self-esteem*. At the six-month follow-up this child showed clinically meaningful negative change in the domain *participation and physical health* and *family health* and in a positive direction in *pain and impact of disability*.

<u>Participant 5 (GMFCS I):</u>

This is a very active child, but they have difficulty with balance, endurance and spatial-awareness. They walk independently with parental supervision. There was positive change (>10 points) seen at the one-month timepoint in the domain *participation and physical health* and in a negative direction in *pain and impact of disability*. At the six-month timepoint there was positive change seen in the domains *participation and physical health*, *emotional wellbeing and self-esteem* and *family health*. There was a negative change in *pain and impact of disability* at six-months.

<u>Participant 6 (GMFCS II):</u>

This child previously used a walker for longer distances, but now walks mostly with supervision only. At the one-month timepoint, change (<10 points) was seen in a positive direction in the domains *social wellbeing and acceptance* and *participation and physical health* and in a negative direction in the domains *feelings about functioning*, *emotional wellbeing and self-esteem* and *pain and impact of disability*. At the six-month timepoint, clinically meaningful positive change is seen in the domains *social wellbeing and acceptance*, *participation and physical health*, *feelings about functioning*, *emotional wellbeing and self-esteem* and *pain and impact of disability.*

Participant 7 (GMFCS IV):

This child uses a posterior walker for supervised therapeutic walking. They typically mobilise in a self-powered wheelchair. After one-month there is change (>10 points) in a negative direction in domains *feeling about functioning* and *family health* and in a positive direction in domain *emotional wellbeing and self-esteem*. After 6 months, there is change (>10 points) in *family health* (positive) and in *participation and physical health* (negative).

Participant 8 (GMFCS III):

This child mobilises using a posterior walker outdoors. They use two crutches for therapeutic walking and hold onto furniture to walk in the house. There is no change (>10 point) in scores at either the one-month or six-month timepoints.

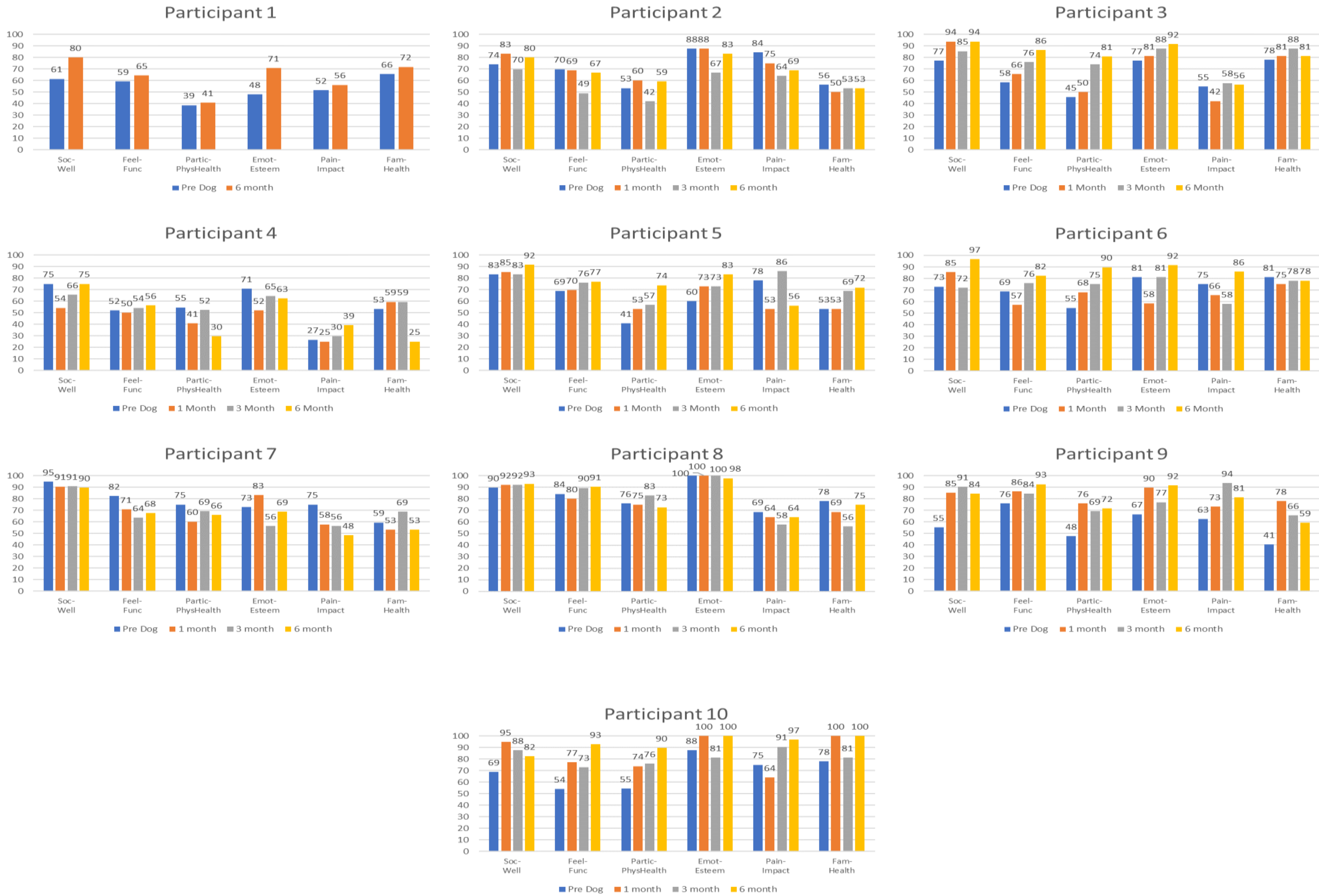
Participant 9 (GMFCS II):

This child typically walks with supervision or hand-held assistance outdoors. They have regular falls when walking independently. At one-month there is change (> 10 point) in all domains. At the six-month timepoint this positive change maintained in all domains.

Participant 10 (GMFCS II):

This child prefers to walk independently but has regular falls. They use a posterior walker for longer distances. At one-month this participant showed positive change (>10 point) in all domains except *pain and impact of disability* which showed negative change. After six-months there is positive change (>10 point) in all domains.

Figure 5-1: CPQoL scores by domain for each participant for each time point (pre-dog, one month, three month and six months)



5.3.2. Group Analysis (n=10)

The results of the analysis of the group of 10 children from pre-dog to one-month after they received their dog and six-months follow-up are presented in Table 5-1. Graphical display of these data are available in Appendix M.

Table 5-1: Pre-dog to one month and six month Wilcoxon/Sign test for the group (n=10)

Domain	Pre-Dog Score (median)	1 month median score (p-value)	6 month median score (p-value)
Social Wellbeing and Acceptance	73.4	85.4 (P=0.17 [a])	87 (P=0.02*[a])
Feelings about Functioning	66.1	68.7 (P=0.9[a])	79.7 (P=0.047*[a])
Participation and Physical Health	52.3	60.27 (P=0.3[a])	72.2 (P=0.1[b])
Emotional Wellbeing and Self Esteem	71.9	81.3 (P=0.9[a])	87.5 (P=0.03*[a])
Pain and Impact of disability	67.2	62.5 (P=0.03*[a])	60.2 (P=0.7[b])
Family Health	62.5	68.7 (P=0.7[b])	71.9 (P=1[b])

[a] Wilcoxon [b] Sign test

After one-month of having their dog, change was seen in the domain of *pain and impact of disability* only ($p<0.05$) in a negative direction of the median scores.

After 6 months of having their dog, positive change ($p<0.05$) was seen in domains *social wellbeing and acceptance*, *feelings about functioning* and *participation and physical health*.

5.3.3. Group A (GMFCS I-II) and Group B (GMFCS III-IV) analysis

The results of the analysis of group A (n=5) and group B (n=5) from pre-dog to one-month after they received their dog and six-months follow-up are presented in Table 5-2.

Table 5-2: Pre-dog to one month and six month Wilcoxon Signed rank by domain for Group A (n=5) and Group B (n=5)

	Group A (GMFCS I&II)			Group B (GMFCS III&IV)		
Domain	**Pre Dog Score (median)**	**1 month median score (p-value)**	**6 month median score (p-value)**	**Pre Dog Score (median)**	**1 month median score (p-value)**	**6 month median score (p-value)**
Social Wellbeing and Acceptance	72.9	85.4 (P=0.04*)	91.7 (P=0.04*)	75	87 (P=0.7)	80.2 (P=0.27)
Feelings about Functioning	68.8	65.6 (P=0.28)	86.5 (P=0.04*)	69.8	69.8 (P=0.7)	66.7 (P=0.68)
Participation and Physical Health	47.7	61.4 (P=0.04*)	80.7 (P=0.04*)	54.5	60.2 (P=0.27)	56.8 (P=0.34)
Emotional Wellbeing	77.1	77.1 (P=0.89)	91.7 (P=0.04*)	72.9	85.4 (P=0.65)	81.3 (P=0.78)
Pain and Impact of disability	75	62.5 (P=0.1)	81.3 (P=0.4)	68.8	60.9 (P=0.7)	56.3 (P=0.41)
Family Health	78.1	77.4 (P=0.7)	78.1 (P=1)	59.4	56.3 (P=0.26)	53.1 (P=0.2)

P* <0.05

There is a significant positive change after one-month in group A in the domains *social wellbeing and acceptance* and *participation and physical health*.

There is significant positive change in domains *social wellbeing and acceptance*, *feelings about functioning*, *participation and physical health* and *emotional wellbeing* for those in group A only from pre dog to six-months post dog.

There was no significant change in pre to post scores for group B in any domain at either timepoint.

5.4. Discussion

This is the first assessment of the QoL effects of introducing MADs to a cohort of 10 children with physical and neurological impairments, measured using a condition specific QOL measure. The children had wide-ranging functional ability and are a heterogeneous group in motor function, but they were all participants in a mobility dog programme in 2021/2022.

The results (Figure 5-1) for the individual children are variable, reflecting a wide range of baseline QoL. However, a clear pattern is discernible. Children with better motor function (GMFCS levels I-II) recorded larger changes in CPQoL score from baseline (pre-dog) to the six-month timepoint compared to the children with more impairment (GMFCS levels III-IV).

In general, over a six-month period clinically significant positive changes in CPQoL scores were observed for children with GMFCS levels I-II across the domains of *social well-being and acceptance*, *feelings about functioning*, *participation and physical health* and *emotional well-being and self-esteem*. A nuance is that after one month, there was a statistically significant reduction in the *pain and impact of disability* score. This may reflect some challenges with becoming accustomed to walking with the dog. However, this was transient and was not seen at six months follow-up. In contrast, no clinically significant positive changes in CPQoL domains were observed for children with GMFCS levels III-IV.

The improvements seen in domains involving social and emotional wellbeing are aligned with previous findings where a trained assistance dog, serving various functions, had a positive effect on social inclusion and perceived QoL in children with varied disabilities (Crowe et al., 2019), (Bibbo et al., 2019; Burgoyne et al., 2014). Previous literature has reported that both trained assistance dogs and therapy dogs have positive effects on social communication in children with developmental disabilities (Crowe et al., 2019; Rramani, 2023). MADs have been found to improve perceived QoL in adults with disabilities, providing emotional support beyond the trained tasks they perform (Winkle et al., 2012). However, this is the first time that the specific effect of a MAD has been analysed in children. The six-month follow-up of those who need little assistance to walk (GMFCS I-II) demonstrated improvements in multiple physical domains of QoL when using a MAD. Children who use an assistance dog to walk may not only show change in social and emotional aspects of QoL, but the dog also may help increase their participation and physical health, which includes their confidence to participate with peers and confidence in their own physical ability. This was previously reported by parents of children with autism who received assistance dogs, where parents found the children to have increased physical safety and comfort when walking with their dog (Burgoyne et al., 2014), however, no previous studies have been specific to children with CP.

There was a negative change in the domain *pain and impact of disability* domain for the group (p=0.03*) in the early stages of having the dog. Eight of the children had a decrease in this domain. This has not been previously reported in the literature. This may be due to the early stages of the training with the dog, which may be challenging and tiring for the child.

Recently, interventions for children with CP have shifted from a focus on improved attainment of developmental milestones for motor skills to include improved PA (Damiano, 2006; Rowland et al., 2015; Verschuren et al., 2016). PA guidelines for people with CP were launched to promote healthy lifestyles and prevent risk of cardiovascular and metabolic diseases (Verschuren et al., 2016). Regarding children with neurodevelopmental disabilities, a systematic review reported that engaging in active physical leisure activities such as cycling or horse riding was positively associated with better QoL. The results from this cohort agree with this idea, as we show positive changes in QoL domains in *participation and physical health* and *feelings about functioning* in children with mild physical impairment. The increased risk of mental health disorders in children with CP has been reported (Downs et al., 2017) and the positive change in social and emotional QoL domains found here, may have an impact on the child's overall psychological health.

This is a small group of children, heterogenous in their level of impairment, and this is a limitation, however they are representative of the variety of children who receive MADs from this programme. The study had a six month timeframe and data collection over a longer timeframe with a larger more homogenous group of children may show more sensitivity to change. The study may have benefitted from a control group.

5.5. Conclusion

The group of ten children showed positive change in the domains social-wellbeing and acceptance, feelings about functioning and emotional-wellbeing and self-esteem after six months of receiving a mobility assistance dog. Children with less impairment (GMFCS I-II) showed change in the above domains and participation and physical health after six months. Children with more impairment (GMFCS III-IV) showed no change at any timepoint measured. This novel therapeutic area of receiving a mobility assistance dog demonstrated a positive quality of life change after six months for a group of ten children with impaired walking, particularly in children with mild walking impairment. This study with a small sample size provides preliminary results. Further research with larger numbers and longer follow up is warranted.

The following chapter, chapter six, will describe the analysis of the effect of the introduction of the MAD on the gait pattern of each of the ten children in the study, this was measured prior to receiving their dog and six months after receiving their dog.

6. Study Three. The effect of mobility assistance dogs on gait in children with physical and neurological impairments, measured using 3D gait analysis

This chapter describes the analysis of the effect of the introduction of the MAD on the gait pattern of each of the ten children in the study. Gait analysis was completed prior to receiving their dog and six months after receiving their dog. Additionally, for those who could walk with their dog, an analysis was performed at the six-month time point, while walking with their dog.

6.1. Introduction

Clinical gait analysis is a systematic way to objectively measure and describe walking (Gage et al., 1995; Perry & Burnfield, 2024; Whittle, 2014). Walking or bipedal gait is the mechanism of transport of the body using coordinated movements of the lower limbs. This requires coordination of the neurological and musculoskeletal systems to convert the vertical movements of the alternate lower limbs to a smooth forward trajectory of the head and trunk, to allow the eyes to remain steady and to conserve energy (Perry & Burnfield, 2024). Physical and neurological impairments such as CP interfere with typical gait, making it difficult to participate in physical activities.

The outputs of the clinical gait analysis used for the purpose of this research study are gait kinematics and a selection of temporospatial parameters, used to describe the walking pattern of the participants. Temporospatial gait parameters which will be included for analysis are gait speed, cadence and time in double support. It has been shown that gait parameters measured in gait analysis such as cadence and gait speed correlate with gross motor function in cerebral palsy (CP) (Damiano & Abel, 1996). One of the five components of clinical gait analysis is the clinical examination, which includes measuring muscle strength, to relate to other findings. It has been shown that muscle strength, and not spasticity, has the largest impact on motor function and daily activities in children with CP (Ross & Engsberg, 2007). Muscle strength is a predictor of independent walking in CP (Begnoche et al., 2016). Several studies have analysed the effect of a guide dog on gait parameters as described in the literature review in Section 2.2.1 Background of Assistance Dogs.

The aims of this study were to determine whether there are improvements in a child's gait pattern using their typical walking aids, measured using 3DGA after six months of walking training with a MAD. The change in lower limb muscle strength measured as part of gait analysis, from pre dog to six months post dog will be analysed. An additional aim was to measure changes to the gait pattern of the child while walking with the dog.

6.2. Methods

6.2.1. Walking Training

Walking training with the dog is described here 3.8 Walking Training with the Dog

6.2.2. Participants

Recruitment and participants are as previously described here 3.4 Recruitment.

6.2.3. Gait Analysis

Prior to receiving their dog, all children attended the National Gait Analysis Laboratory at the Central Remedial Clinic (CRC), Dublin for their gait analysis. This was completed pre-dog and six months post-dog with their typical walking aids such as shoes/splints and posterior walker, to assess their typical functional gait. The child walked up and down a 9-metre walkway at a self-selected pace until a sample of four clean datasets were collected. Using the CODA © cx1 active marker system (Charnwood Dynamics Limited), infrared light-emitting diodes were placed on 20 body points on the lower limbs in accordance with a modified Helen Hayes model, data were collected at capture rates of 100 Hz as previously described (Kiernan et al., 2017).

There are four Coda© infrared sensors suspended from the ceiling laterally to the 9-metre walkway. The Coda software set up and light emitting diode (LED) positions are interdependent and correct set up according to the local protocol is necessary for calculation of kinematic and force plate data for each subject. Battery boxes power the LED sensors, these are prepared before the subject enters the lab. These are applied to the subject with double sided sticky tape.

As per standard lab protocol, data were visually examined for each trial for outliers and considered with respect to the walking pattern of the child on the day. Multiple trials were examined for consistency and, in consultation with feedback from parents/caregivers, one representative walking trial that best reflected the child’s walking pattern was exported to the laboratory database (Kiernan & Malone, 2024). Kinematic and spatiotemporal data were analysed using Codamotion ODIN software (version 2.02.02.01). The data is then analysed and presented graphically. Each wand and anatomical marker are numbered. See Figure 6-1 and Figure 6-3 below.

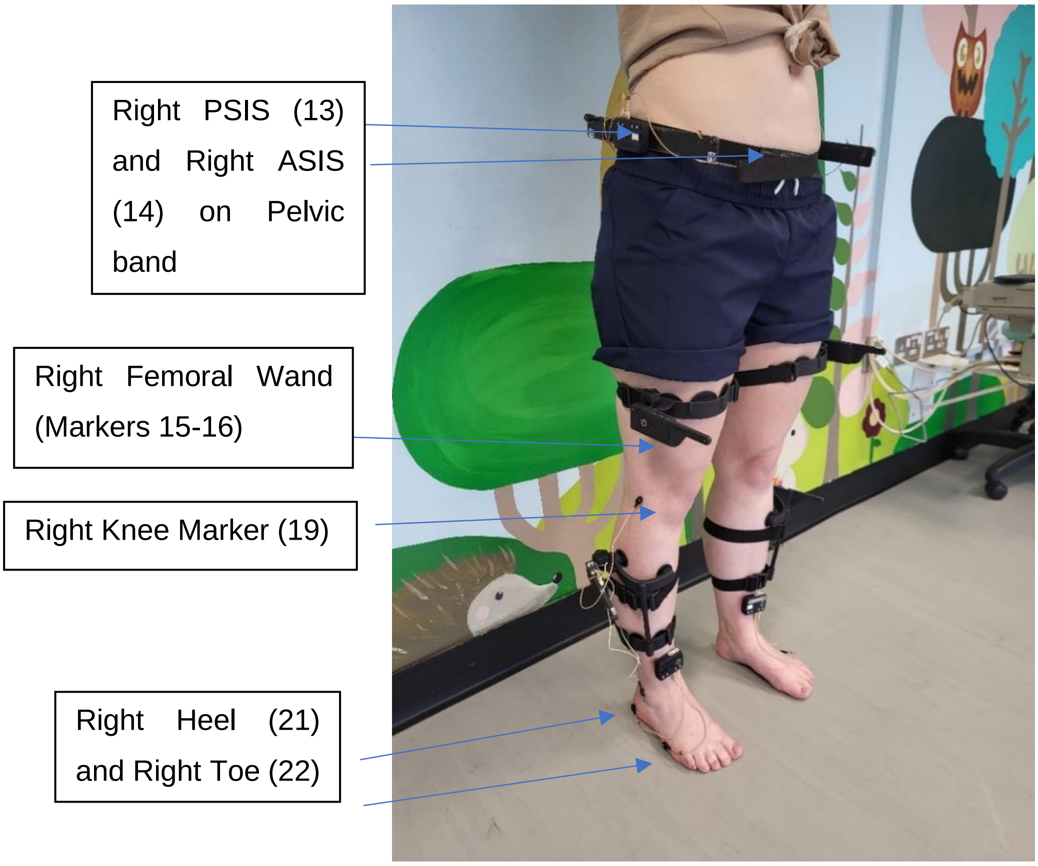


Figure 6-1: A child with markers in place ready for gait analysis.

Table 6-1: Marker numbers for gait model

Marker box number	Position	Marker Box Number	Position
3-4	Left pelvic wand	13-14	Right pelvic wand
5-6	Left femoral wand	15-16	Right femoral wand
7-8	Left tibial wand	17-18	Right tibial wand
9-10	Left knee and ankle	19-20	Right knee and ankle
11-12	Left heel and toe	21-22	Right heel and toe

In Figure 6-2, a child in the study walks in the gait laboratory, wearing his typical shoes and AFOs. The infrared sensors are suspended from the ceiling. A number of walking trials are completed, and a representative trial is chosen.

Force plates in middle of 9m walkway Coda Infrared Motion Sensors

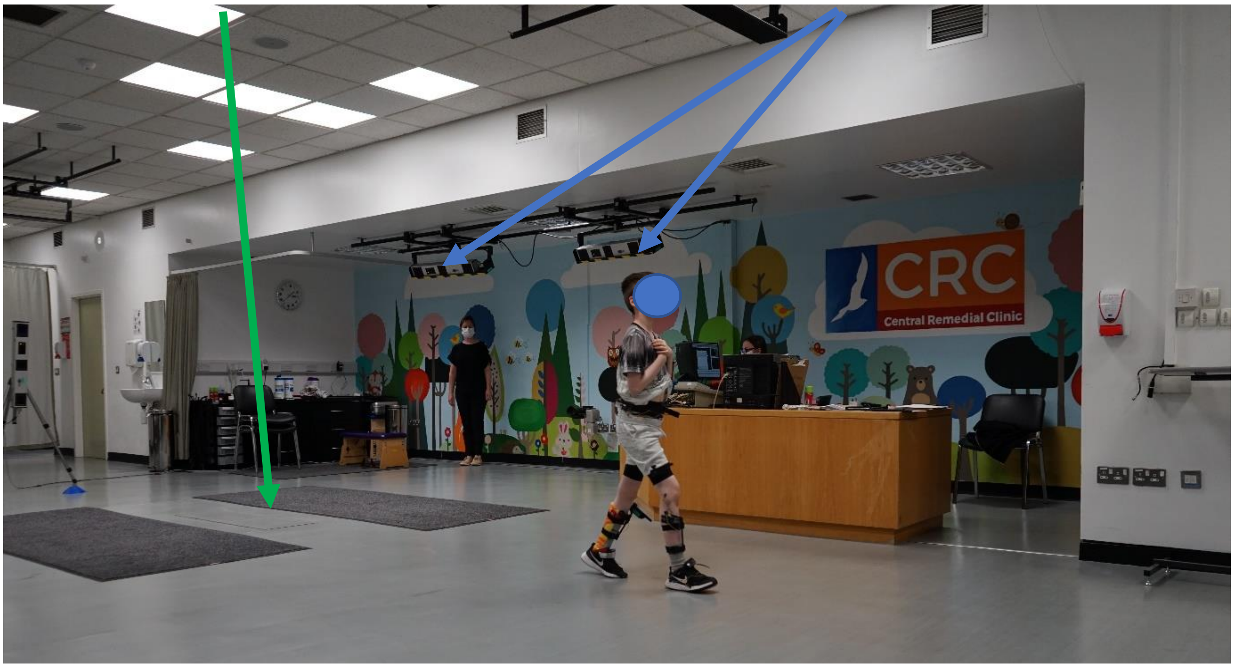


Figure 6-2: A child walking in the gait laboratory wearing the lower limb marker set, as part of the study

In Figure 6-3 a child wears the lower limb LED set; this is shown on a screen as a Realtime display and processed in the Codamotion software to produce a set of nine graphs of kinematic data.

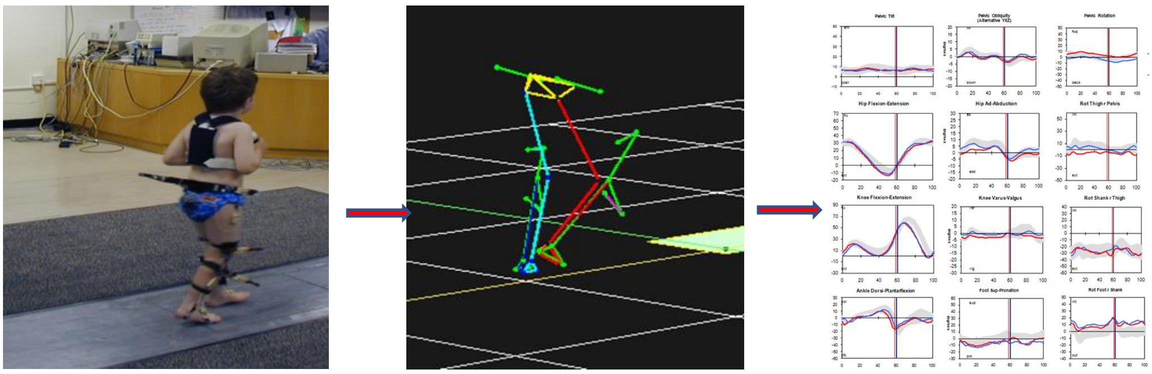


Figure 6-3: A child wears the 22 marker lower limb LED set.

This is captured by infra-red sensors and portrayed as a computer-generated model. An inverse kinematic model is fitted to the marker data to compute joint angles. A software programme exports this as a set of interpretable kinematic gait graphs.

6.2.4. Gait Outcomes

Gait kinematics is the study of joint angles and segment orientation during walking. The gait laboratory serves as a three-dimensional area to capture the movement and this is broken down into three planes of movement for description of joint segments: Sagittal, Coronal and Transverse. Each joint segment is analysed separately, in this case the pelvis, hip, knee and ankle are all portrayed in all three planes of movement. The left (blue) and right (red) sides are recorded separately. These are overlayed on typical data (grey band) from a reference set of 33 sets of typically developing (TD) children. The y-axis represents the degrees of movement at that joint segment. The x-axis represents the percentage of the gait cycle. The typical time in stance (60%) and swing phase (40%) is clearly defined. Deviations from typical gait can clearly be interpreted from the gait graphs and patterns of walking objectively described. A kinematic graph of the sagittal plane knee is described below in Figure 6-4.

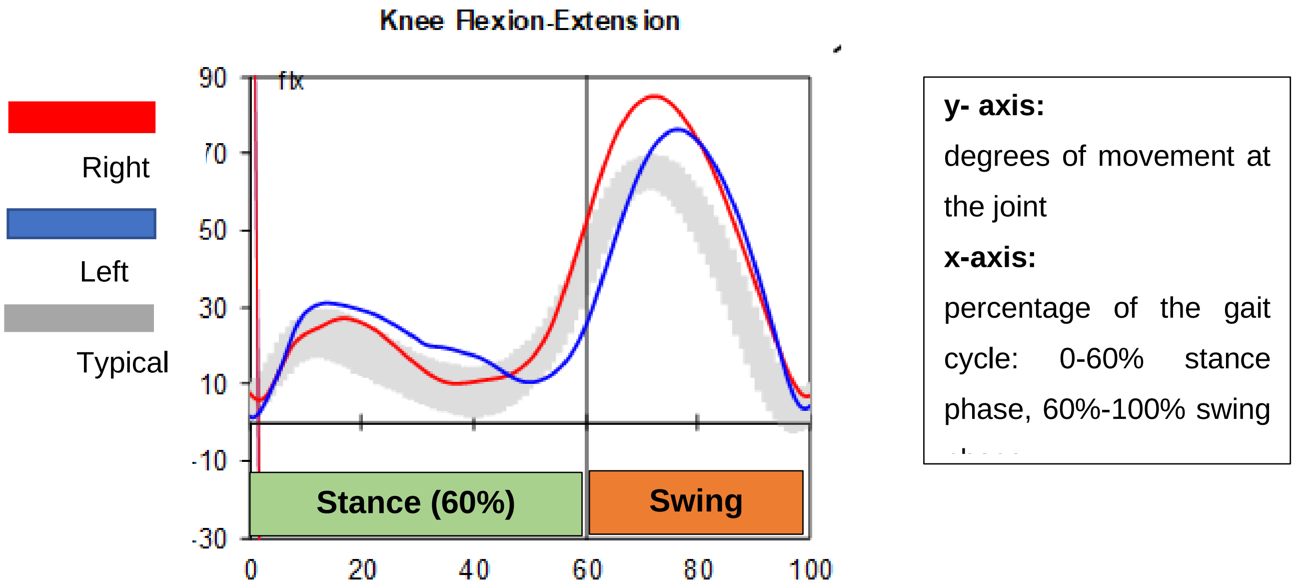


Figure 6-4: Sample of Kinematic gait graph (Sagittal Plane Knee)

The twelve kinematic graphs used to describe the walking pattern at the pelvis, hip, knee and ankle in the three dimensions are shown below in Figure 6-5.

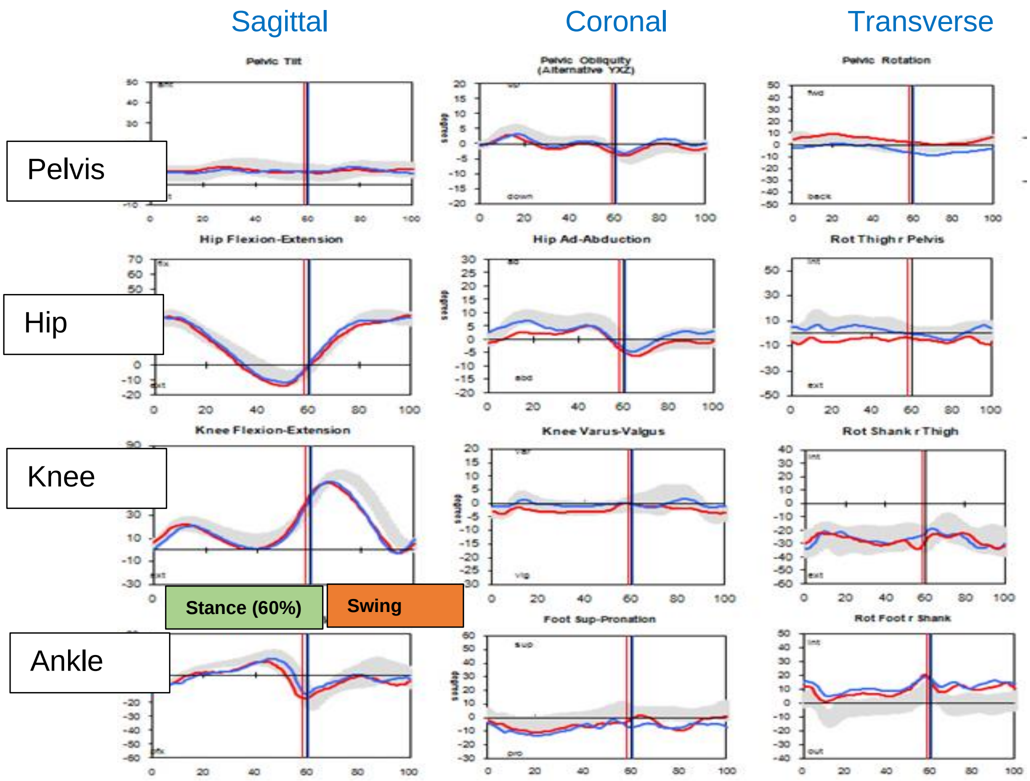


Figure 6-5: Example of Gait Kinematic Graphs (typical gait)

Further analysis included calculating The Gait Deviation Index (Schwartz & Rozumalski, 2008) and temporospatial gait parameters (Speed, Cadence and Time in Double Support) for both the left and right limbs to reflect walking performance, symmetry and balance. These are illustrated in Figure 6-6.

6.2.5. The Gait Deviation Index

The Gait Deviation Index (GDI) was chosen as a single numerical representative of the overall gait kinematic quality. The GDI list is a multivariate measure of overall gait pathology. Pelvic and hip angles in all three planes, knee flexion and extension, ankle dorsiflexion and plantarflexion, and foot progression for the left and right sides are extracted at 2% increments throughout the entire gait cycle (9 angles 51 points = 459 data points). The GDI is defined by calculating a difference between the nine gait feature scores for a subject and the average of the same gait feature scores for a control group of typically developing children (Schwartz & Rozumalski, 2008). Every 10 points that the GDI falls below 100 corresponds to one standard deviation away from the typically developing group mean, and a 10-point change in GDI is seen as a clinical meaningful change. Typical gait GDI is a score of 100.

6.2.6. The phases of gait

Temporospatial gait parameters are based on a typical gait cycle, described in Figure 6-6.

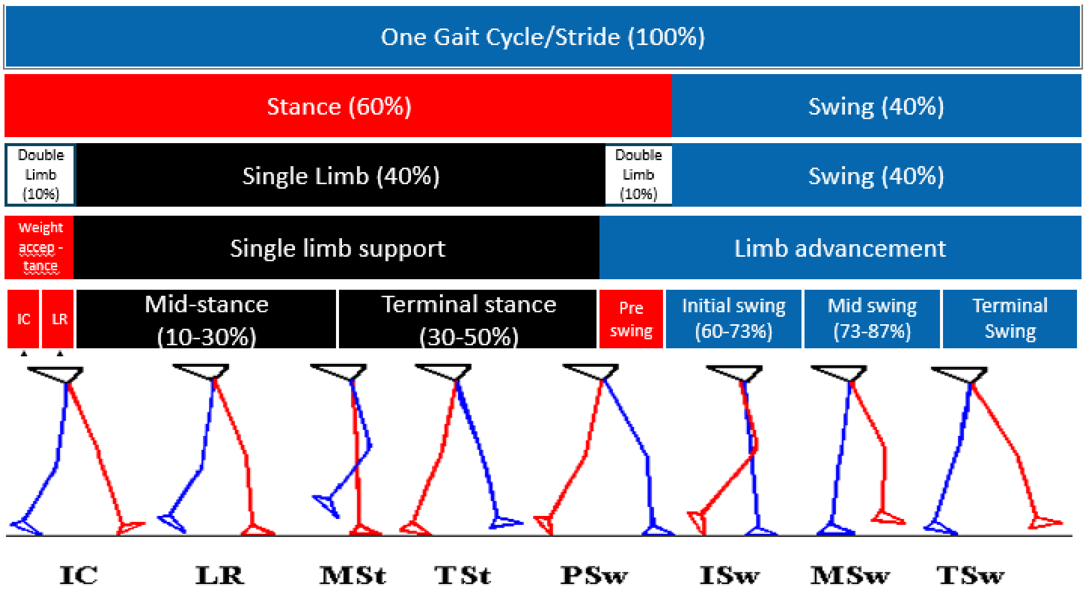


Figure 6-6: The Gait Cycle (O'Brien, 2001)

Gait speed (metres/second): Typical gait speed for a healthy adult is 1.2-1.4 m/s and is a good measure of overall physical function (Carcreff et al 2020). In the CRC gait laboratory, typical gait speed is compared to normal data from a set of 33 typically developing children (age 5-14), 1.13-1.37 m/s and this reference dataset will be used throughout the study.

Cadence (steps/minute): This is the number of steps taken per minute. Typical cadence from the CRC gait laboratory normal data set is 122.4-153.6 steps per minute. Cadence is higher in smaller children as they have shorter legs and require more steps to maintain a given gait speed (e.g. to keep up with their taller peers or parents).

Time in double support: The percentage of the gait cycle when both limbs are in contact with the ground, typically 20% of the gait cycle (Figure 6-6). CRC normal data double support time is 0.07-0.11 seconds.

6.2.7. Data extraction and Statistical Analysis

Kinematic and temporospatial gait data for each child were uploaded to IBM SPSS Statistics Version 28 (Armonk, NY: IBM Corp) for analysis. Due to the small group size, the non-parametric Wilcoxon Signed Rank test was used to assess differences in the group's gait parameters. Statistical significance for the group was set at $p<0.05$.

Kinematic timeseries data for baseline and follow-up analyses were examined using statistical non-parametric mapping paired t-tests (SnPM) using the resources available at spm1d.org (Version 0.4.3,2019), and Matlab Version 2016b (Mathsworks, Natick , MA). SnPM mapping is used for continuous comparison of multiple field observations. Pataky (2010) introduced one-dimensional statistical parametric mapping (spm1d) as a method for biomechanical analysis, enabling the assessment of entire movement curves for statistical significance. This approach has advantages over simpler, point-by-point methods, which might miss widespread changes. SnPM paired t-tests were performed, comparing kinematic angles of each pattern from the pre dog group to the respective kinematic angles of the post dog group.

Comparisons were considered statistically significant if the test statistic exceeded the rejection threshold at one or more points along the continuum and if $p < 0.05$.

6.2.8. Strength

All children had lower limb muscle strength tested as a component of the gait analysis. This involves a trained physiotherapist completing manual muscle testing (Bohannon, 2018) on four lower limb body segments and abdominal muscles and recording strength outcomes based on the Modified Oxford Muscle Strength Grade Scale (Table 6-2). Lower limb muscle groups tested were left and right hip abductors, hip extensors, knee extensors, knee flexors and abdominals.

Table 6-2: Modified Oxford Muscle Strength Grade Scale

Strength Grade	Level of Movement
0/5	No contraction
1/5	Visible/palpable muscle contraction but no movement
2/5	Movement with gravity eliminated
3/5	Movement against gravity only (zero resistance)
4-/5	Movement against gravity with minimum resistance
4/5	Movement against gravity with moderate resistance
4+/5	Movement against gravity with strong resistance
5/5	Movement against gravity with full resistance

6.2.9. Muscle Strength tests

The specific positioning and handling techniques for manual muscle testing each of left and right hip abductors, hip extensors, knee extensors, knee flexors and abdominals is available in Appendix J. Manual Muscle Testing.

6.2.10. Gait analysis while using an assistance dog.

To achieve the aim of analysing the gait pattern while walking with the dog, the typical gait analysis model required adaptation. The typical clinical gait analysis model used in the gait laboratory of the CRC is the modified Helen Hayes Model (Kiernan et al., 2017). To analyse walking patterns and gait parameters while using an assistance dog, this gait model would lack marker visibility for the four laterally placed tracking cameras, due to the dog on one side of the child. Markers would be occluded from the Coda infra-red sensors due to the dog travelling lateral to the child. For this reason, the gait model setup was adapted to use clusters of markers as opposed to gait wands. Cluster based models are less dependent on precise marker placement, and don't have the protruding wands, which in this case could physically be knocked while walking with a dog. Cluster models can increase the time required for participant preparation (Mentiplay & Clark, 2018). Previous research has shown that the cluster based model is consistent with the conventional model for kinematics (Mentiplay & Clark, 2018). To validate our own cluster model, a pilot capture was completed with both models on a volunteer and the graphs were overlayed and shown to have good reliability, as assessed visually, in the sagittal plane pelvis, hip and knee kinematic graphs and for temporospatial parameters. To maximise marker visibility, a 5th motion capture camera was set up at one end of the walkway to capture coronal plane data (the original cameras are positioned laterally and suspended from the ceiling) for use while walking with a dog only. Bony landmarks are acquired via a pointer and calculated in the Codamotion ODIN software (v 6.78.1) used with the CODA motion capture system, as shown in Figure 6-7.

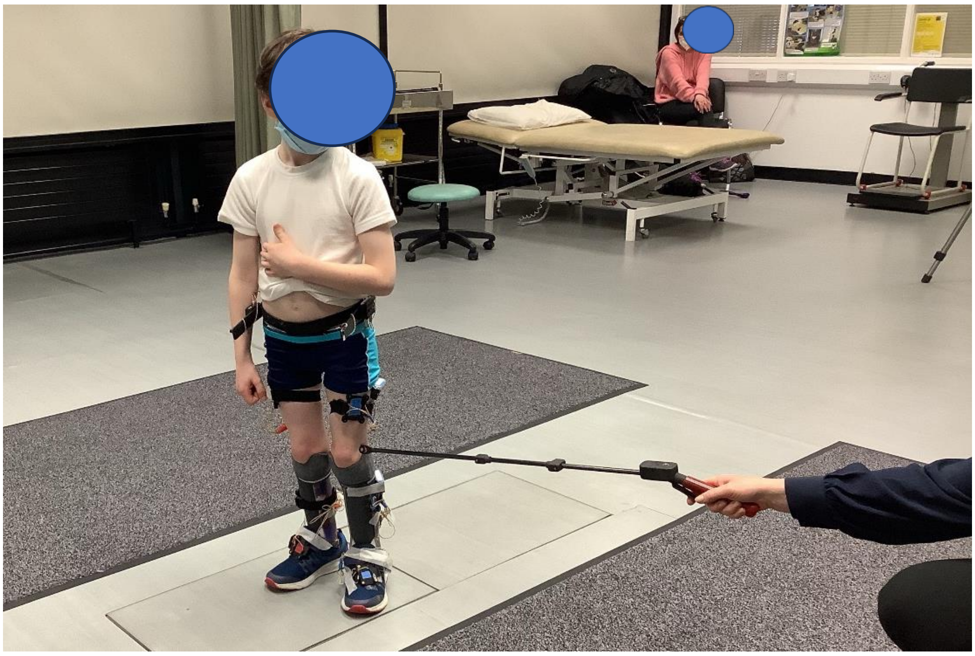


Figure 6-7: The pointer being used to identify anatomical points

This capture procedure requires the child to be able to walk a minimum of seven metres with their assistance dog. The child was required to stand for up to five minutes while bony landmarks were identified using a pointer and thus was not deemed suitable for all children in the study. This also required participants to bring their assistance dog into the gait laboratory which was not suitable for all families due to the distance required to travel to the laboratory. Four children successfully completed the gait analysis with their dog. The protocol for the cluster model is available in Appendix F. Gait Analysis Cluster Protocol.

The marker placement of the clusters is shown in Figure 6-8. Existing battery boxes were reprogrammed to reconfigure the model numbering for the thigh, tibia and foot clusters.

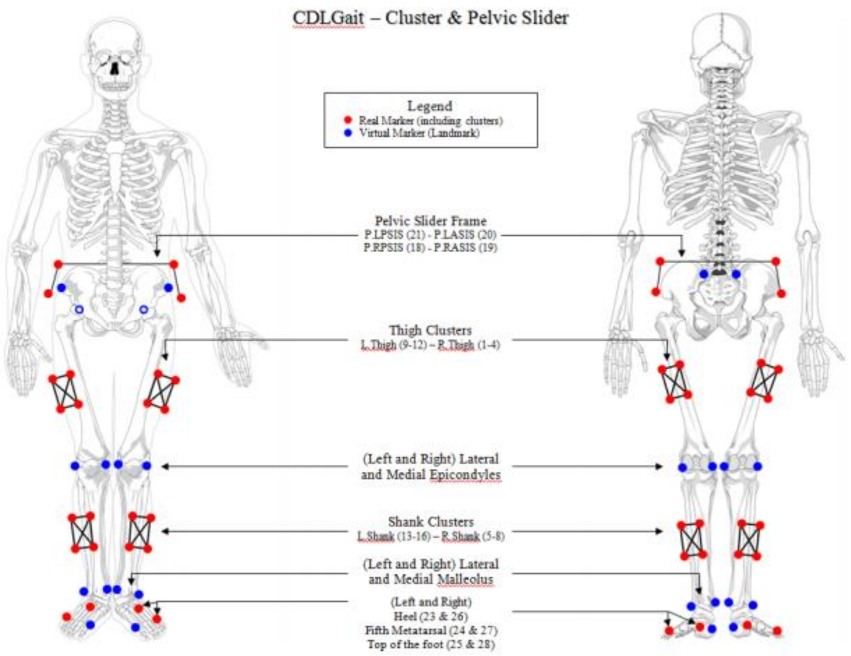


Figure 6-8: Codamotion Cluster Marker Placement

The tibial (shank) cluster with battery box and the sacral wand are shown in Figure 6-9. A child wearing the cluster model as part of the study is shown in Figure 6-10 (left) and the real-time data display of the cluster model is shown in Figure 6-10 (right).

Figure 6-9: (Left) Right Shank Cluster in situ markers # 1 and #2; (Right) Sacral wand is added to the model

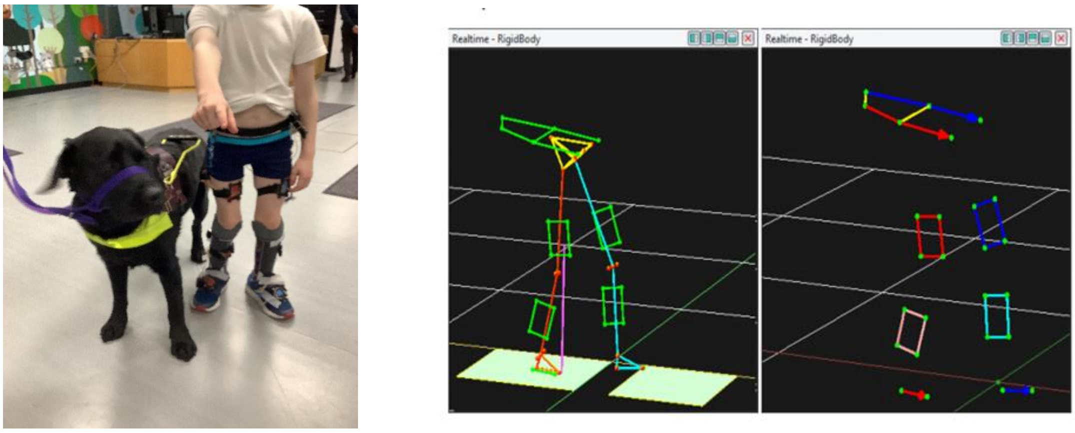


Figure 6-10: (Left) A child ready to walk with his dog as part of the study; (Right) Realtime view of cluster markers in Odin software

6.3. Results

6.3.1. Gait Analysis Results, pre dog to six months post dog with typical walking aid

The Wilcoxon Signed Rank Test was used to look at differences in the group between timepoints in GDI, gait speed, cadence and time in double support. Overall, there was no statistically significant change for the group of ten children for any of the outcomes measured from pre dog to post dog. There was a positive change in left side GDI, there was a positive change in gait speed on both the left and right sides. Cadence increased on the left more than the right. Time in double support decreased marginally for the group on both the left and the right sides.

Table 6-3: Wilcoxon Signed Rank Test for GDI and spatiotemporal gait parameters for group (N=10)

Variable	Pre-Dog Median (Range)	Post Dog Median (Range)	p-value	Pre-Dog Median (Range)	Post Dog Median (Range)	p-value
	Left			Right		
GDI/ 100	58.3 (52.2 - 78.3)	65.5 (54.2 - 89.9)	0.17	64.4 (53.6 - 78.8)	68.5 (55.1 - 82.0)	0.58
Speed (m/s)	0.52 (0.18 - 1.25)	0.74 (0.1 - 1.32)	0.2	0.51 (0.18 - 1.3)	0.67 (0.09 - 1.29)	0.14
Cadence (steps/minute)	90.6 (46.2 - 138.1)	113.4 (32.8 - 133.1)	0.4	88.9 (42.2 - 149.3)	105.8 (33.9 - 141.7)	0.5
Time in Double Support (s)	0.28 (0.09 - 0.42)	0.26 (0.11 - 1.13)	0.96	0.24 (0.1 - 1.16)	0.22 (0.09 - 1.49)	0.96

GDI: Gait Deviation Index; m/s: metres per second; s: seconds

6.3.2. Results of analysis for Group A and Group B

Data were then grouped into those with less physical impairment (group A- GMFCS I-II) and those with more physical impairment (group B- GMFCS III-IV) for further analysis. There was no statistically significant change in either group for any of the gait outcomes from pre dog to post dog analysis.

Table 6-4: Wilcoxon Signed Rank test for GDI and spatiotemporal parameters for group A (n=5)

Variable	Pre-Dog Median (range)	Post Dog Median (Range)	p-value	Pre-Dog Median (Range)	Post Dog Median (Range)	p-value
	Left			Right		
GDI/ 100	74.8 (57.4-78.3)	71 (65.9-89.9)	0.23	73.7 (58-78.8)	71 (55.1-82)	0.5
Speed (m/s)	0.94 (0.51-1.25)	0.97 (0.63-1.32)	0.23	0.96 (0.53-1.3)	1.06 (0.57-1.29)	0.14
Cadence (steps/minute)	115.9 (96.9-138.1)	120.6 (112-133.1)	0.34	114.7 (95.18-149.5)	126.1 (105.9-141.7)	0.5
Time in Double Support (s)	0.15 (0.09-0.35)	0.16 (0.11-0.26)	0.34	0.14 (0.1-0.33)	0.12 (0.09-0.3)	0.1

GDI: Gait Deviation Index; m/s: metres per second; s: seconds

Table 6-5: Wilcoxon Signed Rank for GDI and spatiotemporal parameters for group B (n=5)

Variable	Pre-Dog Median (range)	Post Dog	p-value	Pre-Dog	Post Dog	p-value
	Left			Right		
GDI/ 100	56.2 (52.2-67.4)	58.8 (54.2-65.1)	0.23	61.9 (53.6-71.6)	61.4 (59.2-74.7)	0.89
Speed (m/s)	0.36 (0.18-0.52)	0.31 (0.1-0.8)	0.68	0.38 (0.18-0.49)	0.33 (0.09-0.68)	0.5
Cadence (steps/minute)	78.2 (46.2-84.4)	59.2 ((32.8-114.8)	0.68	76.4 (42.18-82.6)	57.8 (33.9-105.8)	0.5
Time in Double Support (s)	0.39 (0.27-0.42)	0.36 (0.25-1.13)	0.5	0.34 (0.22-1.16)	0.34 (0.15-1.49)	0.28

GDI: Gait Deviation Index; m/s: metres per second; s: seconds

6.3.3. Results of Statistical non-Parametric Mapping for Kinematic Data

In Figure 6-11 the results of SnPM analysis for sagittal and transverse plane kinematics for the whole group (n=10) are shown.

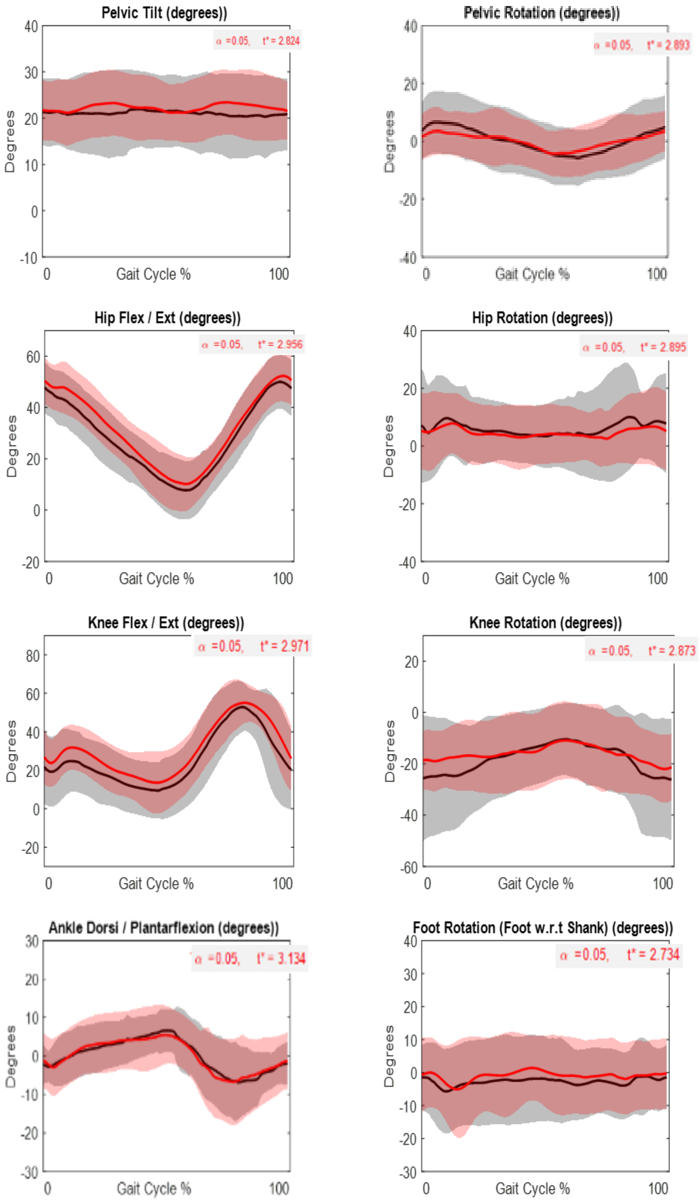


Figure 6-11: SnPM Kinematic data for the group (n=10) from pre dog to 6 month follow up

Pre-dog -solid black line and light grey ±1 SD band; six month follow-up- red line and light red ± 1 SD band). SnPM analysis test statistic and p value shown. Left and ride side data are combined.

No statistically significant difference was found between pre dog and six month post dog in the group (n=10).

In Figure 6-12 the results of SnPM analysis for sagittal plane kinematics for the group A (n=5) and group B (n=5). Full results for sagittal, coronal and transverse planes are available in Appendix K.

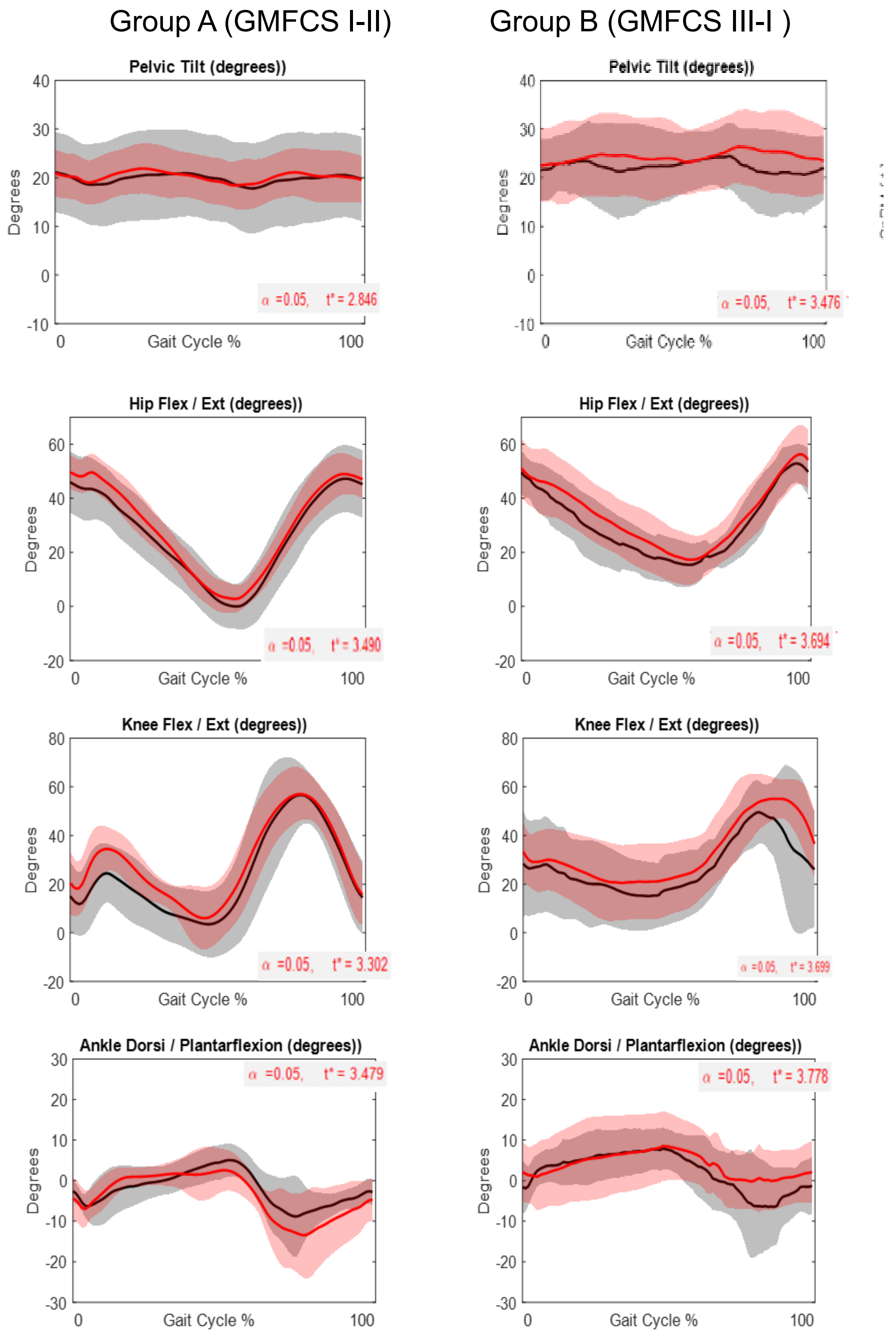


Figure 6-12: Data are presented for group A and B from pre dog to six month follow -up.

Baseline -solid black line and light grey ±1 SD band; 6-month Follow-up- red line and light red ± 1 SD band). SnPM analysis test statistic and p value shown.

The SnPM analysis shows that there was no significant change for kinematic time series data in any plane for the group of 10 or for each of group a (n=5) or group b (n=5) from pre dog to six month follow-up.

6.3.4. Strength results

Positive improvement was found for the group (n=10) in abdominal control and left quadriceps strength at six month follow up, as shown in Table 6-6.

Table 6-6: Wilcoxon Signed Rank Test for muscle strength for group (N=10)

Muscle Tested	Pre-Dog Median	Post Dog Median	p-value
Abdominals	3	4	0.008*
Hip Abduction Left	3	3	0.18
Hip Abduction Right	3	3	0.1
Hip Extension Left	2	3	0.29
Hip Extension Right	2	3	0.28
Quadriceps Left	4	4	.034*
Quadriceps Right	4	4	0.06
Hamstrings Left	4	4	0.41
Hamstrings Right	4	4	0.83

In the group of children with milder impairment (Group A - GMFCS I-II), positive change was found in abdominal strength only. There was no significant change in the group B (GMFCS III-IV) at six-month follow-up. This is shown in Table 6-7.

Table 6-7: Wilcoxon Signed Rank test for muscle strength for group A (n=5) and group B (N=5)

	Group A (GMFCS I & II)			Group B (GMFCS III & IV)		
Variable	Pre-Dog Median	Post Dog Median	p-value	Pre-Dog Median	Post Dog Median	p-value
Abdominals	3	4	0.046*	3	3	0.08
Hip Abduction Left	3.5	4.5	0.083	3	3	1
Hip Abduction Right	3.75	4	0.18	3	3	0.32
Hip Extension Left	4.25	4	0.32	1	2	0.18
Hip Extension Right	4.25	4	0.32	2	2	0.16
Quadriceps Left	4	5	0.16	3	4	0.1
Quadriceps Right	4	4.75	0.18	4	4	0.18
Hamstrings Left	4.75	5	0.32	3	4	0.58
Hamstrings Right	4.75	4.5	0.65	3	4	0.7

6.3.5. Cluster Capture results: Gait Analysis with a Dog

Four participants successfully completed the gait analysis with their dog as part of the study and their individual gait results are below. Time in double support was not calculated while they walked with their dog.

Participant 1 (group B)

Table 6-8: Participant 1 gait parameters

Variable	Pre-Dog		Post Dog		With Dog		Typical
	Left	Right	Left	Right	Left	Right	
GDI	67.4	71.6	64.4	67.8	43.8	59.6	100
Speed (m/s)	0.52	0.49	0.8	0.68	0.84	0.81	1.13-1.37
Cadence (steps/minute)	84.4	82.62	114.8	105.82	108.1	122.2	122.4-153.6
Time in Double Support (seconds)	0.27	0.22	0.25	0.15			0.07-0.11
Stride Length (m)	0.74	0.71	0.8	0.68	0.89	0.85	0.97-1.23

This child walked faster while walking with the dog, due to both an increase in cadence and a longer stride length. GDI decreased on both the left and right while walking with the dog.

Participant 3 (group A)

Table 6-9: Participant 3 gait parameters

Variable	Pre-Dog		Post Dog		With Dog		Typical
	Left	Right	Left	Right	Left	Right	
GDI	77.9	74.5	89.9	73.4	69.7	59.2	100
Speed (m/s)	0.99	0.99	0.97	1.06	1.04	1	1.13-1.37
Cadence	115.9	114.74	120.6	126.06	124.2	112.7	122.4-153.6
Time in Double Support	0.15	0.14	0.14	0.12			0.07-0.11
Normalised Stride Length /Height	1.03	1.03	0.97	1.01	1.01	0.98	0.97-1.23

This child maintained his baseline gait speed. GDI improved on the left side post dog, but not on the right. GDI did not improve while walking with the dog.

Participant 5 (group A)

Table 6-10: Participant 5 gait parameters

Variable	Pre-Dog		Post Dog		With Dog		Typical
	Left	Right	Left	Right	Left	Right	
GDI	74.8	78.8	71	69.3	67.7	65.4	100
Speed (m/s)	1.25	1.3	1.15	1.25	0.84	0.84	1.13-1.37
Cadence	138.1	149.36	133.1	130.97	114.3	136.9	122.4-153.6
Time in Double Support	0.09	0.1	0.16	0.12			0.07-0.11
Stride Length	1.09	1.04	1.04	1.14	0.81	0.89	0.97-1.23

This child walked at a slower speed while walking with the dog. This was the goal for the parent, as she reported he walked too fast and tended to bump into things. Both his stride length and cadence decreased while walking with the dog.

Participant 9 (group A)

Table 6-11: Participant 9 gait parameters

Variable	Pre-Dog		Post Dog		With Dog		Typical
	Left	Right	Left	Right	Left	Right	
GDI	78.3	73.7	70.6	71	66.9	58.1	100
Speed (m/s)	0.81	0.79	0.97	0.97	1.1	1	1.13-1.37
Cadence	111	106	115.7	111.03	114.9	137.3	122.4-153.6
Time in Double Support	0.17	0.2	0.16	0.14			0.07-0.11
Stride Length	1.09	1.04	1.04	1.14	0.81	0.89	0.97-1.23

This child's gait speed increased at the follow up analysis, while walking without the dog and while walking with the dog. He walked with a shorter stride length with the dog and increased his speed by increasing his cadence, right more than left.

6.4. Discussion:

This is the first study analysing gait effects of a MAD on children with walking impairment. The ten children ranged from GMFCS level I- IV and are a small heterogenous group. There was no change to gait kinematic quality as measured by GDI from baseline to six month follow up in the group. Although gait parameters including gait speed, cadence, stride length and time in double support changed in a positive direction, there was no significant change in the gait pattern on the group. There was no change to gait parameters or GDI when the group was divided into those with less impairment (Group A - GMFCS I-II) and those with more impairment (Group B - GMFCS III-IV). Overall, gait and motor function would be expected to decline for children of GMFCS III-IV, from the age of 8 years, as per the GMFM curve (Hanna et al., 2009). To date, no intervention has shown a child change their GMFCS level and overall motor function due to the nature of the chronic neurological condition (CP). The motor function of children of GMFCS I-II would be expected to remain static from the age of eight years as per the GMFM curve.

On muscle strength testing, at six month follow up, the group (n=10) had increased strength for their abdominals ($p<0.05$) and left quadriceps ($p<0.05$). Those with less impairment (Group A - GMFCS I-II) showed improvement in abdominal strength ($p<0.05$), however those with more impairment (Group B - GMFCS III-IV) did not show any significant change in muscle strength. Although there is little previous literature in the area, these findings do not align with previous studies where adults with a dog were shown to walk faster and with less deviations from typical gait after training with a dog (Rondeau et al., 2010; Zabihaylo et al., 2005). Gait speed, cadence, and time in double support did increase for the group, but this was not a statistically significant finding. One child walked at a slower pace, and this was a positive for him. This group of children are very different from each other, and individual presentation for each child is described in Chapter 8: Case Studies. The complex nature of CP means that some children will have altered muscle tone, spasticity, joint contractures and fatigue (Rosenbaum, 2007), which may have affected individual outcomes.

For those children who walked with the dog at follow up (n=4), there was a variety of findings. With the exception of participant 5, who walked at a typical gait speed at baseline, all children increased their gait speed while walking with their dog. Gait speed is a combination of stride length and cadence: although a longer stride length can be attributed to having longer legs it is also directly related to balance on the stance phase leg, allowing the swing leg time to extend fully in terminal swing. The increase in cadence may be related to increased distal strength for push off, as gait speed is directly related to overall strength.

6.4.1. Limitations

GDI was assessed as an overall score for walking quality. Where children with CP might have an established gait pattern, changing the pattern of walking may not be possible by training. However individual markers in the gait cycle may be more easily interpreted and related to clinical findings.

There was individual change in some cases (see 8.2 Case Studis) but there was no overall significant change in the group. There was positive change found in strength on follow up testing in the group. Although manual muscle testing is reliable (Bohannon, 2018), this is not a gold standard method of testing muscle strength and alternative methods such as dynamometry may be superior. Capturing the gait pattern while walking with a dog using 3DGA is a novel method and although four children completed the assessment, we cannot draw clear conclusions from this preliminary data.

6.5. Conclusions

The group of ten children showed no change to their gait quality, measured by GDI or gait parameters speed, cadence or time in double support from baseline to six month follow up. The group showed a positive change in abdominal and left quadriceps strength, but those with more impairment (GMFCS level II-IV) showed no change at follow up. Children who completed a gait analysis while walking with their dog, showed little overall change in laboratory measures at follow up. These are preliminary findings from a small sample size. Individual clinically significant change was seen for some children (see individual case studies Chapter 8), however the small heterogenous group showed no statistically significant change.

In the following chapter, chapter seven, physical activity levels of the ten children at each of the four timepoints as previous, are analysed and described.

7. Study Four. The effect of mobility assistance dogs on physical activity levels in children with physical and neurological impairments, measured using wearable sensors.

In this chapter, physical activity levels of the ten children recruited to the study will be described. All children wore the Stepwatch physical activity monitor for seven consecutive days prior to getting their dog, and this was repeated at one month after they received their dog and at two follow up points.

7.1. Introduction

Children with physical impairments such as cerebral palsy (CP) participate in less physical activity (PA) than their typically developing peers and less than recommended guidelines (Bjornson et al., 2007; Carlon et al., 2013; Verschuren et al., 2016). Reduced physical activity can lead to the development of secondary health problems, including affecting the musculoskeletal and cardiovascular systems, body composition and psychosocial health (Carlon et al., 2013; Ryan et al., 2015). Knowledge of patterns of physical activity in children with physical impairments such as CP may help healthcare professionals involved in their care monitor activity levels across Gross Motor Function Classification (GMFCS) levels (Bjornson et al 2007). Typically, in CP, PA levels are related to gross motor function as per their GMFCS level (Bjornson et al 2007). This level of activity decreases as adulthood approaches (Maher et al 2007), alongside the Gross Motor Function Measure (GMFM) curve. Innovative ways to improve PA levels in children with CP are welcomed (Bjornson et al 2007).

Children with CP tend to spend more time sedentary (sitting or lying down) than their peers, and this sedentary behaviour further leads to complications of inactivity including increased cardiometabolic complications (Ryan et al., 2014). For those who are active, increased time spent at a higher intensity of PA is associated with reduced cardiorespiratory complications and improved cardiometabolic health (Ryan et al., 2015),

As part of the larger mixed methods study, walking was objectively measured in the gait laboratory. It is known that gait analysis provides information on the child's walking capacity, however, children with CP tend to walk a higher gait speed in a testing environment but perform at a lower level in their daily life (Carcreff et al., 2020). Gait characteristics such as a kinematic pattern relate to the body structure and function component of the ICF, whereas gait quantity such as steps per day, measures the amount and intensity of walking and this relates to the activity and participation level of the ICF. It has been shown that gait quality does not directly predict gait quantity (Guinet et al., 2020).

It has been long established that dog owners engage in more physical activity than those who don't have a dog (Sachs-Ericsson et al., 2002). A family dog has been shown to increase PA in children with CP (Tepfer et al., 2017). There have been several studies which have shown that a trained assistance dog can improve mobility in children with disabilities (Lindsay & Thiyagarajah, 2021), however these have focussed on children with visual impairment. The specific effect of introducing a mobility assistance dog (MAD) on the motor performance or physical activity levels in children whose primary impairment is physical mobility has yet to be investigated.

A number of activity monitors are available to measure physical activity levels with several validated for use in a pathological population. The use of wearable sensors to monitor activity levels has been used in several studies in children with walking impairments including CP. In a study by Bjornson et al (2007), they monitored 81 children with CP levels I-III alongside a typically developing control group. They used the Modus Healthcare Stepwatch for 7 days and documented average daily total steps, percentage time active and inactive and the ratio of low, medium and high activity levels. The children with CP had lower steps and activity levels than those with typical development and GMFCS level predicted level of activity. Daily number of steps, time spent inactive versus active, and time spent in moderate-to-vigorous physical activities are common metrics used to quantify motor performance.

In a study with 209 children with ambulant CP (GMFCS level I-III) it was shown that a wearable sensor should be worn for seven consecutive days to accurately show PA in this cohort (Ishikawa et al., 2013).

Young people with CP spend the majority of their daily steps in low intensity activity levels (<30 strides/min), with significantly fewer steps per day in high intensity activity levels (>60 strides/min) per the Stepwatch accelerometer (Bjornson 2014). This limited variability of intensity has potential implications for their daily mobility as both steps per day and high intensity of activity are positively associated with mobility-based habits of daily life (Bjornson 2014).

The aims of this study are firstly to determine if a child's PA levels or gait quantity increases when they receive a MAD. Secondly, can they increase the level of intensity of their PA.

Thirdly, do they spend less time sedentary. Finally, we wanted to measure if a child's level of impairment has an impact on the effect a MAD may have on these changes.

7.2. Methods

7.2.1. Choosing a suitable activity monitor

For the purpose of measuring PA levels in children with impaired walking in this study, it was necessary to analyse available and suitable activity monitors. Four activity monitors were considered for use in the project as described in the literature review here 2.5.2 Choosing a suitable activity monitor. The Modus Healthcare Stepwatch was found to be the most suitable and was used for monitoring PA in the study. Prior to commencing data collection, the Stepwatch was trialled for accuracy of step count, compared to gold standard video step count, in a group of children with impaired walking, described in Appendix G.

The Modus Healthcare Stepwatch had clear advantages over the other activity monitors when considered with regard to the needs of this particular study, given its sensitivity to capture step count in children with ambulant CP and impaired walking, validation in this cohort, wearability, the specific aforementioned outputs and reported ease of data download.

7.2.2. Data Collection Procedure

We monitored PA of all children included in the study for seven consecutive days at baseline (pre-dog) and at one month (post dog), three months (post dog) and six months (follow up) following placement of the MAD using the Modus Healthcare Stepwatch. The three month time point was not used for group analysis, it was introduced to ensure there was adequate data collected in the case of missing data at either of the follow up timepoints.

Figure 7-1: Stepwatch in situ, over lateral malleolus on dominant ankle.

The Stepwatch dimensions are 7.5cm x 4.8cm x 1.4cm and it weighs 41g. It is worn at the ankle to detect foot motion. It was attached to above the dominant lateral malleolus, in line with the manufacturer's instructions. This was worn over an orthotic where applicable.

The Stepwatch uses an individualised set-up procedure to programme its sensitivity to steps which has advantages over other monitors in impaired walking. It also has a high sampling frequency of 128 Hz. The Stepwatch requires sensitivity adjustment as part of the set-up procedure. Its sensitivity is programmed for each participant based on questions relating to the participant's height, gait pattern and gait cycle: “Does the client regularly participate in activities that involve short quick steps?”, “Is their walking speed fast or slow?‘’, “What is the client's range of walking speeds?”, “Describe the appearance of the client's leg motion”. The step data was saved in periods of 10 seconds (time stamp). Both the raw step count and summary data were downloaded.

The participant then completes a 10-step verification to synchronise the monitor with the host iPad application. If Stepwatch over/ undercounts by more than 10% (one step), the algorithm is auto-adjusted and you are given the option to re-verify to confirm that the auto-adjusted settings are now accurate for the participant. The Stepwatch setup user manual is available online here SW4-for-RE-Manual-FINAL.pdf (modushealth.com) . I applied the Stepwatch to the participants at all time points. This was applied initially at the pre dog gait analysis for the first timepoint and at a location convenient for the participant for the two subsequent timepoints (typically the participants' home) and at the final gait analysis for the six month follow-up time point.

Parents were advised to leave the activity monitor on at all times and when it must be removed i.e., for washing or sleeping, to replace it immediately as worn previously. Each participant wears the monitor for seven full days as recommended (Bjornson et al., 2007). The monitor may be worn for a total of 9 consecutive days to obtain seven full days of data, as 7 days of data may include a half day where the monitor was either applied or removed. Parents or guardians are given instruction leaflets on how to correctly apply the monitor and to clean it.

The monitors were then either returned by post to the researcher or collected by the researcher. Data were uploaded for each child at each timepoint.

The study sought to characterise motor performance through several aspects or domains. The domains were chosen to avoid duplication of parameters from one domain to another.

The domains chosen were: steps per day; minutes active (minutes of the day with at least one step); minutes of the day in low level activity (% of the day at low cadence: 1-15 steps/minute), minutes of the day in medium level activity (% of the day with a medium activity cadence: 16-40 steps/minute) and minutes of the day at a high level intensity (% of the day at 41 or more steps/minute) and highest cadence (average cadence of the most intensive 30 individual minutes of the day).

7.2.3. Data Analysis

Uploaded data were collated, and the outcomes were analysed across the ten participants and time points as previously described Figure 3-2. Stepwatch measures steps for the limb wearing the sensor only so all step count data were doubled to obtain total step count as per previous literature (Bjornson et al., 2007). A macro was recorded within the excel spreadsheet to automate steps for editing and formatting the data as it were uploaded.

Data were uploaded to IBM SPSS Statistics Version 28 (Armonk, NY: IBM Corp) for analysis. Due to the small group size, non-parametric tests were used to assess differences in groups across timepoints. The Wilcoxon Signed Rank test was used to determine change in the group (n=10) from pre-dog to one month and from pre dog to six months. These time points were chosen to see if there was an immediate effect of the dog on gait and physical activity and then to see if there was a difference at follow up after a period of accustomisation. Data were then grouped into those with less physical impairment (group A, GMFCS I-II) and those with more physical impairment (group B, GMFCS III-IV) for further analysis. Statistical significance for the group was set at $p<0.05$. Each child was compared to their own baseline across all data collection timepoints to look at the individual changes, and to reflect on activity diary data.

7.2.4. Activity Diary

Each parent or guardian was given an activity diary to complete to accompany the activity monitor. This is a one-page guide where parents could break down their child’s activities at hourly intervals on each day that the activity monitor was worn. This information could then be compared with the uploaded data to check for accuracy of data (i.e., less steps on a rainy day when the child stayed inside or high step count on a day when the whole family went on a 5 km walk) (available in Appendix H).

7.2.5. The Effect of Rainfall

In qualitative interviews and activity diaries, some parents reported that both the weather and time of year may have had an effect on their child's physical activity levels. It was decided to objectively analyse local precipitation at each of the data collection time points. Historical data for local weather stations was obtained (https://www.met.ie/climate/available-data/historical-data) for each child's home location, for each of their individual data collection timepoints.

7.3. Results

7.3.1. Group results

There were two sets of missing data: Participant 1 did not complete time point two as they were non-ambulant for a period due to an injury and participant 7, who did not complete time point 4 as they were scheduled at short notice for orthopaedic surgery immediately following their six month gait analysis.

The results of the analysis of the group of 10 children from pre-dog to one month after they received their dog and six months follow up are presented in Table 7-1.

Table 7-1: Wilcoxon Sign Rank for activity monitor variables for the group (n=10)

Variable	Pre dog median (range)	One month median (range)	Pre-dog-one month p-value	Six-month median (range)	Pre-dog to six-month p-value
Steps	41444 (15948-123196)	40103 (17876-122756)	0.96	65074 (6640-144230)	0.44
Minutes Active	1981 (1128-3478)	2055 (1196-3263)	0.72	2414 (640-3630)	0.86
Highest Cadence (steps/minute)	124 (80-148)	121 (72-152)	0.72	128 (96-152)	0.77
Minutes low activity	1481 (971-1983)	1409 (101-1902)	0.093	1484 (591-2132)	0.68
Minutes medium activity	413 (119-1109)	370 (9-1083)	0.29	647 (41-1217)	0.86
Minutes high activity	62.5 (0-442)	58 (0-442)	0.86	102 (8-568)	0.1

There were no significant changes for the group of ten children from pre dog to one month or 6 month follow up for any of the physical activity parameters.

The results of the analysis of group A (n=5) from pre-dog to one-month after they received their dog and six months follow-up are presented in Table 7-2.

Table 7-2: Wilcoxon Sign Rank for group A (n=5)

Variable	Pre dog median (range)	One month median (range)	Pre dog-one month p-value	Six month median (range)	Pre-dog to six month p-value
Steps	85044 (41842-123196)	89644 (52808-122756)	0.89	107340 (65074-144230)	0.14
Minutes Active	2924 (1955-3478)	2755 (2397-3263)	0.69	2755 (2414-3630)	0.23
Highest Cadence (steps/minute)	132 (122-148)	138 (124-152)	0.34	140 (128-152)	0.08
Minutes low activity	1555 (1416-1983)	1738 (1270-1902)	0.68	1799 (1484-2132)	0.23
Minutes medium activity	813 (406-1109)	723 (484-1083)	0.68	748 (647-1217)	0.5
Minutes high activity	229 (72-442)	308 (78-442)	0.89	350 (102-568)	**0.04***

Group A: Children with less impairment (GMFCS I-II) showed a significant positive change in the amount of time them spent in high level of activity from pre dog to six month follow up ($p<0.05$*). Otherwise, there was no significant change from pre dog to one month or six month follow up for physical activity parameters.

The results of the analysis of group B (n=5) from pre-dog to one-month after they received their dog and six months follow-up are presented in Table 7-3.

Table 7-3: Wilcoxon Sign Rank for group B (n=5)

Variable	Pre dog median (range)	One month median (range)	Pre-dog-one month p-value	Six-month median (range)	Pre-dog to six month p-value
Steps	23574 (15948-41046)	19528 (17876-27398)	0.89	17282 (6640-39004)	0.67
Minutes Active	1605 (1128-2008)	1472 (1196-1714)	0.69	1171 (640-1857)	0.28
Highest Cadence (steps/minute)	108 (80-126)	114 (72-118)	0.68	108 (96-114)	0.7
Minutes low activity	1427 (971-1534)	1251 (982-1599)	0.68	1002 (591-1394)	0.27
Minutes medium activity	218 (119-421)	176 (95-256)	0.04*	150 (41-374)	0.27
Minutes high activity	23 (0-53)	20 (0-38)	0.7	18.5 (8-89)	0.7

Group B: Children with more impairment showed a negative change in minutes of medium level activity from pre dog to one month post dog. Otherwise, there was no change from pre dog to one month or six month follow up in any of the physical activity parameters measured.

7.3.2. Individual Results

Participant One

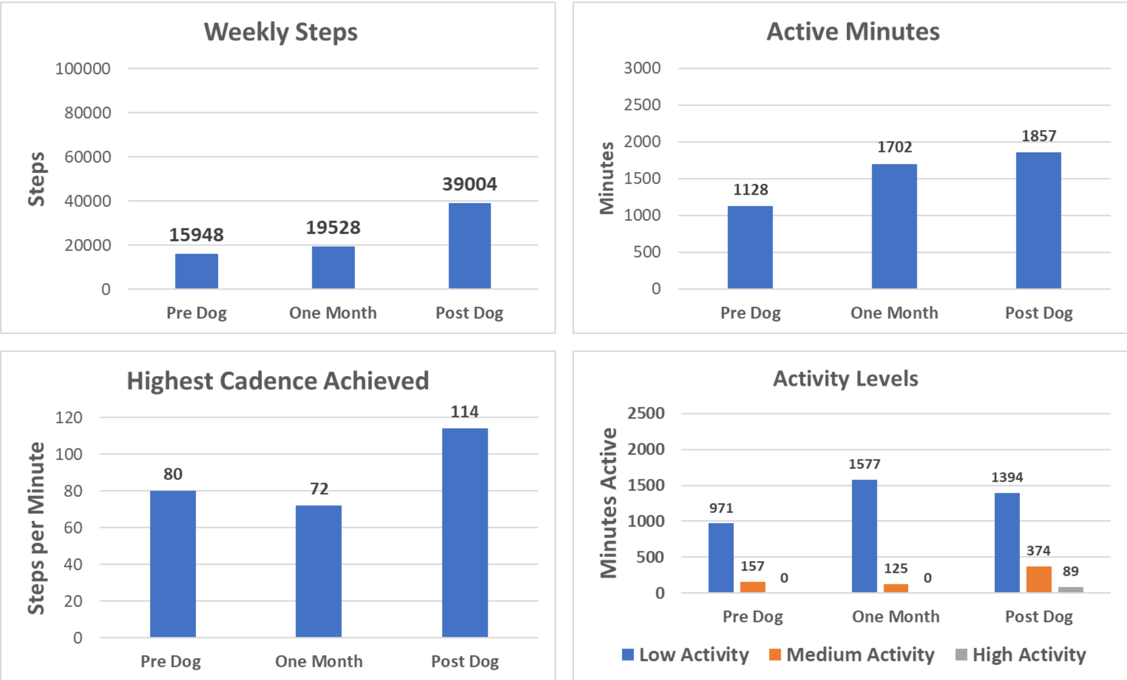


Figure 7-2: Stepwatch output for all timepoints for participant one

Participant number 1 (GMFCS III, Age 12) had low levels of activity at baseline, with 15948 steps per week, this showed a marginal increase after one month and more than doubled by the six month timepoint. They showed a change in active minutes after one month as they may have spent more time on their feet with the dog and maintained this change after 6 months. Their highest cadence increased after 6 months but not after one month, it may have taken them time to become accustomed to walking with the dog. At the six month time point, they spent more time in low, medium and higher level activity than at baseline. There was no timepoint 3 activity monitor data for this child as they were not walking at the time due to an injury.

Participant 2:

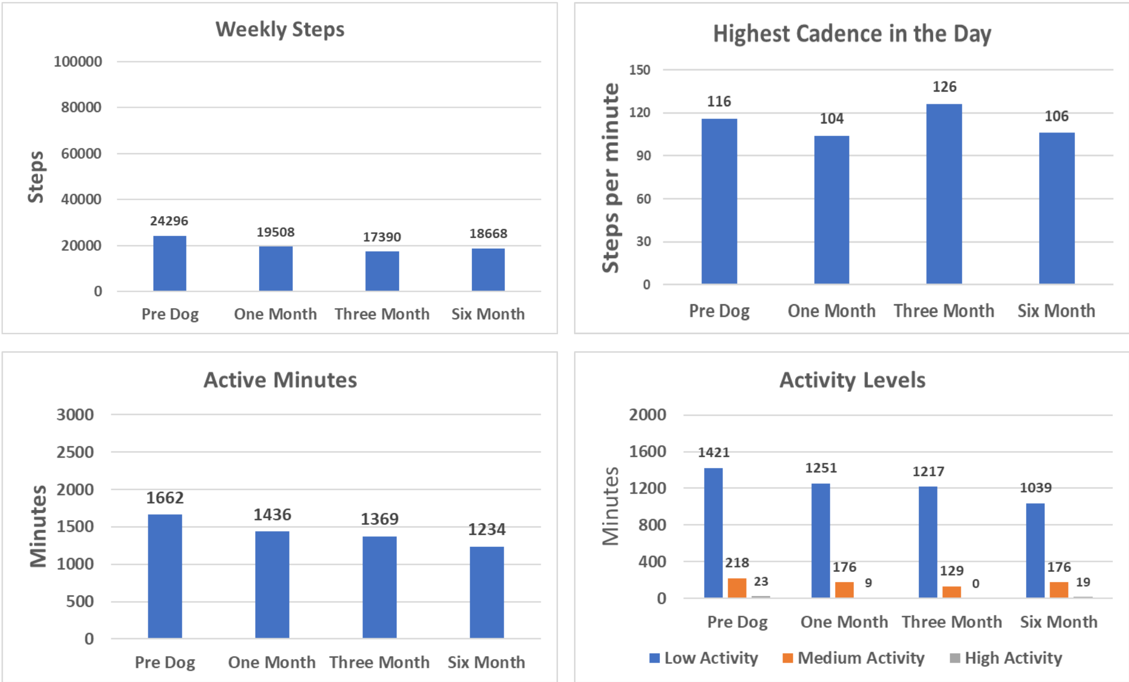


Figure 7-3: Stepwatch output for all timepoints for participant two

Participant 2 (GMFCS IV, age 9) had low level activity at baseline. After one month he became more inactive and this trend continued across timepoints. Although his cadence varied, he had a lower cadence at the six month timepoint and was taking less steps and had less active minutes. This may be due to him going out more in his wheelchair rather than walking with the dog and would be in line with natural progression with his level of impairment.

Participant 3

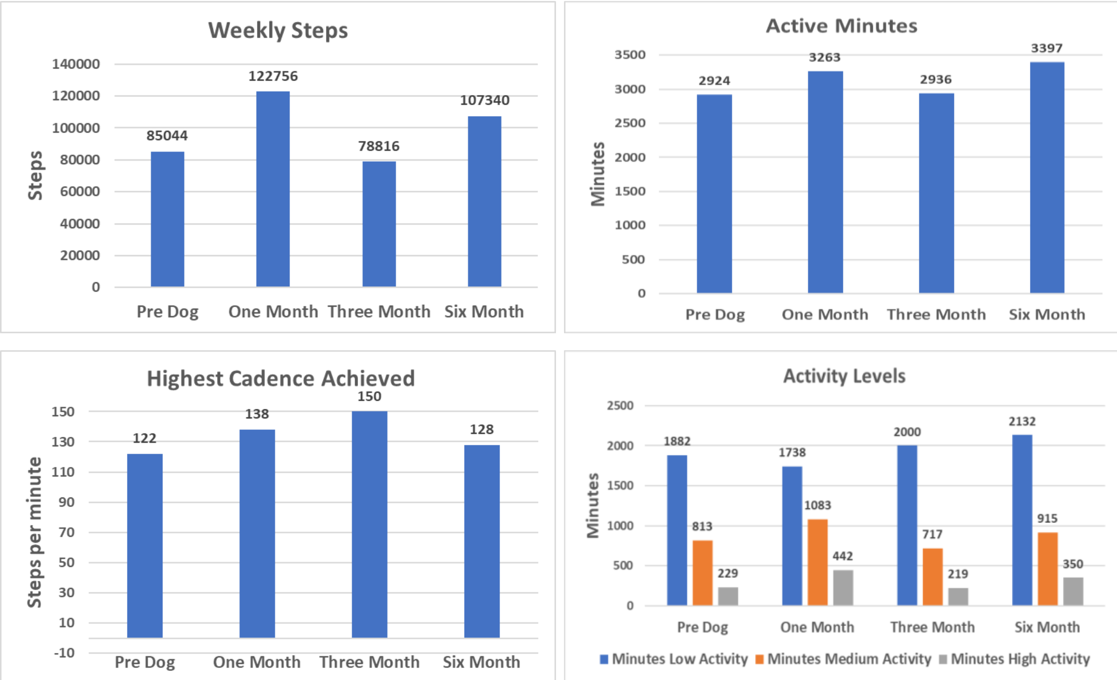


Figure 7-4: Stepwatch output for all timepoints for participant three

This child (Age 9, GMFCS I) was active at baseline, and they became more active after one month of having their dog and this was maintained at 6 months. There was a decrease in step count and physical activity levels at the three month timepoint due to inclement weather. At the 6 month timepoint the child spent more time at a high intensity activity level. Highest cadence increased after three months but this was not maintained at the six month timepoint.

Participant 4

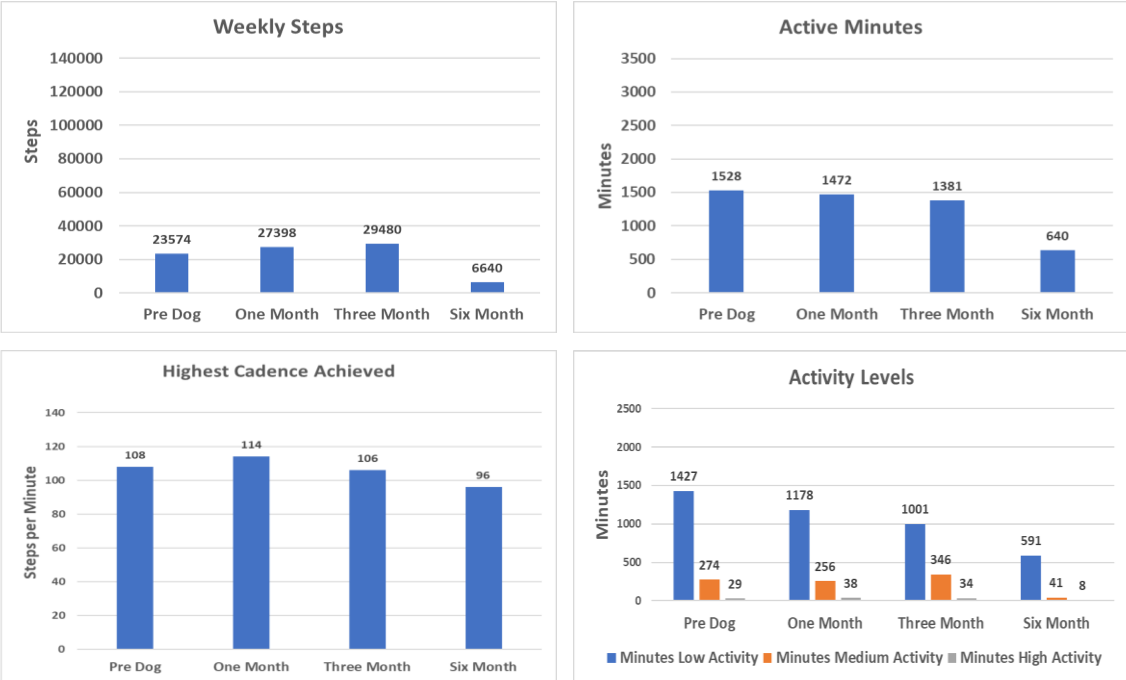


Figure 7-5: Stepwatch output for all timepoints for participant four

Participant 4 (GMFCS III, age 9) had a low level of physical activity at baseline. This increased a little at the one month and three month timepoints, but although she took more steps, she seemed to be generally less active and had a reduction in active minutes. At the six month follow up, there was significant decline in her activity levels. Her parents reported that she was having some knee pain and was finding it difficult to walk at that time.

Participant 5

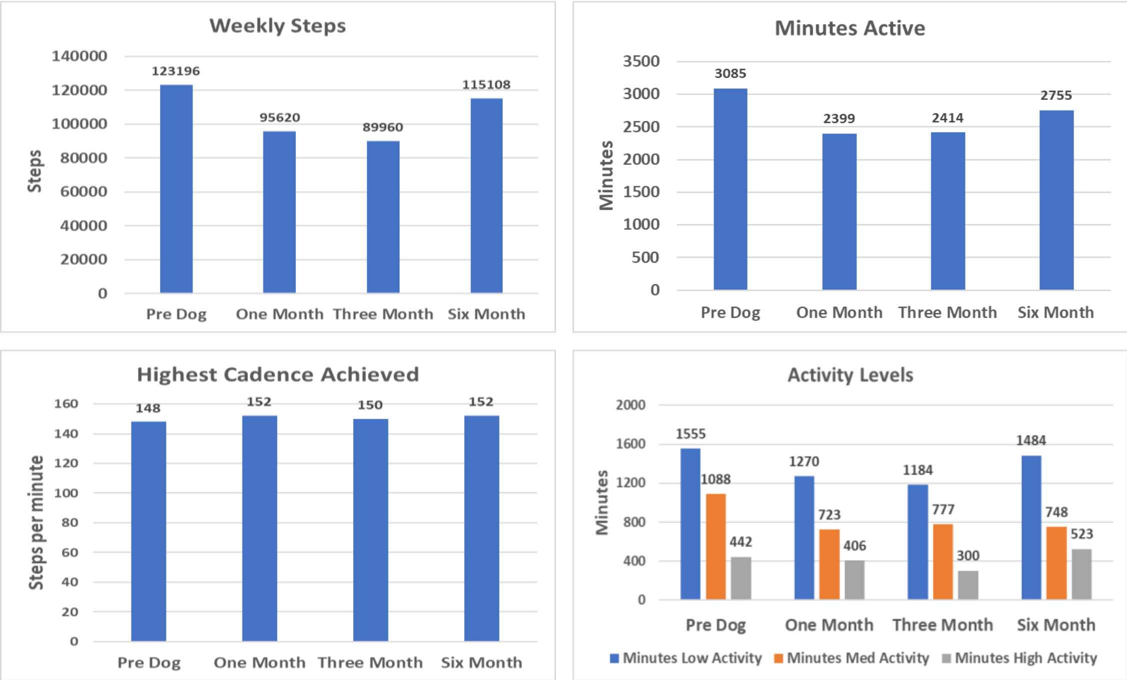


Figure 7-6: Stepwatch output for all timepoints for participant five

Participant 5 (GMFCS I, Age 9) was very active at baseline, reaching recommended daily step count and a typical cadence. Minutes active and step count decreased after one month with the dog but increased again after six months with the dog. At the pre-dog timepoint, mum reported it was a very active week when school finished for the summer and activity levels would have been higher than normal. At the six month timepoint, he spent an increased time at high intensity physical activity level than prior to getting the dog.

Participant 6

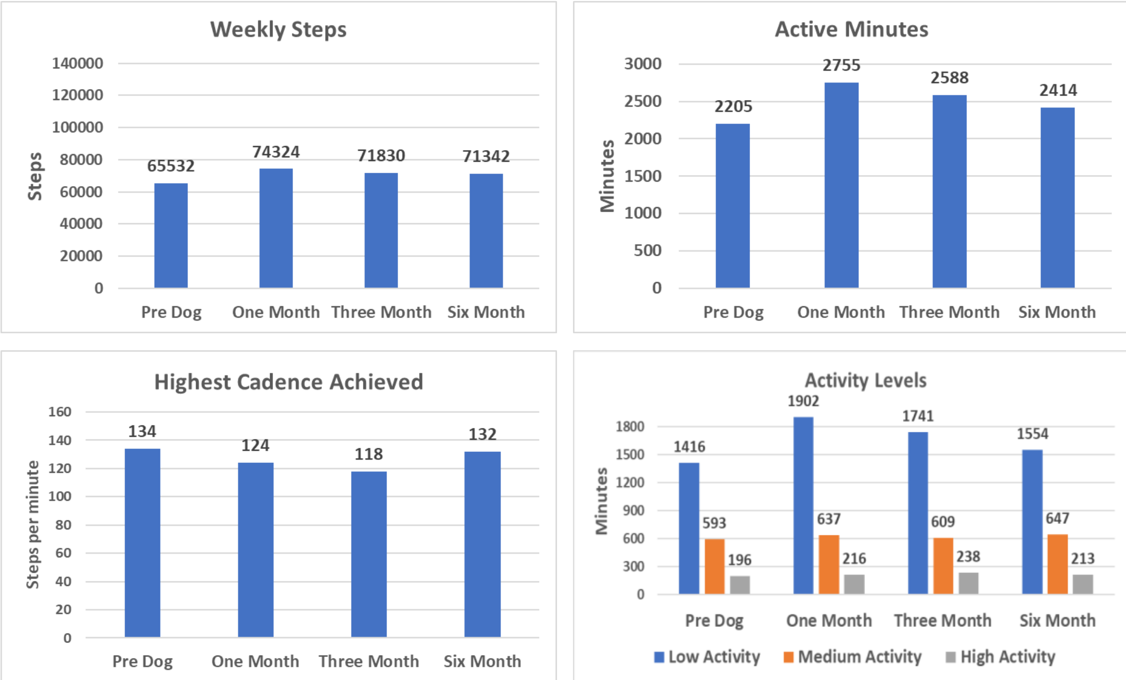


Figure 7-7: Stepwatch output for all timepoints for participant six

Participant 6 (GMFCS II, age 8) increased their daily step count and active minutes after one month. This was somewhat maintained at 6 month follow up. He spent more time at a medium and high level intensity of physical activity at six month follow up.

Participant 7

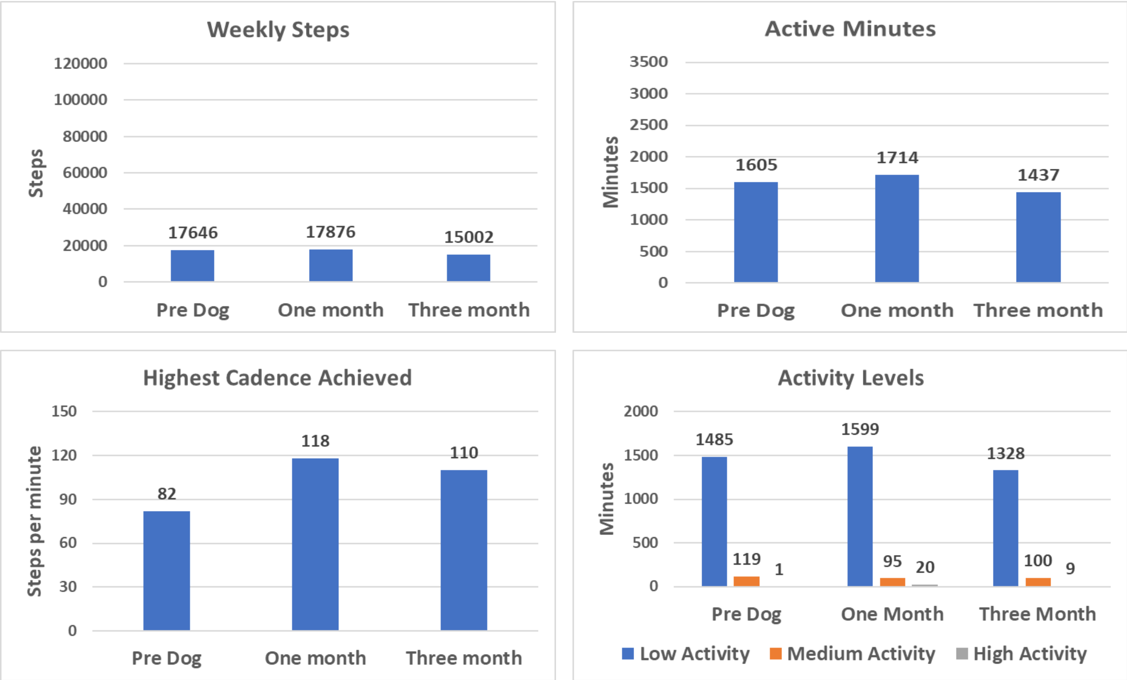


Figure 7-8: Stepwatch output for all timepoints for participant seven

This participant (GMFCS IV, age 9) had a very low weekly step count at baseline. There was a slight increase in steps and active minutes after one month, however this was not maintained at three months. However, cadence did increase after one month and this was somewhat maintained at three months. This child did not achieve any change in intensity of activity level.

Participant 8

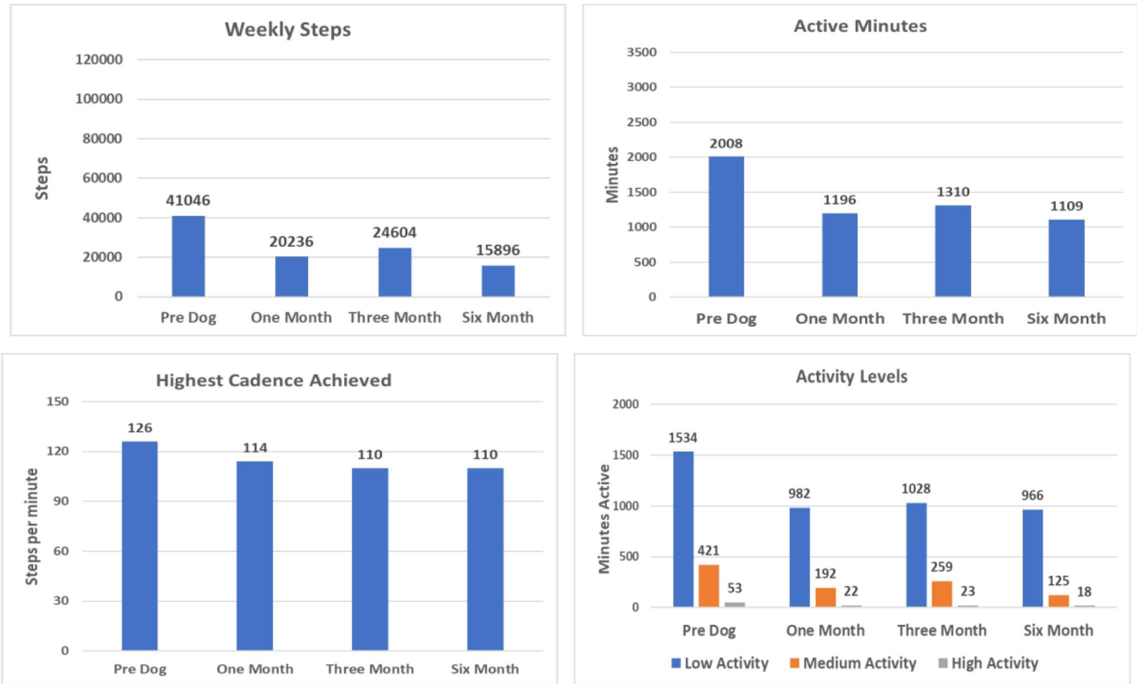


Figure 7-9: Stepwatch output for all timepoints for participant eight

Participant 8 (GMFCS III, age 8) had a low step count at baseline. After one month with their dog, there was a decrease in their activity levels and in their highest cadence. This decrease in activity levels and cadence continued across three and six month timepoints.

Participant 9

Figure 7-10: Stepwatch output for all timepoints for participant nine

Participant 9 (GMFCS II, age 11) had a good physical activity level at baseline. This decreased after one month with the dog, and mum reported that the child was finding walking with the dog challenging initially. After three months there was a small increase and at six months the child had an step count above that of typical. This child spent more time at moderate and high intensity of physical activity after six months with their dog. Highest cadence achieved in the day increased from pre dog to one month post dog and this was maintained.

Participant 10

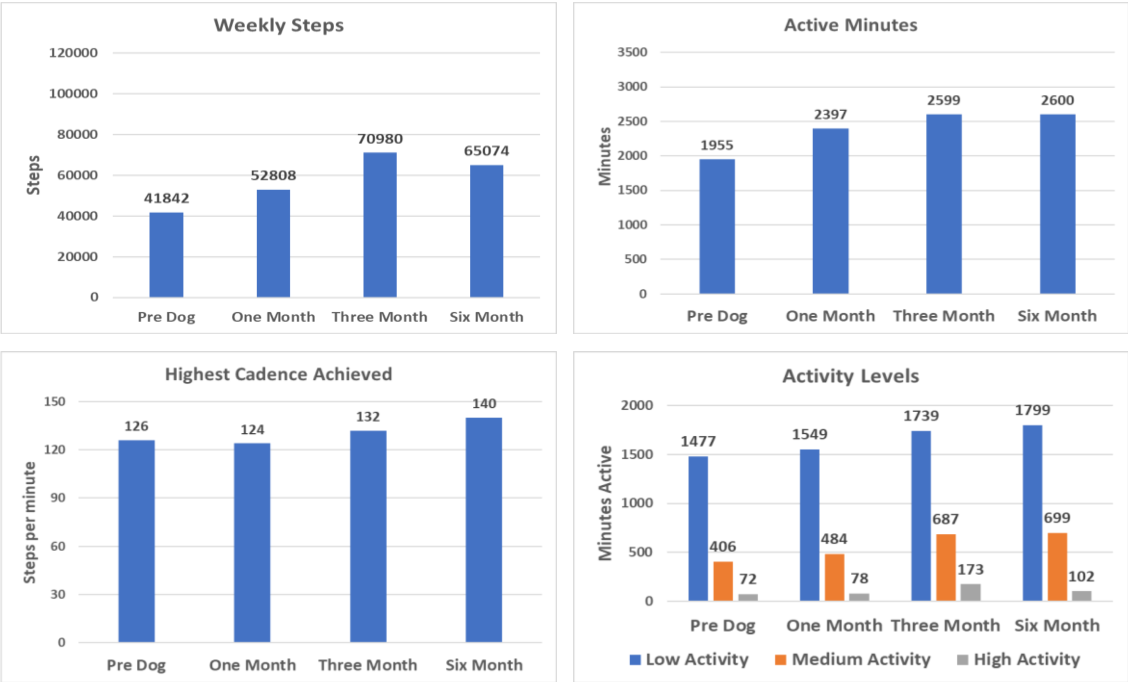


Figure 7-11: Stepwatch output for all timepoints for participant ten

This was the youngest participant in the study (GMFCS II, age 6). They had a low level of activity at baseline, this increased across timepoints. Although step count increased, active minutes increased and this was maintained at the six month timepoint as the child may have been spending more time on their feet with the dog.

The highest cadence achieved also increased across timepoints and the child spent more time at moderate and high intensity of physical activity by the six month timepoint.

7.3.3 The Effect of Rainfall on Daily Steps

The following graphs show a correlation of data between local daily rainfall and total daily steps for each child at each data timepoint. This was completed for the group of ten children and for Group A (n=5) and Group B (n=5).

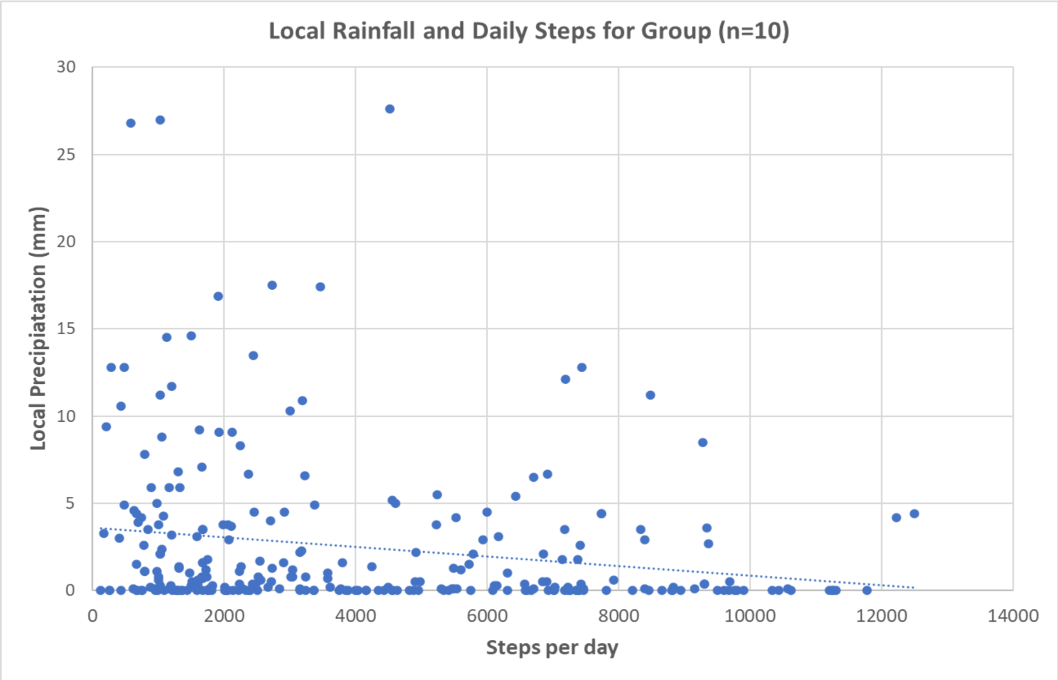


Figure 7-12: Correlation between local daily precipitation and total daily steps for the group of ten children

There was a weak negative correlation (r=-0.2) between total daily steps and local precipitation for the group of ten children.

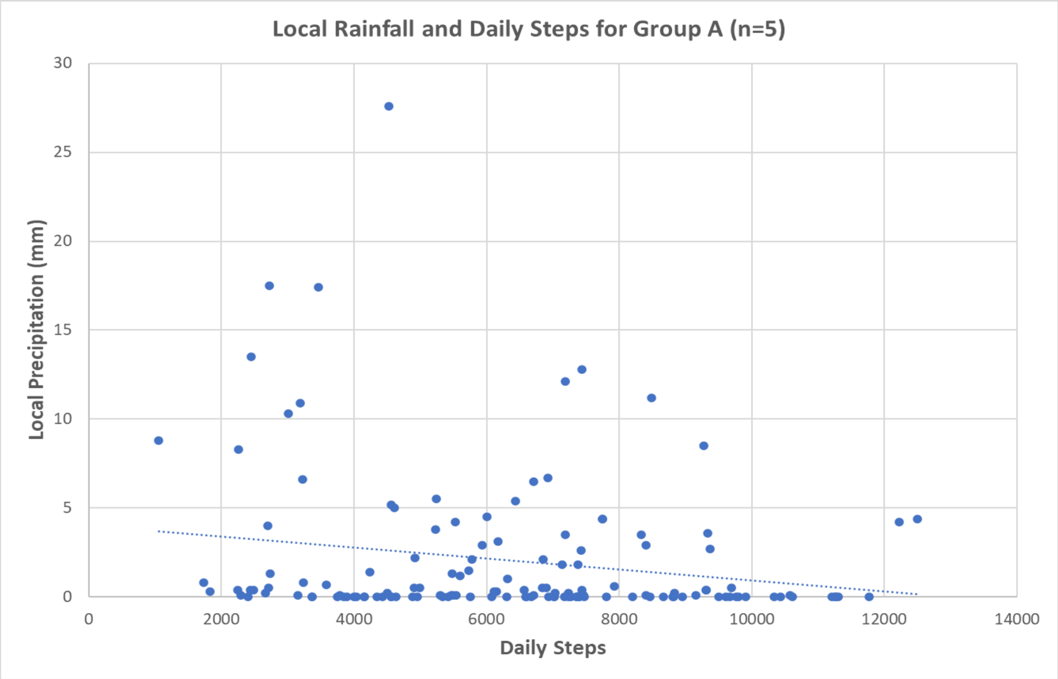


Figure 7-13: Correlation between local daily precipitation and total daily steps for Group A (n=5)

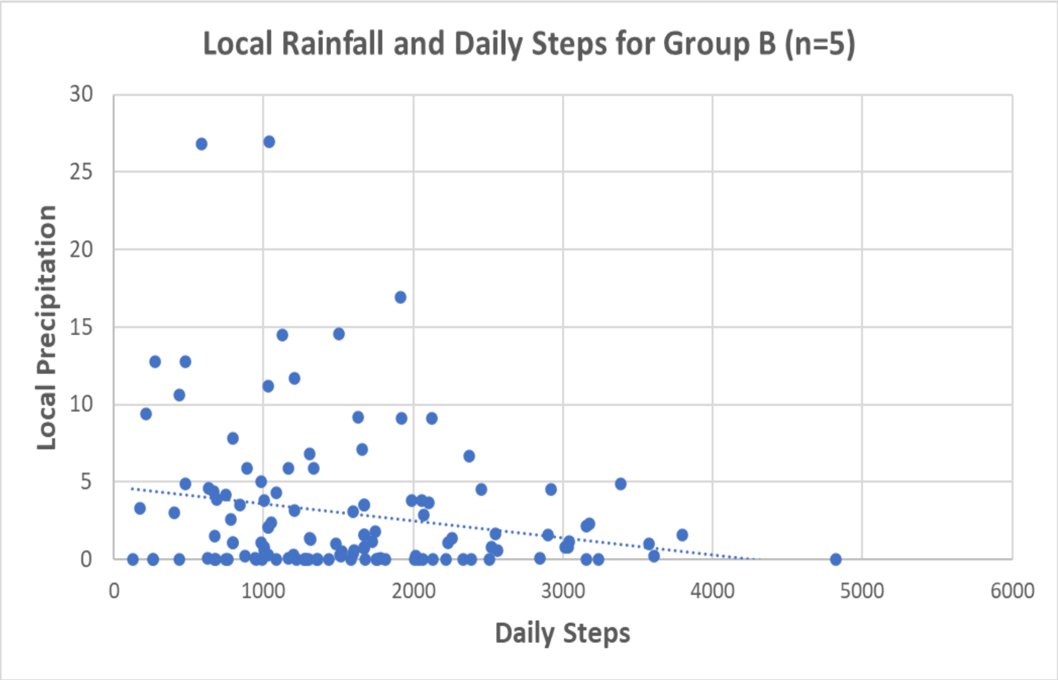


Figure 7-14: Correlation between local daily precipitation and total daily steps for Group B (n=5)

There was a weak negative correlation (r=-0.2) between total daily steps and local precipitation for Group A and Group B.

7.4. Discussion

This small group of ten children showed no significant change in physical activity outcomes from pre-dog to six month follow up. This may be due to variation in the level of impairment in the group and activity diaries showed inclement weather may have had an effect on physical activity. Children with milder impairment (GMFCS I-II) did spend more time at a higher intensity of physical activity ($p<0.05$) at six month follow up. Children with more impairment (GMFCS III-IV) did not show change in any domain of physical activity measured. Given the heterogeneity of the group, children's physical activity levels were analysed on a case-by-case basis to assess the unique attributes of each child. Overall, there is improvement seen from pre dog to one month for children with less impairment (Group A GMFCS I-II), who not only seem to be more physically active (increased step count) but spend more time on their feet (active minutes) and therefore less time being sedentary. There was little change to highest daily cadence. The MADs did not seem to increase the speed or motor function of the children. In children with more impairment there was, overall, little positive change within individual cases and some children became less active. Their activity diaries portrayed that they may go out in their wheelchair more for family walks with their MAD.

These findings somewhat agree with previous studies where children with visual impairment are more active and have improved mobility with an assistance dog (Lindsay & Thiyagarajah, 2021). However, our findings do not agree with study by Carcreff et al (2020) where they found that gait quality does not predict gait quantity. We found that those with more impairment did not show positive change, therefore gait quality, denoted here by a higher GMFCS level, did somewhat predict increased gait quantity, both at baseline and at follow up. Although MADs have previously been shown to improve physical health, psychological health and social wellbeing in people including children with disabilities (Lindsay & Thiyagarajah, 2021; Winkle et al., 2012), little is known about the specific effect of MADs on PA in children with motor impairment and this data provides a preliminary grasp of the effects of a current practice

There are limitations to the study. This was a small heterogenous group, and quantifying statistical significance may be inappropriate given the sample size. Inclement weather was reported as being a factor affecting PA levels by parents and the time of year varied for data capture. A weak correlation was found between local rainfall and daily steps, which supports this anecdotal evidence. The first timepoint was during the summer for nine out of ten of the children and they may have been more active at this time.

This is an early study and the findings are preliminary. For more robust conclusions, future work may benefit from focussing on children of GMFCS level I-II only over an extended period to eliminate the effect of weather and time of year on PA levels. The study would benefit from a larger sample size.

7.5. Conclusions

The group of ten children showed no statistically significant change in physical activity domains from pre dog to six month follow up. Children with less impairment may increase the intensity of their physical activity after six months of having a MAD. There are changes in individual cases, however environmental factors affected physical activity levels. These are preliminary findings in a novel therapeutic area.

In the next chapter, chapter eight, individual cases studies are presented. Summary data from each of the methodologies utilised in the study are collated for each of the ten participants. This is followed by a discussion of the findings of the case studies, and an overall discussion of the results from the overall mixed methods study.

8. Case Studies

8.1. Introduction

In the following chapter, summary data from each of the methodologies utilised in the study are collated for each of the ten participants. This includes background data collected in the qualitative interviews regarding each child's home environment, their particular mobility needs and their expectations about how their mobility assistance dog may help.

Gait laboratory data is presented from their individual pre dog assessment and compared graphically to their post dog assessment. Outcomes covered are: the Gait Deviation Index (GDI) as an overall indicator of their gait kinematic quality, gait speed as an overall indicator of their gait function, cadence and time in double support.

Clinical examination data included measuring strength of abdominals, hip abduction, hip extension, quadriceps and hamstrings (see chapter 5) and this has been included for each child from their pre dog assessment to post dog follow up.

A summary of data collected from the Stepwatch is shown from pre-dog to follow up for each child. The key points from each parent's qualitative interviews across the four timepoints are summarised for each child. The results from the Cerebral Palsy Quality of Life questionnaire (CPQoL) are presented from pre dog to post dog follow up for each child.

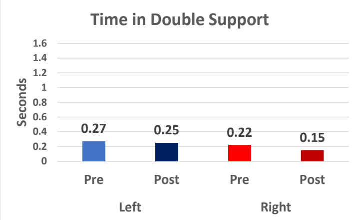
A short summary is then described for each child and how the data types reflect their progress in their gait, physical activity and quality of life after 6 months with their dog. This includes a reflection on their expectations with their dog. A reflection is also given on how the quantitative data interacts or agrees with the qualitative interview data. This is followed by a discussion of the individual case studies.

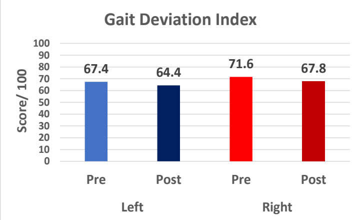
8.2. Case Studies

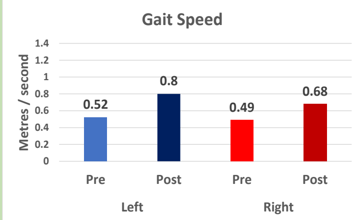
Participant 1 Data Summary

Background: 12-year-old boy; CP spastic bilateral; GMFCS III. Walks with handheld support ++ or Kaye walker at baseline; Wears bilateral rigid AFOs; Selective Dorsal Rhizotomy 2018
Lives with family in a housing estate with good access to green space; plays guitar; child has difficulty with steps, slopes and has regular falls.
Expectations from the dog: Parents would like for their child to be able to walk into the cinema or a restaurant without holding their hand and that he could hold the dog instead.

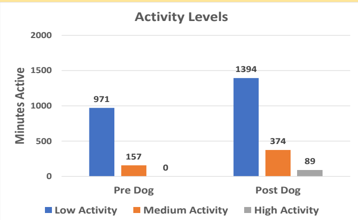
Gait Laboratory Data:

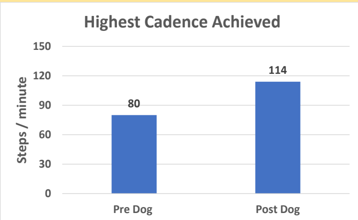


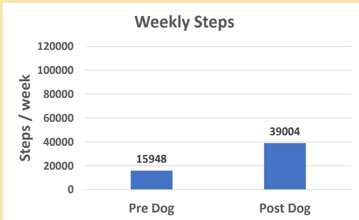




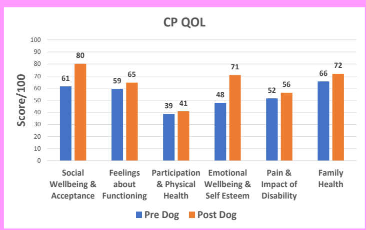
Activity Monitor:



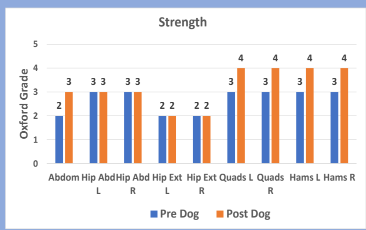




Quality of Life:



Clinical:



Qualitative Interviews (key points): As reported by mum

- 15 minute walk a day with the dog and finds this tiring
- Confidence boost with his peers as he gets positive attention with the dog
- Overall the dog has been a great addition to family life
- Reason to go outside and tends to be more active
- He still finds walking with the dog challenging but seems steadier on his feet

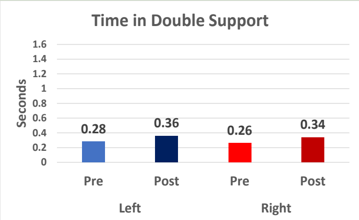
Data Collection Dates: Pre Dog: 10th May 2021 Post Dog: 3rd May 2022

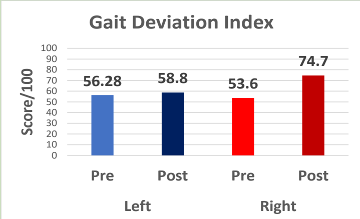
Conclusion: This boy showed positive change in his level of PA and functional gait speed both in the laboratory setting and in his own environment. This agreed with parental report of him being more active, going outdoors more and being steadier on his feet. There was no improvement to the pattern of his walking. He showed positive change in social and emotional QOL domains, and this agreed with parental report. He achieved his goal of walking into a restaurant holding the dog.

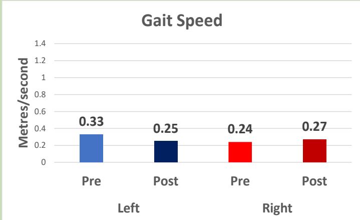
Participant 2 Data Summary

Background: 10-year-old boy ; CP spastic bilateral, GMFCS IV; Walks for therapy only using a Kaye-walker; uses a powered wheelchair. Wears bilateral rigid AFOs, had botulim toxin (October 2021) to bilateral hamstrings.
Family live in a housing estate with good access to green space. Plays wheelchair rugby.
Expectations from the dog: Would love to be able to walk a few steps with the dog. To 'bring him out of himself' a bit by being proud of his dog

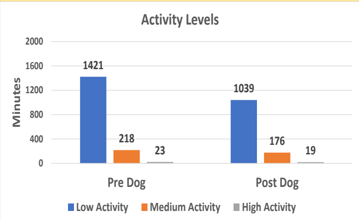
Gait Laboratory Data:

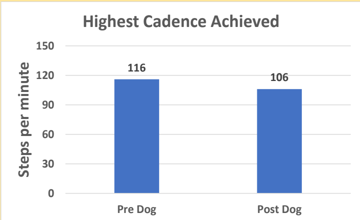


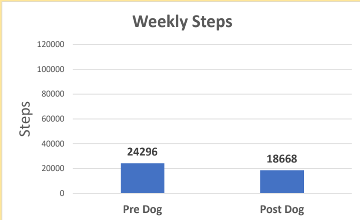




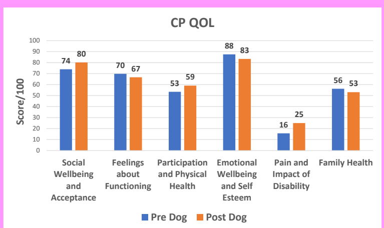
Activity Monitor:



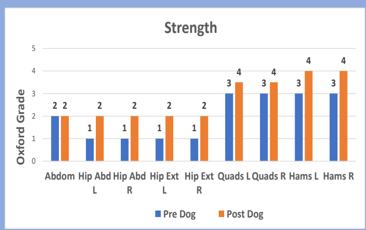




Quality of Life:



Clinical:



Qualitative Interviews (key points): as reported by child's mother in all interviews.

- more confidence talking to strangers, will voice information he has about the dog
- the child enjoys the companionship of the dog
- great addition to family- dog motivates family to get out, but child goes in his wheelchair
- motivates the child to do his physiotherapy exercises as he does an extra set with the dog
- walking practice has been weather dependent;
- activity levels – same, but has got stronger as he does his physio exercises well with the dog

Data Collection: Pre Dog: 3rd June 2021 Post Dog: 12th April 2022

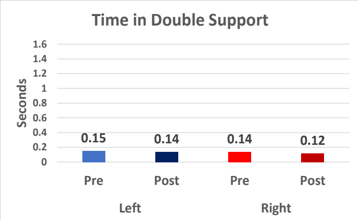
Conclusion: This boy's parents perceived that he benefited socially from having a MAD and that he appeared stronger but was no more active. Objective data shows that there was no improvement in his functional gait pattern or activity levels or in QoL domains. He did not achieve his goal of taking steps with the dog, but parents report he was more confident socially. In line with typical progression at this functional level, this boy tends to use his wheelchair more for participation.

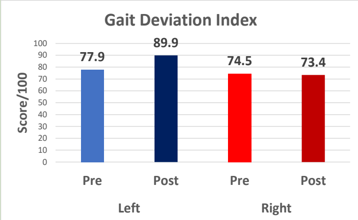
Participant 3 Data Summary

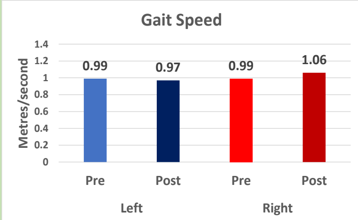
Background: Boy age 10 ; Genetic syndrome: low muscle tone, fatigue, weakness, pes planus, visual impairment; Functions as GMFCS I; Walks independently or with handheld support at baseline; Wears bilateral rigid AFOs. Lives with family in a housing estate with good access to green space; Loves football, plays with special needs team

Expectations: To hold the dog instead of a hand; give him confidence to do things himself. Have fun walking with the dog and improve his stability as a result.

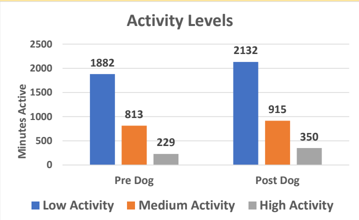
Gait Laboratory Data:

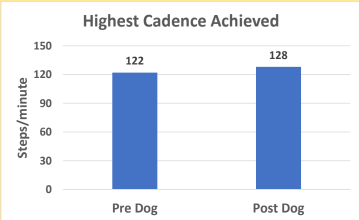


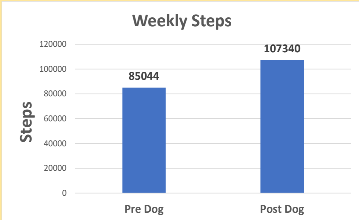




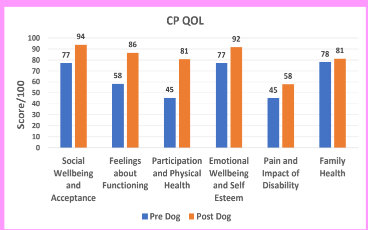
Activity Monitor:



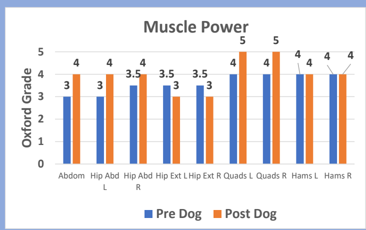




Quality of Life:



Clinical: Significant plano valgus feet; Low muscle tone



Qualitative (key points): as reported by mother

- more freedom when out for walks and her child was safe walking to the beach
- Difficult to navigate the child and dog in the shops;
- More included in conversations now; loves to tell people about his dog
- public give her child the space he needs;
- walking further distances as motivated by the dog, he likes to be seen out with the dog; He is less anxious about attending hospital appointments.
- confident walking with dog; more active as he is up playing with the dog in the garden.

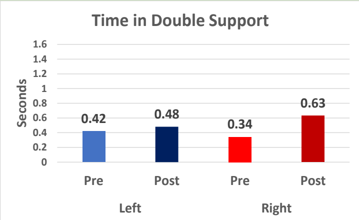
Data Collection Dates: Pre Dog 14th June 2021 Post Dog 9th April 2022

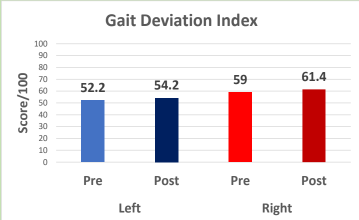
Conclusion: Positive change in his daily activity, strength and QOL scores. His lower limb gait pattern showed little change from baseline. These objective findings somewhat agree with interview data where he was perceived to be more active since having the dog and showed social gains with his peers, reflected in QOL domains. The child was walking holding the dog instead of his parents' hand and was having fun with the dog as was the intention.

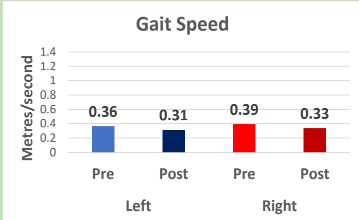
Participant 4 Data Summary

Background: 9-year-old girl; GMFCS III. Walks using a Kaye walker, uses tripods for therapy; manual wheelchair for long distances, wears bilateral rigid AFOs, SDR 2019
Lives with family in the countryside. No paths and road is unlevel. Family are very active.
Expectations: To use the dog to manoeuvre into tight spaces such as bathroom; to walk across different surfaces, i.e. across the garden (undulating grass), walk into school with dog.

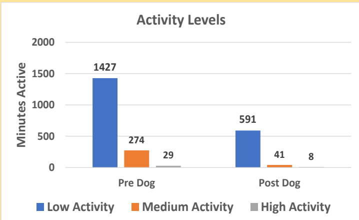
Gait Laboratory Data:

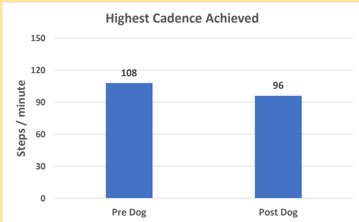


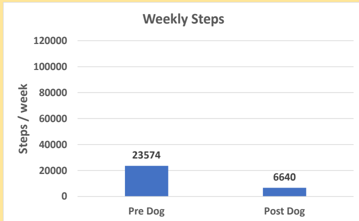




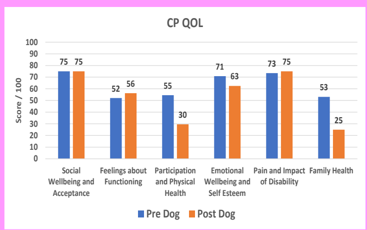
Activity Monitor:



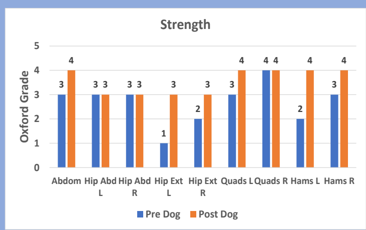




Quality of Life:



Clinical Presentation:



Qualitative: As reported by mother

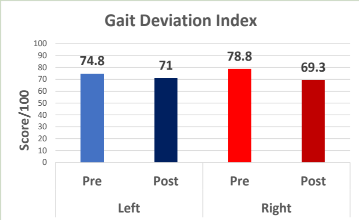
- Walking on tripods improved, standing taller now, but left knee is flexing more
- Benefitted from the companionship of the dog; dog makes her happy, calming
- Walking with the dog is hard work, some days, does not want to walk with the dog; walking with the dog requires two adults
- After 6 months, walking in to school with the dog
- No more active as she is parent dependent
- Very positive addition to the household.
- Takes attention away from her disability when out in public - positive effect on confidence as she gets anxious in public when people look at her

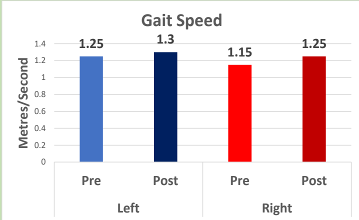
Data Collection Dates: Pre Dog: 7th July 2021 Post Dog: 25th May 2022
Conclusion: This girl showed negative change in objective data of gait speed, activity levels and QoL scores from pre dog to follow up. She measured physically stronger on follow up. Qualitative data somewhat reflects this as her mother reports she is stronger but no more active and finds walking with the dog hard work. Qualitative data reflected positive change in confidence and anxiety, not reflected elsewhere. She achieved the goal of walking into school with the dog, but not manoeuvring tight spaces or walking on grass.

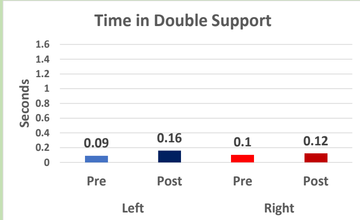
Participant 5 Data Summary

Background: 8-year-old boy with Ataxia, GMFCS 1; walks independently or with handheld support in crowds, using a walker in yard at school. Lives in the countryside near a beach. The road has no footpaths; Large garden with space on grass and paths around the house; he has some difficulty with steps, stairs, turning and running into things. He is a very active boy.
Expectations: Mum would like him to be safer when walking, less running into things and to slow down his walking; allow people to see his disability

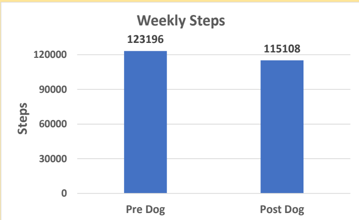
Gait Laboratory Data:

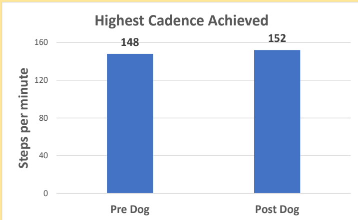


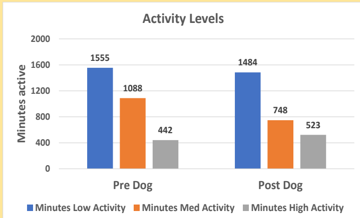




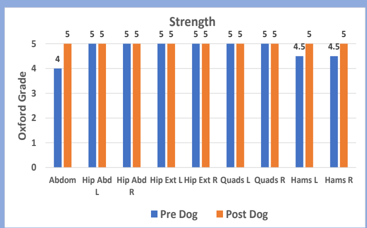
Activity Monitor:



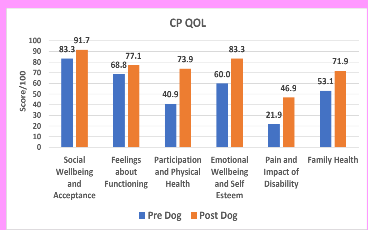




Clinical Presentation: No muscle tightness



Quality of Life:



Qualitative (key points): as reported by mum

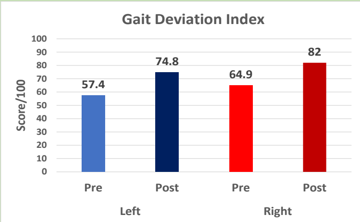
- Brought a lot of happiness to family; Smiles when walking with dog ; companionship
- Walks more slowly and safer with dog; more upright; tripping has stopped; structured walking has helped his stability; looks where he is going
- Arm gets tired walking with the dog
- Walking on beach, not falling; Mum's stress has gone down when out walking
- Proud of his dog, people are inclined to say 'hi' and to smile when out with the dog
- Still active but its more structured now rather than running around

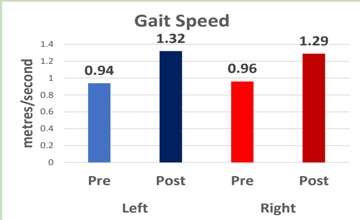
Data Collection Dates: Pre dog: 8th July 2021; Post Dog: 24th February 2022
Conclusions: Very active at baseline. His objective measures of activity and gait quality did not change significantly from pre to post. Cadence decreased as his mother had hoped. QoL data shows positive change in social and emotional domains as well as participation, reflected in interview data where his mother reports he is happy while out with the dog and benefits from the companionship of the dog. She says he is no more active but is safer walking with the dog and looks where he is going instead of looking down; not reflected in objective data.

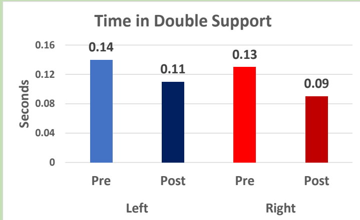
Participant 06 Data Summary

Background: 7-year-old boy with CP, spastic bilateral, GMFCS II; walks with supervision/handheld support or walker for distances. Has anxiety. Lives in a housing estate in a village with good paths and access to green space; has difficulty with endurance and balance. Tries to play soccer but gets very tired. Likes the PlayStation, difficult to motivate to walk
Goals with dog: to increase the distance he can walk, to help with balance, to help with anxiety.

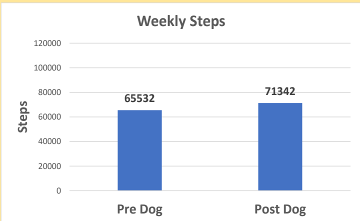
Gait Laboratory Data: Pre Dog to Follow Up

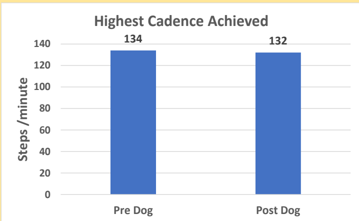


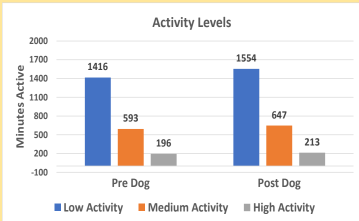




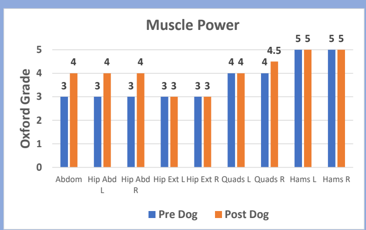
Activity Monitor:



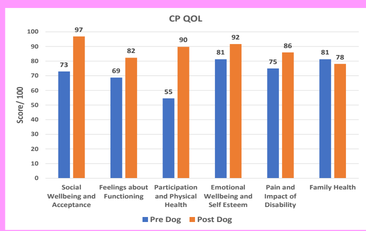




Clinical:



Quality of Life:



Qualitative (key points): as reported by mum

- going for more walks and walking further; managing better on uneven surfaces/slopes; more motivated to walk, considerably more active
- positive attention through dog and communicates in the community about the dog
- completed 5km walk over rough terrain with dog; walking on beach; bond developed between child and dog; dog can be challenging to manage when they meet other dogs
- more confidence walking; improved endurance; more general energy; less PlayStation

Data Collection Dates: Pre Dog 24th August 2021 Post Dog 22nd August 2022

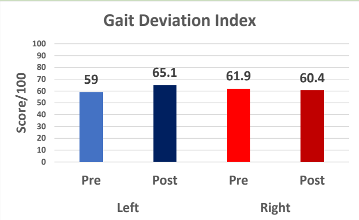
Conclusions: This boy showed measurable improvement in his gait quality and gait speed from pre to post dog. He was more active post dog than at baseline and this is reflected in QoL domains and in the interview data where his mum reports that he is walking further, more stable when he walks and more confident while walking. In the interview data he is now more active in sports and on all terrains, not reflected objectively.

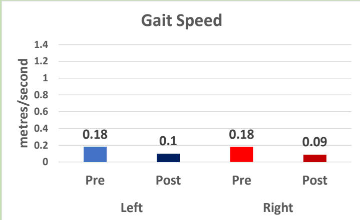
Participant 7 Data Summary

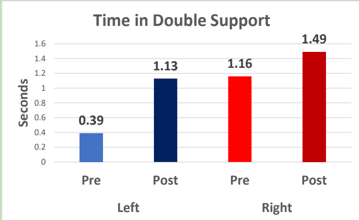
Background: 7-year-old girl with CP spastic bilateral; GMFCS IV; Uses a powered wheelchair, walks short distances for therapy only using a Kaye walker and supervision. Lives in rural village close to a beach, very social, loves drama, participates in water sports with her family using an adapted surfboard and uses a beach wheelchair regularly in the sea.

Expectations: to take a step with the dog, to motivate her; to continue walking as part of therapy as she is not motivated; to make physiotherapy more fun.

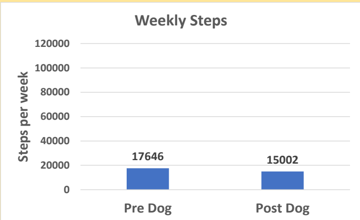
Gait Laboratory Data:

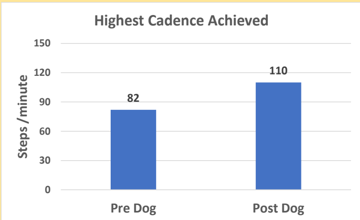


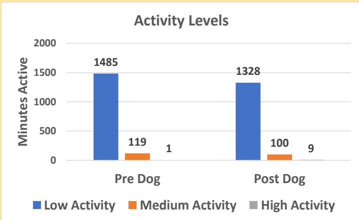




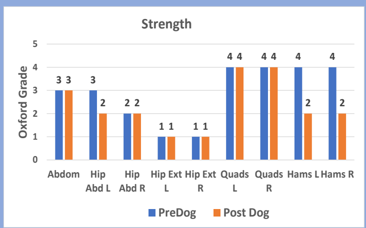
Activity Monitor:



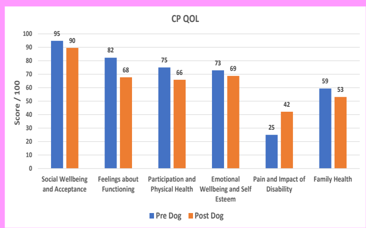




Clinical: lower limb contractures



Quality of Life:



Qualitative (key points): as reported by mum

- The family adore the dog; encourages the family to get out together for walks
- Gets positive attention socially through the dog when out in her wheelchair
- Motivated to do physiotherapy with the dog; less fighting to get her to do her therapy
- Finds walking with dog training very tiring, two people are required to do the walking practice, motivated by the dog to continue her therapy
- Very proud of her dog and likes to talk about her dog with her peers

Data Collection Dates: Pre Dog: 9th September 2021 Post Dog : 25th May 2022

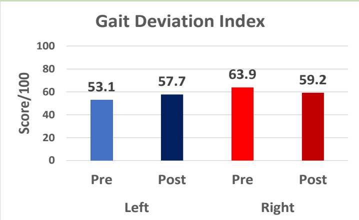
Conclusions: This girl has a low level functional baseline. Some gait laboratory measures disimproved from pre to post dog such as cadence and time in double support. She was less active at the post dog time point. Interview data shows that her mother perceived that she had social gains and gains in motivation to do her therapy exercises however found walking with the dog very effortful. She showed disimprovement in her *Feelings about Functioning* scores on the QOL measure and in her overall gait scores, she walked more slowly in the post dog analysis.

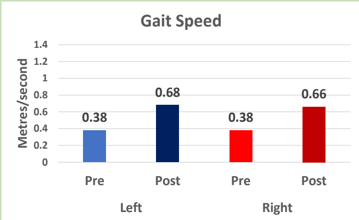
Participant 8 Data Summary

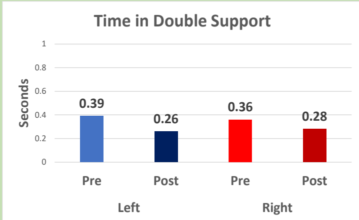
Background: 7-year-old girl with CP , spastic bilateral, GMFCS III; SDR 2018. Walks using a Kaye walker and tripods for therapy. The family live in a housing estate on the edge of a large town. They have good footpaths. It is too far for the child to walk to the local shop. She plays out in the estate in her Kaye walker.

Expectations: That the dog may help to improve her confidence and improve her walking ability by encouraging her to walk more

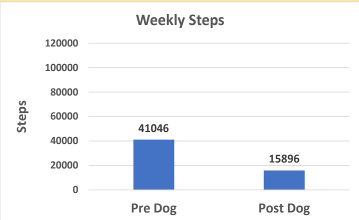
Gait Laboratory Data:

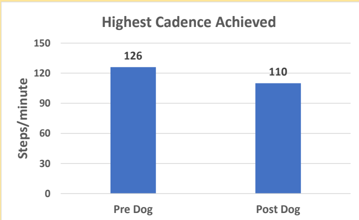


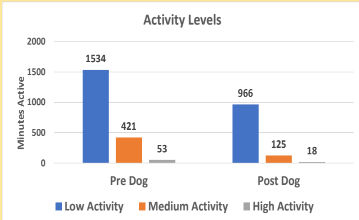




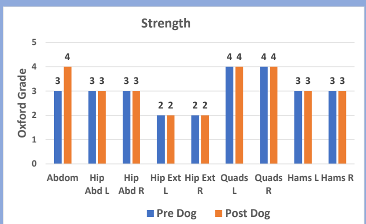
Activity Monitor:



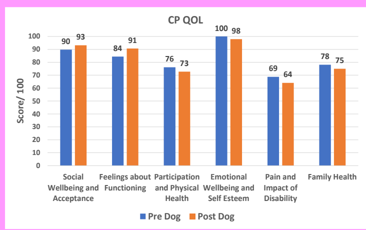




Clinical:



Quality of Life:



Qualitative (key points): as reported by dad

- Great companionship with the dog…"buddies"
- Likes to talk about the dog and her confidence in social interactions has improved.
- Motivated to walk further with the dog and dad feels this has improved her stamina
- Walking with the dog is challenging but she keeps her trunk more still with the dog
- More active in the house playing with the dog
- Going for walks is more fun now that the dog is there
- She is braver to try new things with the dog such as going down steps

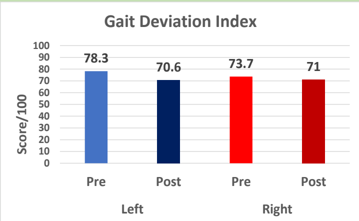
Data Collection Dates: Pre Dog: 13th September 2021 Post Dog : 30th June 2022

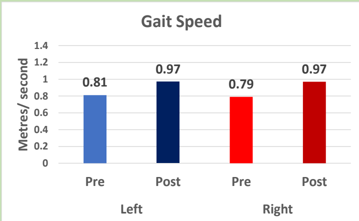
Conclusions: This girl showed positive change in her gait speed and spends less time in double support after 6 months with her dog. Overall, her activity levels decreased from pre to post dog analysis. In the interview data her dad described that she was walking much further and that her walking improved as a result. This is somewhat reflected in gait laboratory data but conflicts with activity monitor data. She doesn't not show change in QoL domains, despite her dad describing an improvement in physical and social confidence. The expectations of the child being more confident and walking more was not measured.

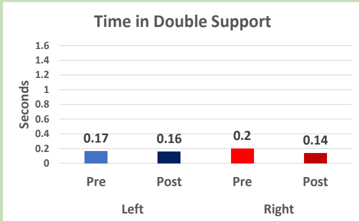
Participant 9 Data Summary

Background: 11-year-old boy with Cerebral Palsy; spastic asymmetrical, walks with supervision or handheld support at baseline. Wears a left AFO. Lives in a housing estate on the edge of a large town; good paths; access to woods nearby for walking.
Expectations from the dog: Long term - that the dog would help her child to be independent from her; to walk without holding someone's hand; to not be embarrassed if he falls and to help him stop falling; companionship and emotional support

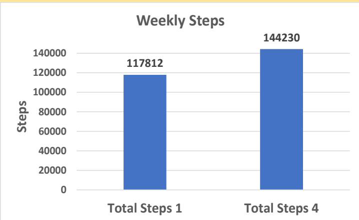
Gait Laboratory Data:

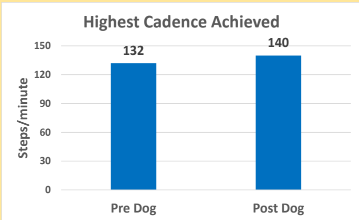


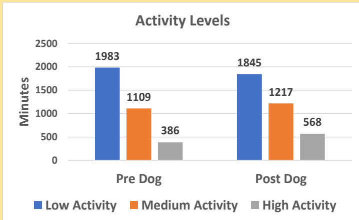




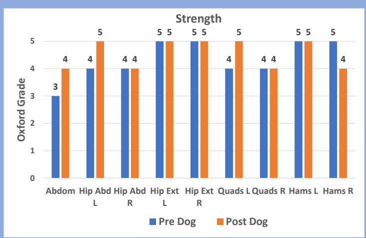
Activity Monitor:



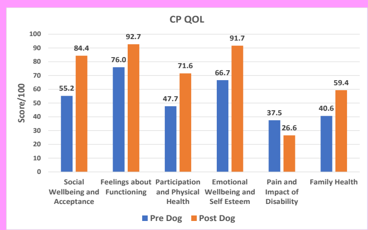




Clinical Presentation:



Quality of Life:



Qualitative (key points): as reported by mother

- less falls while walking with the dog
- motivated to walk with the dog and to walk further
- outdoors more as they have to walk the dog
- more aware of his surroundings when he is out
- proud of the dog and mum feels it has 'brought him out of his shell' or given him more confidence socially when the dog is with him
- walking independently of the mother, holding dog instead of her hand, she feels this is better for his confidence
- walking is straighter and more flat footed with the dog

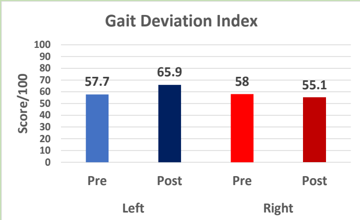
Data Collection Dates: Pre Dog: 13th September 2021 Post Dog : 30th June 2022

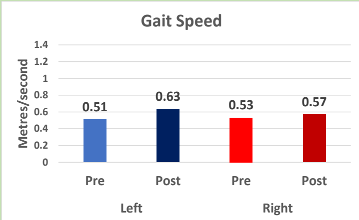
Conclusions: Increase in gait speed and physical activity after six months. Improvements in almost all QoL domains. Interview data agrees, where the mother reports her child is more active now as he is doing more structured walking. He is more confident socially and his walking is more stable and he has less falls. This boy seems a good candidate for a MAD.

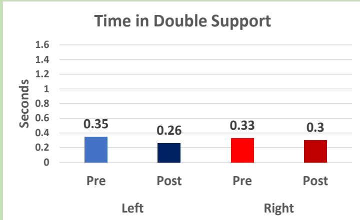
Participant 10 Data Summary

Background: 6-year-old boy with CP Ataxia; GMFCS II, walks with hand held support at baseline and beginning to use a Kaye walker; Wears bilateral rigid AFOs part time.
Lives in the countryside with a large garden on a busy road with no footpaths. Has difficulty navigating ramps, steps, uneven surfaces and has poor spatial awareness.
Expectations from the dog: To slow down and improve walking; to be less reliant on his parents while out walking; to hold the dog instead of their hand; to stop people staring at her child

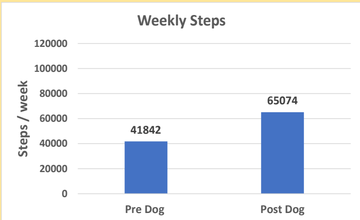
Gait Laboratory Data:

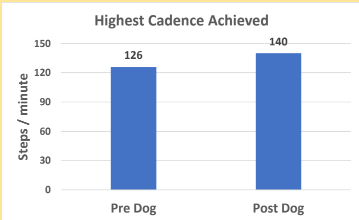


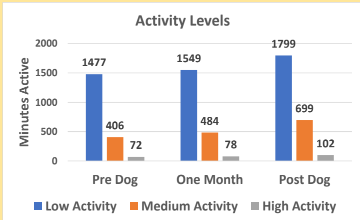




Activity Monitor:



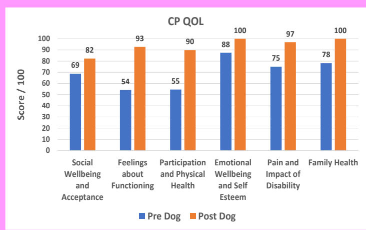




Clinical Presentation:

- not possible to test strength due to an inability to follow verbal commands
- appears to have lower limb weakness
- this boy has joint laxity
- low muscle tone but has some evidence of spasticity at the ankles

Quality of Life:



Qualitative (key points): as reported by mother

- Positive attention from his peers through the dog, people say hello to the dog and she feels there is more of a positive reaction to her child in public
- The child is walking outside with the dog, he can walk up a step with the dog
- His walking is more steady with the dog and he can walk further with the dog without complaining about being tired
- Other family members benefit from the dog as there is now something to bring a positive focus to the child with the disability

Data Collection Dates: Pre Dog: 18th January 2022 Post Dog : 22nd August 2022
Conclusions: Positive change in objective measures of gait speed and time in double support; Increased level of activity shown on the activity monitor; Mum reports that he walks better and further with the dog than previously as he is motivated by the dog. He shows improvement in all QoL domains and mum reports that there is a positive response to the child socially and that he and other family members benefits from the companionship of the dog. He is now holding the dog instead of the parents' hand and mum feels that people do not stare at her child now.

8.3. Case Studies Synthesis

The individual case studies give an insight into the baseline differences for each child, an understanding of how their home environment, their own physical differences and their expectations from their dog may have affected their progress in each of the data types measured.

Each child showed a variety of outcomes, and the results are highly individualised. Overall, most parents reported that the child reached their expectations with the dog after 6 months. For example, participants 3, 9 and 10 are all holding the dog's handle while out walking rather than holding the parent's hand as was their goal and this is not reflected in quantitative data.

8.3.1. Qualitative

Overall, the qualitative interviews report positive outcomes for each child, for psychosocial functioning and social interaction gained through the dog. This tends to agree with social and emotional domains in the CPQoL measure. However, the measurable QoL benefits are not seen for children with more physical impairment (GMFCS III-IV), for example participant 2 and participant 8, where neither showed measurable change in the CPQoL domains and physical activity levels decreased from baseline to follow up. Despite this, parents reported that both of these children were motivated to engage in doing their physiotherapy programmes with their dog.

8.3.2. Gait and Activity Monitor data: measured and perceived.

There are positive changes seen in both the gait data and the activity monitor data for some children. For participant 6, the overall quality of his kinematic walking pattern (GDI) improves as do all gait parameters measured. His activity levels increase. There is positive QoL changes for him in all domains. All of these results are in agreement with the parents' qualitative report which notes that, he has improved ability to walk over different terrain, he is more inclined to go for a walk and so, has improved his overall strength. This is reflected in his overall walking pattern and functional walking speed. Perhaps this child is a very good candidate to receive a dog. At baseline, his main mobility difficulties were endurance, balance and walking over uneven terrain and the dog appears to help with his reported anxiety. This boy was age 8 years old at the beginning of data collection. On the GMFM curve, the predicted motor function trajectory plotted for a child of this age and functional level, shows little expected increase at this age. Physical activity has been shown to be in line with this motor function (Bania et al.,2017; Lee, 2017). This is similar to child 10, (also GMFCS II, age 6). There are measurable gains in his gait laboratory parameters and a small change in the quality of his walking, although changes seen on the left side are not seen on the right side. There are measurable changes in his QoL domains and this is all in agreement with his qualitative report. The baseline expectation was that the dog would help with the child's ability to not hold the parent's hand and to make him safer. The parents felt that the public did not stare at their child and this had a big influence on the parent's own anxiety in public. However at his age (6) and functional level, in relation to the GMFM curve, the curve is still inclining and it's possible that you would expect to see progression in his function and therefore physical activity levels in line with natural progression. Both of these children lived in the countryside and the dog allowed the child to navigate them over rough terrain, paths and to go for long walks.

There was little change to measurable gait laboratory data for child 3, 5 and child 9 (GMFCS I). Although they did somewhat improve in the GDI and cadence, these changes were asymmetric: changes seen on the left side, were not seen on the right. This may be reflective of the effect of walking with the dog on the left and is consistent with previous evidence (Altman et al., 2021). These children had quite good activity levels at baseline. Participant 5 had the highest daily step count and gait speed at the pre dog time point and his mum reported that one of the expectations was the dog would slow down his walking and thus the goal with the dog was not that he would walk faster. His activity levels reduced a little and his mum reported that although he is still quite active, he now does more structured walking and less free play after school as they do a daily walk with the dog. She feels this has been beneficial for his walking. These three children all improved in their QoL measures and the parents reported that they are all happier with their walking. They report that their balance is better and they are more aware of their surroundings and perceived as safer. However, they all had a comparatively good baseline and the measurable change may not be as apparent as those children who are GMFCS II. These findings agree in part with a previous study where two adults with ataxia showed improvement in their gait speed and gait pattern while using a mobility assistance dog rather than a walking aid. These clients would have reduced balance, difficulty with coordination and risk of falling as some of the main issues with their mobility (Abbud et al., 2014). The children of GMFCS level I and II who did not use a walking aid may have had some similar needs. Although they do not require a rigid walking aid such as a posterior walker for energy conservation and safety, they may require guidance and a lower level of rebalancing achieved through the dog via the handle.

8.3.3. Children with more impairment

Three children (participants 2, 4 and 7) showed negative change in the gait laboratory measures of gait speed, cadence and time in double support after 6 months. These same three children showed a lower level of physical activity at follow up. Kinematic data was variable but overall, their gait function appears to disimprove. Although this may be somewhat in line with their typical motor function progression at their specific level of impairment, as per the GMFM curve, for the purpose of energy conservation , perhaps the goal of walking with a dog is less suitable for these children. They did not gain the same QoL benefits. The parents reported that they generally benefitted socially from being seen with the dog, but there were reports of walking with the dog being too hard work. And perhaps therapy time may be better spent on more suitable functional tasks for their level of impairment.

8.3.4. Individual Differences

Overall children with physical impairments such as CP have complex needs and in this study, there are a variety of physical presentations. Children had baseline differences in motor ability, muscle tone, strength and joint contractures. The children had different home environments and different ideas of how the dog may help with their needs. Overall, all the families were satisfied with their child's progress with their dog , but more so, satisfied with the introduction of the dog to their family as a whole. Measurable change was seen in the children with less impairment (GMFCS I-II), children of GMFCS II had the most measurable gains, children of GMFCS I had other reported gains, perhaps not measured here. Possibly, there is scope to more accurately and objectively measure balance or upper body posture to reflect the reported gains. For some children who made physical gains in their gait parameters, these changes were asymmetric and the effect of walking with the dog consistently on one side should be followed up. If the side of the dog was alternated, this may allow for more symmetrical training effects.

Individual change was seen in those of GMFCS II (n=2), who showed positive change in GDI, gait speed and time in double support. These are children who are on the cusp of requiring a walking aid. They would have held a parent's hand when encountering obstacles and on longer walks. Both increased their activity levels and may have reaped the benefit of walking more with the dog. They may have achieved increased lower limb strength due to both increased quantity of walking, and increased muscle activation while not relying on a walking aid.

For children with CP GMFCS IV, the two children here enjoyed the social aspect of having the dog to a more positive effect. Both of these children enjoyed involving the dog in their regular physiotherapy and both parents reported that the dog motivated the child to do their therapy. This may be a learning point for those involved in the training and supply of the MADs: these children may be more suited to using a dog as a motivational tool rather than a physical aid.

8.3.5. Conclusions

To conclude, complementary insights from the different strands of data types show some make physical gains. Almost all children gain psychosocial benefits of a specially trained assistance dog. These findings may help providers of the therapy dogs to improve their service by training dogs to walk on both sides of the child and to more accurately identify children who would benefit from walking with a mobility assistance dog and those children who may gain more benefit from having a dog involved in their physiotherapy programme to make it more enjoyable and for the family to gain the psychosocial benefits of having a therapy dog.

9. Discussion

In this chapter, the results from each of the group studies and the individual case studies will be discussed. The mixed methods outcomes will be combined. Limitations of the study and areas for future work are outlined. Conclusions are drawn from the studies' results, in light of the aims of the thesis.

9.1.1. Introduction

Walking with a dog as a mobility aid for a child with a physical impairment is a very new concept. This study used a mixed methods approach to investigate if MADs introduced to children with physical or neurological impairments led to measurable benefits in their gait, physical activity levels and QoL. The existing literature relating to the specific area was somewhat limited. It was known that ADs have psychosocial benefits in adults with physical impairments. It is known that children with developmental disorders have QoL gains when using therapy dogs. There were small size studies which have shown that using a mobility dog may improve gait speed for an adult with a physical impairment (Abbud et al., 2014; Blanchet et al., 2013). However, the specific effects of a MAD for children with physical impairments is a new concept and thus a new research question.

9.1.2. Qualitative

In the qualitative component of the study, the group of ten parents perceived substantial benefits of mobility assistance dogs for their children. The themes which emerged were the perceived improved social interaction and inclusion; personal development; motivation instilled through the dog, improved physical mobility for children of GMFCS I-II; and finally, the positive effect the dog brought to the whole family. The themes of increased social interaction and the positive effect on the whole family is similar to findings found by Crowe et al where they found that children benefited socially and behaviourally from the introduction of a dog (Crowe et al., 2019). This study shows some similarity to findings in the Crowe et al study, with emerging themes in social confidence and personal growth gained through the dog, being described as more confident, having pride in the dog and having fewer tantrums. The reported physical gains in this study were due to the specific effect of the child walking with the dog as a mobility aid. This shows some agreement reported previously that children have increased mobility and independence with an assistance dog (Winkle et al., 2012), however the majority of studies in the review included task type dogs who would perform physical tasks for wheelchair users rather than helping with walking (Winkle et al., 2012).

9.1.3. Quality of Life

The QoL measurement tool showed clear benefits across QoL domains in this group of ten children. There were significant positive QoL changes measured in social-wellbeing and acceptance, feelings about functioning and emotional-wellbeing and self-esteem after six months of receiving a mobility assistance dog. Children with less impairment (GMFCS I-II) showed change in the above domains alongside participation and physical health after six months. Children with more impairment (GMFCS III-IV) showed no change. The improvements seen in domains involving social and emotional wellbeing are aligned with previous findings where a trained assistance dog, serving various functions, had a positive effect on social inclusion and perceived QoL in children with varied disabilities (Bibbo et al., 2019; Burgoyne et al., 2014; Crowe et al., 2019). Previous literature has reported that both trained assistance dogs and therapy dogs have positive effects on social communication in children with developmental disabilities (Crowe et al., 2019; Rramani, 2023). Although the QOL measurement tool measures parents' perceptions in parallel to the qualitative interviews, the data is converted to a numerical format for analysis and thus is appropriately treated as quantitative data. The QoL data largely agreed with the qualitative interviews, as there was both measurable and perceived gains in QOL domains after 6 months with the dog. This is somewhat expected as both types of data reflect the parents' perception of the benefits of the dog, whether defined as qualitative or quantitative data. The QoL tool showed measurable change in those with less impairment (GMFCS I-II), however those with more impairment (GMFCS III-IV) did not show the same benefit. This conflicts a little with previous findings in the review in 2020 by Rodriguez, where benefits were found across levels of impairment and across different types of therapy dogs (Rodriguez et al., 2020). However, none of these studies consisted of children using a dog as a walking aid. There is a possibility that walking with the dog is tiring and hard work for the children of GMFCS III-IV and for this reason they did not practice the walking training to the extent advised and thus did not reap the benefits of the MAD for their intended purpose. The QoL gains may be seen for those of GMFCS I-II as they have a better baseline walking ability and therefore were able to practice walking with the dog, enjoyed walking with the dog and reaped the benefits of the increased physical activity and general benefits of exercise such as improved mood and self-esteem. If the child is walking regularly with the dog they may gain more confidence in themselves physically, however if walking with the dog is too effortful, given the muscle fatigue associated with increasing level of impairment in CP (Verschuren et al., 2016), increased activity may be too energy consuming and cause musculoskeletal pain and fatigue.

9.1.4. Gait Analysis

Each child had their gait pattern measured prior to getting their dog and at six months follow up. For the group of 10 children there was no statistically significant change in any of the gait parameters measured, GDI, gait speed, cadence nor time in double support. There was no change when the group was divided by level of impairment. The group (n=10) showed a positive change in abdominal and left quadriceps strength, but those with more impairment (GMFCS level II-IV) showed no change at follow up. Children who completed a gait analysis while walking with their dog, showed little overall change in laboratory measures at follow up.

This somewhat conflicts with findings of Blanchet et al, where a mobility assistance dog increased walking speed in the timed up and go test and stair ascent (Blanchet et al., 2013), however this study was performed in adults with an established gait pattern, rather than growing children and did not look at the training effect of the dog over a period of time.

In a more recent study (Altman et al., 2021), video footage was used to measure upper limb and trunk joint angles while 16 adults walked both with and without their mobility dog. They found that the significant differences were found on the left elbow and shoulder abduction and left hip extension angles when walking with their dog on the left side. We found that there was asymmetrical change in the gait pattern (GDI and cadence) of some individuals: participants 3, 5 and 9 in particular showed asymmetric changes to the gait pattern, changes seen on the left side were not equal to changes on the right. There was a significant improvement in left quadriceps strength ($p<0.05$)*, not seen on the right. Monitoring of potential impacts of a mobility dog on asymmetry of the gait pattern may require follow up.

When reflection is given to the qualitative findings in light of this, most parents perceived that their children were walking ‘more upright’, ‘ more grounded, ‘less swaying’ and ‘looking up’ . There was little attention given to the child’s lower limb pattern in the interview data. Those children of GMFCS IV showed negative change in their overall gait analysis. These children walk for therapy only and are heavily reliant on a posterior walker for support to ambulate. Both children walk with reduced quality kinematics, described by low GDI. This is somewhat reflected in qualitative data where parents reported that walking with the dog was very tiring and sometimes the child does not want to do it (the walking).

9.1.5. Physical Activity

Participants had their physical activity measured over seven consecutive days before getting their dog, at one month after getting their dog and at three and six month follow up. Physical activity domains of step count, active minutes, cadence and level of activity intensity were measured using an ankle worn sensor, sensitive to impaired walking. The group (n=10) showed no statistically significant change in physical activity outcomes from pre-dog to six month follow up. Children with less impairment may increase the intensity of their physical activity after six months of having a MAD. Physical activity guidelines for people with CP, state that 60 minutes of moderate to vigorous physical activity per day is recommended and that sedentary behaviour is limited to no more than two hours per day (Verschuren et al., 2016). Introducing a MAD to these children may help encourage some people with CP to integrate this level of exercise into their daily life.

Qualitative data reflected that most children were more motivated to walk, more interested in walking but as a group, did not show a measurable improvement in their daily motor performance at the six month timepoint. However, qualitative interview data explained that inclement weather may have had an effect on physical activity. Most (9) children had their first data collection timepoint in the summer months and the six month timepoint in the winter months. In this scenario the qualitative data very much told the story of why the children did not show an increase in their physical activity levels, not captured by quantitative data alone.

9.1.6. Case Studies

Complementary insights from the different strains of data types show some children make physical gains. Almost all children gain psychosocial benefits of a specially trained assistance dog. Overall children with physical impairments such as CP have complex needs and, in this study, there are a variety of physical presentations. Children had baseline differences in motor ability, muscle tone, strength and joint contractures. The children had different home environments and different ideas of how the dog may help them. Overall, families were satisfied with their child's progress with their dog , but more so, satisfied with the introduction of the dog to their family as a whole. For the most part, each child met their intended goal or expectation of how the dog may help them. Measurable change was seen in the children with less impairment (GMFCS I-II), but not in children of GMFCS III-IV.

9.1.7. Qualitative and quantitative data compared.

Combining both types of data and interpreting the qualitative and quantitative findings as a single body of evidence, rather than treating them independently has been referred to as meta inference (Regnault et al., 2018). To understand a new phenomenon, combined methods were used to gain a larger picture of varied outcomes. The consideration of both qualitative and quantitative outcomes has been deemed as key to contextualising a participant experience within a clinically meaningful framework (Regnault et al., 2018). The use of mixed methods can also make best use of small sample sizes such as this. Integrating these methods allowed for a deeper understanding of the overall sentiment of how the introduction of a MAD may affect each child. Although quantitative data may provide statistical significance, qualitative data gives context and understanding behind the change and has been described as measuring what matters from a user perspective (Regnault et al., 2018). The comparison of qualitative and quantitative data outcomes are summarised in Figure 8-1 below.

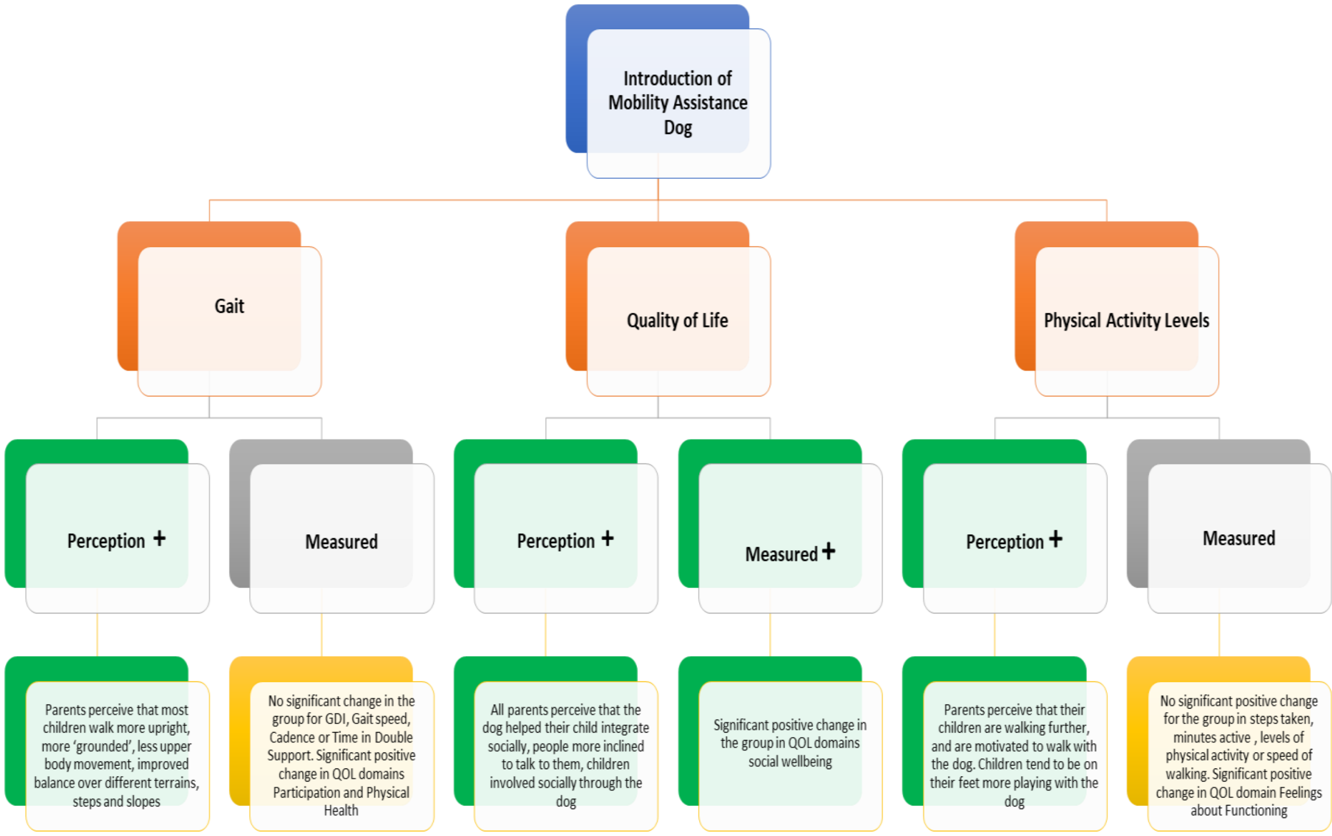


Figure 8-1: Comparison between qualitative and quantitative findings

The aims of the study were to measure the effect of a MAD on gait, QoL and physical activity in the group of ten children. The mixed methods approach found that parents perceived gait improvement, however this was not clearly measured for the group. Parents perceived QoL benefits for their children, and this was measured using the CPQoL and finally parents perceived that their children were walking further, were more motivated to go walking with the dog and tended to be on their feet more. This perceived increase in physical activity was not measured in the group, although measured data may have been affected by environmental factors.

9.1.8. Limitations to the study

There are limitations to this study. Firstly, it is a small sample size of ten children, quantifying statistical significance is limited and a larger sample would yield more robust results. The group of children vary widely in their level of impairment and thus are a heterogenous group, however they are representative of the variety of children who receive MADs from IDFD. Data collection and follow up was over a six month period and therefore, longer term outcomes are unknown. The study may have benefitted from a control group, however within the bounds of the timeframe of data collection and small number of children who receive dogs this was not achievable. All children had received a dog from the same assistance dog charity and there is also a possibility that families may have felt indebted to positive reporting due to their commitment to their own decision to get a dog, although all families were given ample opportunity to express challenges with the experience. Finally, inclement weather was reported as being a factor affecting physical activity levels by parents and the time of year varied for data capture. The first timepoint was during the summer for nine out of ten of the children and they may have been more active at this time and less active in the winter months when it was dark after school, as reported in qualitative interviews.

9.1.9. Impact of COVID-19

The data collection period for this research took place during the COVID-19 pandemic. All restrictions were adhered throughout the course of the study. Questions were included in qualitative interviews which gathered information of the perceived effects of the COVID-19 pandemic and restrictions on the data. Parents reported that overall, there was no effect on their child's training with their MAD. Some children were at home instead of at school during tightened restrictions, but parents reported that their physical activity levels did not change.

9.1.10. Clinical Implications

Based on the results of this preliminary study, there are findings which are of interest to both the trainers involved in the MAD programme, the parents of the families of children who received a dog and to the therapists involved in their care. This novel therapeutic area of receiving a MAD demonstrated positive QoL changes after six months for a group of ten children with impaired walking, particularly in children with mild walking impairment. The group showed a positive change in abdominal and left quadriceps strength, but those with more impairment (GMFCS level II-IV) showed no change at follow up. Parents perceive substantial gains from this novel training method for their children with walking challenges.

Providers of assistance dogs may use this finding to help streamline their approach to the training and supply of their dogs to the most suitable clients.

Results were highly individual, dependent on the child's baseline functional level. The providers of the dogs should consider each child's baseline functional level and individual goals when training and supplying MADs. This novel approach includes all aspects of the F-words (Rosenbaum & Gorter, 2012) as outlined in the ICF, working towards participation, function and longer term QoL. The MAD is reported as fun, includes family, may improve function and fitness for some children and the child receives a positive response from their friends. Therefore, it may be of interest to therapists involved in their care, for specific goal setting incorporating ICF principles. This study developed a core outcome set to measure the multifactorial impact of the introduction of a MAD to a group of children with physical and neurological impairments. This methodology can be readily replicated.

9.1.11. Future Work

These preliminary findings highlight the need for future research in children who receive MADs. For more robust conclusions, this would include analysing longer term effects of the dog, including gathering data over a full calendar year to allow for changes in weather/seasons. It would be of benefit to analyse a larger sample size of children, particularly those of GMFCS I-II, as this would help to draw clearer conclusions from the benefits of the dog on the gait pattern and physical activity levels of the children. In qualitative interviews, parents perceive benefits in their child's balance, posture and head position ("looking up") and there is potential to objectively measure these attributes in particular, using upper body motion analysis. In the interviews, parents described the dogs facilitating the child to negotiate different terrains, slopes and obstacles with more ease and independence than their typical walking aid. This would benefit from follow up objective measurement.

10. Conclusions

- Introducing a mobility assistance dog to a group of ten children did not show measurable benefit in their gait pattern, measured by the gait deviation index, gait speed, cadence or time in double support after six months. However, clinically meaningful positive changes were observed in individual cases.
- Introducing a mobility assistance dog to a group of ten children does not show measurable benefit to physical activity levels after six months, in areas of step count, active minutes and cadence, for the group as a whole. Children with less impairment (GMFCS I-II) spent more time at a higher level of physical activity intensity after six months, compared to children of GMFCS III-IV. Clinically meaningful positive changes in step count, active minutes and cadence were observed in individual cases.
- There are measurable changes in quality of life domains in the group of ten children after six months with their mobility assistance dog, as reported by their parent. The group showed positive change in domains of *social-wellbeing and acceptance*, *feelings about functioning* and *emotional-wellbeing and self-esteem* after six months of receiving a mobility assistance dog. Children with less impairment (GMFCS I-II) showed change in the above domains and *participation and physical health* after six months. A nuance found, was that after one month there was in increase in the domain *pain and impact of disability*.
- Parents perceive considerable benefits for their children in quality of life, physical activity levels and physical mobility from having a mobility assistance dog for six months.
- Individual case studies show substantial overall benefits for some children, in quality of life and motivation to be more physically active.
- Results are highly individual and environmental factors such as the weather affected measurable physical activity levels.

10.1. Thesis statement

Introducing a mobility assistance dog to children with physical and neurological impairments aged 6-12 leads to measurable benefits in quality of life after six months but does not lead to measurable change in gait or physical activity for a group of ten children. Individual case studies show substantial overall benefits for some children, in quality of life and motivation to be physically active.

References

Abbud, G., Janelle, C., & Vocos, M. (2014). The Use of a Trained Dog as a Gait Aid for Clients with Ataxia: A Case Report. *Physiotherapy Canada*, *66*(1), 33-35. https://doi.org/10.3138/ptc.2013-17

Aliyu, M. M. (2019). Rights of Persons Living with Disabilities under the Discrimination against Persons with Disabilities (Prohibition) Act 2018. *IJOCLLEP*, *1*, 112.

Altman, K., Glumm, S., Stainton, K., Herlache-Pretzer, E., Webster, S., & Winkle, M. Y. (2021). Impacts of Mobility Dogs on Kinematics during Ambulation: A Quantitative Study. *Veterinary Sciences*, *8*(11), 250.

Assistance Dogs International Summary of Standards 2024. (2024).

Audrestch, H. M., Whelan, C. T., Grice, D., Asher, L., England, G. C., & Freeman, S. L. (2015). Recognizing the value of assistance dogs in society. *Disabil Health J*, *8*(4), 469-474. https://doi.org/10.1016/j.dhjo.2015.07.001

Bania, T. A., Taylor, N. F., Baker, R. J., Graham, H. K., Karimi, L., & Dodd, K. J. (2014). Gross motor function is an important predictor of daily physical activity in young people with bilateral spastic cerebral palsy. *Developmental Medicine & Child Neurology*, *56*(12), 1163-1171.

Begnoche, D. M., Chiarello, L. A., Palisano, R. J., Gracely, E. J., McCoy, S. W., & Orlin, M. N. (2016). Predictors of independent walking in young children with cerebral palsy. *Physical Therapy*, *96*(2), 183-192.

Bell, K. J., Õunpuu, S., DeLuca, P. A., & Romness, M. J. (2002). Natural progression of gait in children with cerebral palsy. *Journal of Pediatric Orthopaedics*, *22*(5), 677-682.

Berry, A., Borgi, M., Francia, N., Alleva, E., & Cirulli, F. (2013). Use of assistance and therapy dogs for children with autism spectrum disorders: a critical review of the current evidence. *J Altern Complement Med*, *19*(2), 73-80. https://doi.org/10.1089/acm.2011.0835

Bibbo, J., Rodriguez, K., & O'Haire, M. E. (2019). Impact of Service Dogs on Family Members'
Psychosocial Functioning. *The American Journal of Occupational Therapy*, *73*(3).

Biddle, S. J., & Asare, M. (2011). Physical activity and mental health in children and adolescents: a review of reviews. *British journal of sports medicine*, *45*(11), 886-895.

Bjornson, K. F., Belza, B., Kartin, D., Logsdon, R., & McLaughlin, J. F. (2007). Ambulatory Physical Activity Performance in Youth With Cerebral Palsy and Youth Who Are Developing Typically. *Physical Therapy*, *87*(3), 248-257. https://doi.org/10.2522/ptj.20060157

Bjornson, K. F., & McLaughlin, J. F. (2001). The measurement of health-related quality of life (HRQL) in children with cerebral palsy. *European Journal of Neurology*, *8*, 183-193. https://doi.org/ DOI: 10.1046/j.1468-1331.2001.00051.x

Bjornson, K. F., Yung, D., Jacques, K., Burr, R. L., & Christakis, D. (2012). StepWatch stride counting: accuracy, precision, and prediction of energy expenditure in children. *Journal of Pediatric Rehabilitation Medicine*, *5*(1), 7-14.

Blanchet, M., Gagnon, D. H., Vincent, C., Boucher, P., Routhier, F., & Martin-Lemoyne, V. (2013). Effects of a mobility assistance dog on the performance of functional mobility tests among ambulatory individuals with physical impairments and functional disabilities. *Assist Technol*, *25*(4), 247-252. https://doi.org/10.1080/10400435.2013.810183

Bohannon, R. W. (2018). Reliability of manual muscle testing: A systematic review. *Isokinetics and Exercise Science*, *26*(4), 245-252. https://doi.org/10.3233/ies-182178

Bradley, E. (2022). Impact of Mobility Dog Assistance on Gait Patterns.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*, 77-101.

Braun, V., & Clarke, V. (2014). What can "thematic analysis" offer health and wellbeing researchers? *Int J Qual Stud Health Well-being*, *9*, 26152. https://doi.org/10.3402/qhw.v9.26152

Burgoyne, L., Dowling, L., Fitzgerald, A., Connolly, M., J, P. B., & Perry, I. J. (2014). Parents' perspectives on the value of assistance dogs for children with autism spectrum disorder: a cross-sectional study. *BMJ Open*, *4*(6), e004786. https://doi.org/10.1136/bmjopen-2014-004786

Carcreff, L., Gerber, C. N., Paraschiv-Ionescu, A., De Coulon, G., Newman, C. J., Aminian, K., & Armand, S. (2020). Comparison of gait characteristics between clinical and daily life settings in children with cerebral palsy. *Scientific Reports*, *10*(1). https://doi.org/10.1038/s41598-020-59002-6

Carlon, S., Shields, N., Yong, K., Gilmore, R., Sakzewski, L., & Boyd, R. (2010). A systematic review of the psychometric properties of Quality of Life measures for school aged children with cerebral palsy. *BMC Pediatr*, *10*, 81. https://doi.org/10.1186/1471-2431-10-81

Carlon, S. L., Taylor, N. F., Dodd, K. J., & Shields, N. (2013). Differences in habitual physical activity levels of young people with cerebral palsy and their typically developing peers: a systematic review. *Disabil Rehabil*, *35*(8), 647-655. https://doi.org/10.3109/09638288.2012.715721

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public health reports*, *100*(2), 126.

Chaput, J. P., Willumsen, J., Bull, F., Chou, R., Ekelund, U., Firth, J., Jago, R., Ortega, F. B., & Katzmarzyk, P. T. (2020). 2020 WHO guidelines on physical activity and sedentary behaviour for children and adolescents aged 5-17 years: summary of the evidence. *Int J Behav Nutr Phys Act*, *17*(1), 141. https://doi.org/10.1186/s12966-020-01037-z

Clark, V. L. P., & Creswell, J. W. (2008). *The mixed methods reader*. Sage.

Colver, A., Rapp, M., Eisemann, N., Ehlinger, V., Thyen, U., Dickinson, H. O., Parkes, J., Parkinson, K., Nystrand, M., Fauconnier, J., Marcelli, M., Michelsen, S. I., & Arnaud, C. (2015). Self-reported quality of life of adolescents with cerebral palsy: a cross-sectional and longitudinal analysis. *Lancet*, *385*(9969), 705-716. https://doi.org/10.1016/S0140-6736(14)61229-0

Cresswell, J. (2013). Qualitative inquiry & research design: Choosing among five approaches.
.
Creswell, J. W., Fetters, M. D., & Ivankova, N. V. (2004). Designing a mixed methods study in primary care. *The Annals of Family Medicine*, *2*(1), 7-12.

Crowe, T. K., Deitz, J. C., Winkle, M. Y., Nelson, R. A., & Woolf, J. (2019). Effects of Partnerships between Adolescents with Developmental Disabilities and Service Dogs. *The Open Journal of Occupational Therapy*, *7*(1). https://doi.org/doi.org/10.15453/2168-6408.1520

Damiano, D. L. (2006). Activity, activity, activity: rethinking our physical therapy approach to cerebral palsy. *Phys Ther*, *86*(11), 1534-1540. https://doi.org/10.2522/ptj.20050397

Damiano, D. L., & Abel, M. F. (1996). Relation of gait analysis to gross motor function in cerebral palsy. *Developmental Medicine & Child Neurology*, *38*(5), 389-396.

Davis, B. W., Nattrass, K., O'Brien, S., Patronek, G., & MacCollin, M. (2015). Assistance dog placement in the pediatric population: Benefits, risks, and recommendations for future application. *Anthrozoös*, *17*(2), 130-145. https://doi.org/10.2752/089279304786991765

Davis, E., Shelly, A., Waters, E., & Davern, M. (2010). Measuring the quality of life of children with cerebral palsy: comparing the conceptual differences and psychometric properties of three instruments. *Developmental Medicine & Child Neurology*, *52*(2), 174-180.

Davis, E., Waters, E., Mackinnon, A., Reddihough, D., Graham, H. K., Mehmet-Radji, O., & Boyd, R. (2006). Paediatric quality of life instruments: a review of the impact of the conceptual framework on outcomes. *Developmental medicine and child neurology*, *48*(4), 311-318.

Debuse, D., Gibb, C., & Chandler, C. (2009). Effects of hippotherapy on people with cerebral palsy from the users' perspective: a qualitative study. *Physiother Theory Pract*, *25*(3), 174-192. https://doi.org/10.1080/09593980902776662

Deutz, U., Heussen, N., Weigt-Usinger, K., Leiz, S., Raabe, C., Polster, T., Daniela, S., Moll, C., Lucke, T., Krageloh-Mann, I., Hollmann, H., & Hausler, M. (2018). Impact of Hippotherapy on Gross Motor Function and Quality of Life in Children with Bilateral Cerebral Palsy: A Randomized Open-Label Crossover Study. *Neuropediatrics*, *49*(3), 185-192. https://doi.org/10.1055/s-0038-1635121

Downs, J., Blackmore, A. M., Epstein, A., Skoss, R., Langdon, K., Jacoby, P., Whitehouse, A. J. O., Leonard, H., Rowe, P. W., & Glasson, E. J. (2017). The prevalence of mental health disorders and symptoms in children and adolescents with cerebral palsy: a systematic review and meta-analysis. *Developmental Medicine & Child Neurology*, *60*(1), 30-38. https://doi.org/10.1111/dmcn.13555

Elmaci, D. T., & Cevizci, S. (2015). Dog-assisted therapies and activities in rehabilitation of children with cerebral palsy and physical and mental disabilities. *Int J Environ Res Public Health*, *12*(5), 5046-5060. https://doi.org/10.3390/ijerph120505046

Fishman, G. A. (2003). When your eyes have a wet nose: the evolution of the use of guide dogs and establishing the seeing eye. *Surv Ophthalmol*, *48*(4), 452-458. https://doi.org/10.1016/s0039-6257(03)00052-3

Friesen, L. (2010). Exploring animal-assisted programs with children in school and therapeutic contexts. *Early Childhood Education Journal*, *37*, 261-267.

Gage, J. R., Deluca, P. A., & Renshaw, T. S. (1995). Gait analysis: principles and applications. *JBJS*, *77*(10), 1607-1623.

Gage, J. R., Schwartz, M. H., Koop, S. E., & Novacheck, T. F. (2009). *The identification and treatment of gait problems in cerebral palsy* (Vol. 180). John Wiley & Sons.

Guinet, A.-L., Khouri, N., & Desailly, E. (2020). Clinical gait analysis and physical examination don’t correlate with physical activity of children with cerebral palsy. Cross-sectional study. *International Biomechanics*, *7*(1), 88-96. https://doi.org/10.1080/23335432.2020.1812429

Hanna, S.E., Rosenbaum, P.L., Bartlett, D.J., Palisano, R.J., Walter, S.D., Avery, L. and Russell D.J. (2009), Stability and decline in gross motor function among children and youth with cerebral palsy aged 2 to 21 years. Developmental Medicine & Child Neurology, 51: 295-302. https://doi.org/10.1111/j.1469-8749.2008.03196.x

Harvey, A. R. (2017). The gross motor function measure (GMFM). *Journal of physiotherapy*, *63*(3), 187-187.

Herlache-Pretzer, E., Winkle, M. Y., Csatari, R., Kolanowski, A., Londry, A., & Dawson, R. (2017). The impact of service dogs on engagement in occupation among females with mobility impairments: a qualitative descriptive study. *International Journal of Environmental Research and Public Health*, *14*(6), 649.

Ishikawa, S., Kang, M., Bjornson, K. F., & Song, K. (2013). Reliably measuring ambulatory activity levels of children and adolescents with cerebral palsy. *Arch Phys Med Rehabil*, *94*(1), 132-137. https://doi.org/10.1016/j.apmr.2012.07.027

Jones, R. A., Hinkley, T., Okely, A. D., & Salmon, J. (2013). Tracking physical activity and sedentary behavior in childhood: a systematic review. *Am J Prev Med*, *44*(6), 651-658. https://doi.org/10.1016/j.amepre.2013.03.001

Joyner, M. (2022). Fatigue and functionality in cerebral palsy. *Developmental Medicine & Child Neurology*, *65*(4), 447-448. https://doi.org/10.1111/d mcn.15472

Keawutan, P., Bell, K. L., Oftedal, S., Davies, P. S., Ware, R. S., & Boyd, R. N. (2017). Habitual physical activity in children with cerebral palsy aged 4 to 5 years across all functional abilities. *Pediatric Physical Therapy*, *29*(1), 8-14.

Kiernan, D., & Malone, A. (2024). Age related progression of lower limb coordination during gait in children with cerebral palsy without a history of surgical intervention. *Journal of Biomechanics*, *171*. https://doi.org/10.1016/j.jbiomech.2024.112206

Kiernan, D., O’Sullivan, R., Malone, A., O’Brien, T., & Simms, C. K. (2017). Pathological Movements of the Pelvis and Trunk During Gait in Children With Cerebral Palsy: A Cross-Sectional Study With 3-Dimensional Kinematics and Lower Lumbar Spinal Loading. *Physical Therapy*, *98*(2), 86-94. https://doi.org/10.1093/ptj/pzx113

King, A. P., & Eckersley, R. (2019). *Statistics for biomedical engineers and scientists: How to visualize and analyze data*. Academic Press.

Krautwurst, B. K., Dreher, T., & Wolf, S. I. (2016). The impact of walking devices on kinematics in patients with spastic bilateral cerebral palsy. *Gait Posture*, *46*, 184-187. https://doi.org/10.1016/j.gaitpost.2016.03.014

Lee, B.-H. (2017). Relationship between gross motor function and the function, activity and participation components of the International Classification of Functioning in children with spastic cerebral palsy. *Journal of physical therapy science*, *29*(10), 1732-1736.

Lemmon, M. E., Huffstetler, H. E., & Reeve, B. B. (2020). Measuring Health-Related Quality of Life in Pediatric Neurology. *J Child Neurol*, *35*(10), 681-689. https://doi.org/10.1177/0883073820923809

Lindsay, S., & Thiyagarajah, K. (2021). The impact of service dogs on children, youth and their families: A systematic review. *Disabil Health J*, *14*(3), 101012. https://doi.org/10.1016/j.dhjo.2020.101012

Maher, C. A., Williams, M. T., Olds, T., & Lane, A. E. (2007). Physical and sedentary activity in adolescents with cerebral palsy. *Developmental Medicine & Child Neurology*, *49*(6), 450-457.

Makris, T., Dorstyn, D., & Crettenden, A. (2021). Quality of life in children and adolescents with cerebral palsy: a systematic review with meta-analysis. *Disabil Rehabil*, *43*(3), 299-308. https://doi.org/10.1080/09638288.2019.1623852

McCullagh, R., Dillon, C., O'Connell, A. M., Horgan, N. F., & Timmons, S. (2017). Step-Count Accuracy of 3 Motion Sensors for Older and Frail Medical Inpatients. *Arch Phys Med Rehabil*, *98*(2), 295-302. https://doi.org/10.1016/j.apmr.2016.08.476

McCune, S., Esposito, L., & Griffin, J. A. (2017). Introduction to a thematic series on animal assisted interventions in special populations. In (Vol. 21, pp. 136-138): Taylor & Francis.

McCune, S., Kruger, K. A., Griffin, J. A., Esposito, L., Freund, L. S., Hurley, K. J., & Bures, R. (2014). Evolution of research into the mutual benefits of human–animal interaction. *Animal Frontiers*, *4*(3), 49-58.

Mentiplay, B. F., & Clark, R. A. (2018). Modified conventional gait model versus cluster tracking: Test-retest reliability, agreement and impact of inverse kinematics with joint constraints on kinematic and kinetic data. *Gait & Posture*, *64*, 75-83. https://doi.org/10.1016/j.gaitpost.2018.05.033

Modlin, S. (2001). From puppy to service dog: Raising service dogs for the rehabilitation team. *Rehabilitation Nursing Journal*, *26*(1), 12-17.

Mudge, S., Stott, N. S., & Walt, S. E. (2007). Criterion validity of the StepWatch Activity Monitor as a measure of walking activity in patients after stroke. *Arch Phys Med Rehabil*, *88*(12), 1710-1715. https://doi.org/10.1016/j.apmr.2007.07.039

Novak, I., Morgan, C., Fahey, M., Finch-Edmondson, M., Galea, C., Hines, A., Langdon, K., Namara, M. M., Paton, M. C. B., Popat, H., Shore, B., Khamis, A., Stanton, E., Finemore, O. P., Tricks, A., te Velde, A., Dark, L., Morton, N., & Badawi, N. (2020). State of the Evidence Traffic Lights 2019: Systematic Review of Interventions for Preventing and Treating Children with Cerebral Palsy. *Current Neurology and Neuroscience Reports*, *20*(2), 3. https://doi.org/10.1007/s11910-020-1022-z

O'Brien, T. (2001). *A Manual of Gait Analysis*.

O'Sullivan, R., French, H. P., Van Rossom, S., Jonkers, I., & Horgan, F. (2021). The association between gait analysis measures associated with crouch gait, functional health status and daily activity levels in cerebral palsy. *J Pediatr Rehabil Med*, *14*(2), 227-235. https://doi.org/10.3233/PRM-200676

Odom, S., & Buysse, V. S., E. (2011). Inclusion for Young Children with Disabilities: A Quarter Century of Research Perspectives. *Journal of Early Intervention*, *33*(4), 344-356.

Oskoui, M., Majnemer, A., Dagenais, L., & Shevell, M. I. (2013). The relationship between gross motor function and manual ability in cerebral palsy. *J Child Neurol*, *28*(12), 1646-1652. https://doi.org/10.1177/0883073812463608

Osoba, D., Bezjak, A., Brundage, M., Zee, B., Tu, D., Pater, J., & Quality of Life Committee of the, N. C. (2005). Analysis and interpretation of health-related quality-of-life data from clinical trials: basic approach of The National Cancer Institute of Canada Clinical Trials Group. *Eur J Cancer*, *41*(2), 280-287. https://doi.org/10.1016/j.ejca.2004.10.017

Palisano R, R. P., Walter S, Russell D, Wood E, Galuppi B. (1997). Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol*, *39*(4), 214-223. https://doi.org/ DOI: 10.1111/j.1469-8749.1997.tb07414.x

Perry, J., & Burnfield, J. (2024). *Gait Analysis: Normal and Pathological Function*. CRC Press.

Pistrang, N., & Barker, C. (2012). Varieties of qualitative research: A pragmatic approach to selecting methods.

Portney, L. G. (2009). Foundations of clinical research: applications to practice. *Upper Saddle River/PearsonPrentice Hall*.

Rapp, M., Eisemann, N., Arnaud, C., Ehlinger, V., Fauconnier, J., Marcelli, M., Michelsen, S. I., Nystrand, M., Colver, A., & Thyen, U. (2017). Predictors of parent-reported quality of life of adolescents with cerebral palsy: A longitudinal study. *Res Dev Disabil*, *62*, 259-270. https://doi.org/10.1016/j.ridd.2016.12.005

Regnault, A., Willgoss, T., Barbic, S., & Group, I. S. f. Q. o. L. R. M. M. S. I. (2018). Towards the use of mixed methods inquiry as best practice in health outcomes research. *Journal of patient-reported outcomes*, *2*(1), 19.

Rintala, D. H., Matamoros, R., & Seitz, L. L. (2008). Effects of assistance dogs on persons with mobility or hearing impairments: a pilot study. *J Rehabil Res Dev*, *45*(4), 489-503. https://doi.org/10.1682/jrrd.2007.06.0094

Rodriguez, K. E., Greer, J., Yatcilla, J. K., Beck, A. M., & O'Haire, M. E. (2020). The effects of assistance dogs on psychosocial health and wellbeing: A systematic literature review. *PLoS One*, *15*(12), e0243302. https://doi.org/10.1371/journal.pone.0243302

Rondeau, L., Corriveau, H., Bier, N., Camden, C., Champagne, N., & Dion, C. (2010). Effectiveness of a rehabilitation dog in fostering gait retraining for adults with a recent stroke: A multiple single-case study. *NeuroRehabilitation*, *27*(2), 155-163. https://doi.org/10.3233/nre-2010-0592

Rosenbaum, P. (2007). A report: the definition and classification of cerebral palsy *Dev Med Child Neurol*.

Rosenbaum, P., & Gorter, J. W. (2012). The 'F-words' in childhood disability: I swear this is how we should think! *Child Care Health Dev*, *38*(4), 457-463. https://doi.org/10.1111/j.1365-2214.2011.01338.x

Rosenbaum, P. L., Walter, S. D., Hanna, S. E., Palisano, R. J., Russell, D. J., Raina, P., Wood, E., Bartlett, D. J., & Galuppi, B. E. (2002). Prognosis for gross motor function in cerebral palsy: creation of motor development curves. *Jama*, *288*(11), 1357-1363.

Ross, S. A., & Engsberg, J. R. (2007). Relationships between spasticity, strength, gait, and the GMFM-66 in persons with spastic diplegia cerebral palsy. *Archives of physical medicine and rehabilitation*, *88*(9), 1114-1120.

Rowland, J. L., Fragala-Pinkham, M., Miles, C., & O'Neil, M. E. (2015). The scope of pediatric physical therapy practice in health promotion and fitness for youth with disabilities. *Pediatr Phys Ther*, *27*(1), 2-15. https://doi.org/10.1097/PEP.0000000000000098

Rramani, V. A. (2023). THE EFFECT OF DOG THERAPY ON CHILDREN WITH DISABILITIES. *EDUCATION–Journal of Educational Research*, *5*(9-10), 289-295.

Rutkowska, I., Bednarczuk, G., Molik, B., Morgulec-Adamowicz, N., Marszałek, J., Kaźmierska-Kowalewska, K., & Koc, K. (2015). Balance functional assessment in people with visual impairment. *Journal of human kinetics*, *48*(1), 99-109.

Ryan, J. M., Hensey, O., McLoughlin, B., Lyons, A., & Gormley, J. (2014). Reduced Moderate-to-Vigorous Physical Activity and Increased Sedentary Behavior Are Associated With Elevated Blood Pressure Values in Children With Cerebral Palsy. *Physical Therapy*, *94*(8), 1144-1153. https://doi.org/10.2522/ptj.20130499

Ryan, J. M., Hensey, O., McLoughlin, B., Lyons, A., & Gormley, J. (2015). Associations of Sedentary Behaviour, Physical Activity, Blood Pressure and Anthropometric Measures with Cardiorespiratory Fitness in Children with Cerebral Palsy. *PLoS One*, *10*(4). https://doi.org/10.1371/journal.pone.0123267

Sachs-Ericsson, N., Hansen, N. K., & Fitzgerald, S. (2002). Benefits of assistance dogs: A review. *Rehabilitation Psychology*, *47*(3), 251-277. https://doi.org/10.1037//0090-5550.47.3.251

Sandelowski, M. (2010). What's in a name? Qualitative description revisited. *Res Nurs Health*, *33*(1), 77-84. https://doi.org/10.1002/nur.20362

Schwartz, M. H., & Rozumalski, A. (2008). The gait deviation index: A new comprehensive index of gait pathology. *Gait & Posture*, *28*(3), 351-357. https://doi.org/10.1016/j.gaitpost.2008.05.001

Shelly, A., Davis, E., Waters, E., Mackinnon, A., Reddihough, D., Boyd, R., Reid, S., & Graham, H. K. (2008). The relationship between quality of life and functioning for children with cerebral palsy. *Dev Med Child Neurol*, *50*(3), 199-203. https://doi.org/10.1111/j.1469-8749.2008.02031.x

Shimmell, L. J., Gorter, J. W., Jackson, D., Wright, M., & Galuppi, B. (2013). "It's the participation that motivates him": physical activity experiences of youth with cerebral palsy and their parents. *Phys Occup Ther Pediatr*, *33*(4), 405-420. https://doi.org/10.3109/01942638.2013.791916

Smyth, C., & Slevin, E. (2010). Experiences of family life with an autism assistance dog. *Learning disability practice*, *13*(4).

Tashakkori, A., & Creswell, J. (2007). The new era of mixed methods (Vol. 1, pp. 3-7). In: Sage Publications.

Tepfer, A., Ross, S., MacDonald, M., Udell, M. A. R., Ruaux, C., & Baltzer, W. (2017). Family Dog-Assisted Adapted Physical Activity: A Case Study. *Animals (Basel)*, *7*(5). https://doi.org/10.3390/ani7050035

Tong, A., Sainsbury, P., & Craig, J. (2007). Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International Journal for Quality in Health Care;*, *19*, 349--357.

Verschuren, O., Peterson, M. D., Balemans, A. C., & Hurvitz, E. A. (2016). Exercise and physical activity recommendations for people with cerebral palsy. *Dev Med Child Neurol*, *58*(8), 798-808. https://doi.org/10.1111/dmcn.13053

Viau, R., Arsenault-Lapierre, G., Fecteau, S., Champagne, N., Walker, C.-D., & Lupien, S. (2010). Effect of service dogs on salivary cortisol secretion in autistic children. *Psychoneuroendocrinology*, *35*(8), 1187-1193.

Waters, E., Davis, E., Mackinnon, A., Boyd, R., Graham, H. K., Kai Lo, S., Wolfe, R., Stevenson, R., Bjornson, K., Blair, E., Hoare, P., Ravens-Sieberer, U., & Reddihough, D. (2007). Psychometric properties of the quality of life questionnaire for children with CP. *Developmental medicine and child neurology*, *49*, 49-55.

Whitmarsh, L. (2009). The Benefits of Guide Dog Ownership. *Visual Impairment Research*, *7*(1), 27-42. https://doi.org/10.1080/13882350590956439

Whittle, M. W. (2014). *Gait analysis: an introduction*. Butterworth-Heinemann.

WHOQoL, G. (1994). The development of the World Health Organization quality of life assessment instrument (the WHOQOL). Quality of Life Assessment: International Perspectives: Proceedings of the Joint-Meeting Organized by the World Health Organization and the Fondation IPSEN in Paris, July 2–3, 1993,

Winkle, M., Crowe, T. K., & Hendrix, I. (2012). Service dogs and people with physical disabilities partnerships: a systematic review. *Occup Ther Int*, *19*(1), 54-66. https://doi.org/10.1002/oti.323

Wyrwich, K., W., & Warinski, F., D. (2000). Identifying meaningful intra-individual change standards for health-related quality of life measures. *Journal of Evaluation in Clinical Practice*, *6*, 39-49.

Zabihaylo, C., Couturier, J.-A., Termoz, N., & Prince, F. (2005). Analysing the postural and gait behaviour of a person with retinitis pigmentosa travelling with a guide dog. *International Congress Series*, *1282*, 767-771. https://doi.org/10.1016/j.ics.2005.05.037

Appendix A. Participant Information Leaflet for parent or guardian.

Participant Information Leaflet

Title of Study: An examination of the effect of mobility assistance dogs on activity levels, gait and quality of life in children with physical and neurological impairments.

Site	**Trinity College Dublin**
Principal Investigator(s) and Co-Investigator(s) (insert names, titles and contact details)	**Professor Ciaran Simms, csimms@tcd.ie 01 8963768** **Heather Curtin , Senior Physiotherapist and Research Masters Student hkenned@tcd.ie 087 6316422** **Dr Michelle Spirtos, spirtosa@tcd.ie 0877552362** **Professor Richard Reilly, reillyri@tcd.ie 018961000**
Study Organiser/ Sponsor (if applicable)	**Dogs for the Disabled**
Data Controllers	**Trinity College Dublin**
Data Protection Officer	**Data Protection Officer** **Secretary's Office** **Trinity College Dublin** **Dublin 2**

You and your child are invited to take part in a research study which is being completed by Trinity College Dublin. Professor Ciaran Simms is the principal investigator and Heather Curtin is the lead researcher. Before you decide whether or not you wish you and your child to take part, please read this information sheet carefully. We have attached an information sheet for your child also. Ask Ciaran or Heather any questions. Don't feel rushed or under pressure to make a quick decision. You should understand the risks and benefits of taking part in this study so that you can make a decision that is right for you. You may wish to discuss it with your family, friends or GP.

Part 1 – The Study

Why is this study being done?

- This study is being done to explore the potential impact of mobility assistance dogs on children's patterns of walking, balance, leg strength and quality of life. The study will gather assessments before your child gets their mobility assistance dog and then one month, three months and six months later.
- We are doing this study to understand better the effects of using a mobility assistant dog with children who have physical or neurological challenges.

Why have I been invited to take part?

- You and your child have been invited to participate in this study because your child has a physical or a neurological impairment and is on the list for receiving a mobility assistance dog.
- We aim to involve 10 children and their parents who are receiving mobility assistance dogs.
- We are only including children who have not been in receipt of a mobility assistance dog before

Do I have to take part? Can I withdraw?

- Your participation and that of your child is entirely voluntary.
- If you chose <u>not</u> to be involved in the study this will have no adverse consequences and will not affect your receipt of a mobility assistance dog or any other services through Dogs for the Disabled.
- You can decide to withdraw from the study at any time during the study. As there are only 10 children taking part in the study, we would need to keep any data already collected up until that point, as its removal would affect the quality of the research. Please also note, that once data is analysed, it cannot be withdrawn as it will be pooled with all other data.
- If you wish to withdraw contact Ciaran Simms on 01-896376

How will the study be carried out?

It is expected that 10 children and their parents will take part in the study. You have received this information leaflet because your child is on the list for receipt of a mobility assistance dog. This study involves gathering information from you and your child before your child receives their mobility assistance dog, and then at one month, three months and six months following your receipt of the dog. The study will gather information in relation to your child's mobility, balance, strength and quality of life. It will also gather your perceptions of the impact of the mobility assistance dog on your child and your family. The majority of the study will take place at a place suitable to you. It does involve two visits to the gait analysis laboratory in the Central Remedial Clinic, Clontarf, Dublin.

What will happen to me if I decide to take part?

1. If you decide to take part in this study, you will meet a member of the research

2. team.
3. You and your child will be asked to attend the Central Remedial Clinic, Clontarf, Dublin for a gait analysis which will measure your child's gait pattern, their balance and their leg muscle strength. You and your child will be asked to attend the Central Remedial Clinic one more time for a gait analysis after they have had their dog for six months.
4. Your child will be asked to wear an **activity monitor** at different times:
    - The week before they receive their dog your child will wear an activity level tracker which will be attached by a strap to either your child's thigh or ankle. This will measure time spent walking and the number of steps they take.
    - You will keep an activity diary during this week.
    - Your child will wear the activity monitor for one more week after they have their assistance dog for one month, three months and six months.
    - You will keep the activity diary at one month, three months and six months.
5. We will ask you to complete a short semi-structured interview with a member of the research time prior to your child getting their mobility assistance dog at, one month, three months and six months following receipt of the dog. The questions in this interview will be about your perceptions of the mobility assistance dog prior to getting it and after getting it will be about your experiences with the dog and your perceptions of change/or not in your child's walking and their participation and in activities.
6. You will be asked to complete a short quality of life questionnaires in relation to your child prior to receiving the dog, one month, three months and six months following receiving the dog. You will also be asked to assist your child in completing a short child-focused questionnaire.
7. The gait analysis will take place in the Central Remedial Clinic. All other appointments will be completed at a time and place of convenience to you.
8. The flow chart below shows what will happen with you and your child if you choose to participate.

Before receiving mobility assistance dog

- Child wears an activity monitor for one week
- Parent completes activity log of week
- Parent and child complete quality of life questionnaire
- Semi- structured interview with parent
- Gait analysis (gait analysis, balance and strength measurements)

One month following receipt of mobility assistance dog

- Child wears an activity monitor for one week
- Parent completes activity log of week
- Parent and child complete quality of life questionnaire
- Parent interview

Three months following receipt of mobility assistance dog

- Child wears an activity monitor for one week
- Parent completes activity log of week
- Parent and child complete quality of life questionnaire
- Parent interview

Six months following receipt of mobility assistance dog

→

- Child wears an activity monitor for one week
- Parent completes activity log of week
- Parent and child complete quality of life questionnaire
- Parent interview
- Gait analysis (gait analysis, balance and strength measurements)

The two visits to the Central Remedial Clinic will involve the Gait Analysis and can also combine the interview with you as the parent. This visit should last about one hour.

What will happen to my Data?

- On registering with the study, you and your child will be assigned a case number, and this will be the only identifier stored with the information you provide in the interviews and questionnaires and with your child's data from their gait analysis, balance assessments, strength assessments, activity monitor and questionnaire.
- This data from your child which does not contain identifying information will be combined with the data from the other children and parents participating.
- The combined data from all the participants will be shared with Dogs for the Disabled.
- The results of analysing the data in this study will likely be published in peer reviewed journals and may also be shared through Dogs for the Disabled.
- The data which has been pseudonymised (identifying information removed) will be kept secure by being stored on an encrypted laptop and password protected desktops. Only the research team will have access to the data.

Are there any benefits to taking part in this research?

- There is currently a lack of scientific information which can tell us what the impact is of mobility assistance dogs with children. Through taking part in this study your data and that of your child can inform future service development in this area.
- The direct benefit to you is that you will have information about the impact of having

a mobility assistance dog.

Are there any risks to me or others if I take part?

- There are no risks to your child from participating in the study. It is possible that by talking about the challenges which your child may be experiencing that you may experience distress. If this is the case you can either take a break in the interview, ask to finish the interview on a different day or discontinue participating in the interview.
- There is a low risk that your participation in the study will be connected to the study due to the small number of children who receive mobility assistance dogs. However, only pseudonymised data will be used and the results of all the children participating will be presented together.

Will I be told the outcome of the study? Will I be told the results of any tests or investigations performed as part of this study that relate to me?

A summary of the overall study findings will be provided to you on completion of the study.

- The findings of the study for your child in relation to their activity and gait can be provided to you on your request.
- A summary of the overall study findings will be provided to you on completion of the study.
- The study findings will also be disseminated at academic conferences and in academic journals. Dogs for the Disabled may present the findings. No information which reveals your identity will be disclosed.

Part 2 – Data Protection

What information about me and my child (personal data) will be used as part of this study? Will my medical records be accessed?

In order to contact you for the completion of study assessments you will need to provide your first name and telephone number to the lead researcher.

The only identifiable information collected in relation to your child will be your child's first name, age, and medical diagnosis.

Your child and you will be assigned a code, and this will be used by the research team, (instead of you or your child's name) for analysing the information you provide in the questionnaires.

The link which matches you and your child's identification code, and you and your child's first name will be kept in a separate locked cabinet to the research data, and then destroyed after seven years. No other parties will have access to this code.

The consent form signed by you will be kept in a locked cabinet for a period of 7 years and then destroyed.

Will my personal data be kept confidential? How will my data be kept safe?

- The key code will be kept in a locked cabinet.
- The consent form will also be kept in a locked cabinet for seven years and then destroyed.
- A **Data Protection Impact Assessment** was carried out and the risk was considered very low.
- All the persons involved in carrying out this research project are bound by professional codes of secrecy or contractual codes of secrecy that will protect your confidentiality.
- **Training in data protection law** and practice has been completed by the individuals involved in carrying out the research.

What is the lawful basis to use my personal data?

By law,[6] we can use your personal information for scientific research[7] (in the public interest[8]). We will also ask for your explicit consent to use your data as a requirement of the Irish Health Research Regulations.

[6] The European General Data Protection Regulation (GDPR)
[7] *Article 9(2) (j))*
[8] *(Article 6(1)(e)*

What are my rights in relation to my and my child's personal data?

You and your child are entitled to receive a copy of your data in a portable format and to have it transferred to another data controller.

You can exercise these rights by contacting your study principal investigator, Ciaran Simms, csimms@tcd.ie or the Trinity College Data Protection Officer, Secretary's Office, Trinity College Dublin, Dublin 2, Ireland. Email: dataprotection@tcd.ie. Website: www.tcd.ie/privacy.

Part 3 – Costs, Funding and Approval

Has this study been approved by a research ethics committee?

Yes, this study has been approved by TCD Faculty of Health Sciences Research Ethics Committee. Approval was granted on 20/01/2021.

Who is organising and funding this study? Will the results be used for commercial purposes?

This research is being carried out by The School of Engineering and The School of Medicine, Trinity College Dublin. Funding for completion of the study was provided by Dogs for the Disabled who are funding a student stipend and two years of fees for Masters' student. However, Dogs for the Disabled are not involved in the data collection or analysis and do not have any influence over the results or access to your specific data. On successful completion of the study, the student (Heather Curtin) will receive a Masters through Research. There is no payment for recruitment of participants and the results will not be disclosed for commercial purposes.

Is there any payment for taking part? Will it cost me anything if I agree to take part?

No, we are not paying patients to take part in the study. However, you will receive reimbursement for reasonable travel expenses for the two visits to the Central Remedial Clinic.

Part 4 – Future Research

Will my personal data be used in future studies? (May not apply)

We will not use your personal data and that of your child in any future studies.
The aggregate anonymised data may be used for future research in this area. You and your child will not be identifiable from any use of this anonymised data.

Part 5 – Further Information

Who should I contact for information or complaints?

If you have any concerns or questions, you can contact:

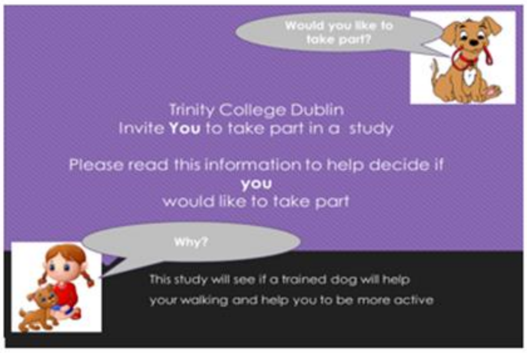
- Principal Investigator: Ciaran Simms, csimms@tcd.ie, 01-8963768.
- Data Protection Officer, Trinity College Dublin: Data Protection Officer, Secretary's Office, Trinity College Dublin, Dublin 2, Ireland. Email: dataprotection@tcd.ie. Website: www.tcd.ie/privacy.

Under GDPR, if you are not satisfied with how your data is being processed, you have the right to lodge a complaint with the Office of the Data Protection Commission, 21 Fitzwilliam Square South, Dublin 2, Ireland. Website: www.dataprotection.ie.

Will I be contacted again?

If you would like to take part in this study, you will be asked to sign the Consent Form on the next page. You will be given a copy of this information leaflet and the signed Consent Form to keep.

Appendix B. Child Friendly Information Leaflet



Appendix C. Trinity College Dublin Ethics Confirmation

Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Ollscoil Átha Cliath | The University of Dublin

Heather Curtin,
Central Remedial Clinic,
Vernon Avenue,
Clontarf,
Dublin 3

31st March 2021

Ref: 210106

Title of Study: An examination of the effect of mobility assistance dogs on activity levels, gait and quality of life in children with physical and neurological impairments

Dear Heather,

Further to a meeting of the Faculty of Health Sciences Ethics Committee held in January 2021. We are pleased to inform you that the above project has ethical approval to proceed.

This study has been ethically approved. We would advise you to seek review and comments on your DPIA from the DPO if required prior to study commencement'

As a researcher you must ensure that you comply with other relevant regulations, including DATA PROTECTION and HEALTH AND SAFETY.

Yours sincerely,

Prof. Jacintha O'Sullivan
Chairperson
Faculty Research Ethics Committee

Dámh na nEolaíochtaí Sláinte
Foirgneamh na Ceimice,
Coláiste na Tríonóide,
Ollscoil Átha Cliath,
Baile Átha Cliath 2, Éire.

Faculty of Health Sciences
Chemistry Building,
Trinity College Dublin,
The University of Dublin,
Dublin 2, Ireland.

www.healthsciences.tcd.ie

Appendix D. Central Remedial Clinic Research Ethics Confirmation

CRC
Central Remedial Clinic
AN LÁRCHLINIC FEABHAIS

Registered Office Address: Foirgneamh Penny Ansley, Ascaill Vernon, Cluain Tarbh, Baile Átha Cliath 3, D03 R973, Éire.
Penny Ansley Memorial Building, Vernon Avenue, Clontarf, Dublin 3, D03 R973, Ireland.
Tel/Fon: +353 (0) 1 854 2200 Web: www.crc.ie

11th February 2021

Heather Curtin
Senior Physiotherapist,
Gait Laboratory
Central Remedial Clinic

Ref: CRC Ethics approval 12105

Dear Heather

I am delighted to tell you that the Central Remedial Clinic Ethics Committee has considered and approved your ethics application for your research study "The effects of mobility training dogs on activity levels, gait and quality of life in children with cerebral palsy". The gait analysis will take place in the CRC gait analysis laboratory.

Please state on any correspondence with the participants that ethical approval has been given by the CRC Ethics Committee and ensure that the CRC Privacy Notice for Research is provided for all participants.

We look forward to reading your research and results

Kind regards

Trish MacKeogh

Trish MacKeogh
CRC Research Ethics Committee

Appendix E. Consent Forms

Parent/Guardian Consent Form

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

STUDY NAME: An exploration of the effect of mobility assistance dogs on activity levels, gait and quality of life in children with neurological and physical impairments.   **Centre ID:**   **Identification Number for study:**

There are 2 sections in this form. Each section has statements and asks you to tick if you agree. **Please ask <u>any</u> questions you may have when reading each of the statements.** **Thank you for participating.** **The end of this form is for the researchers to complete.**	
1. General	**Tick box**
I confirm I have read and understood the **Information Leaflet** for the above study. The information has been fully explained to me and I have been able to ask questions, all of which have been answered to my satisfaction.	
I understand that this study **is entirely voluntary. If I decide that I do not want to take part or decide that I want myself and my child to stop taking part in this study that I can do so at any time without giving a reason**. I understand that deciding not to take part will not affect my present or future services with Dogs for the Disabled.	
I understand that all information will be kept private and confidential and that my name or that of my child will not be disclosed.	

I understand that I **will not be paid for taking part in this study**[9].	
I know how to contact the research team if I need to.	
I agree to take part in this research study having been fully informed of the **risks, benefits and alternatives** which are set out in full in the information leaflet which I have been provided with.	
I agree to being contacted by researchers by phone/online as part of this research study.	
2. Data processing	**Tick box**
I understand that only the principal investigator and the student will have access to any personal data collected for this study, and that this will not be shared with any third parties as described in the Information leaflet.	
I understand that the benefit to me and my child will be to understand further the impact of mobility assistance dogs. I understand that **results from analysis of my personal information will not be given to me**.	
I understand that **I can stop taking part in this study** at any time without giving a reason and this will not affect my future services with Dogs for the Disabled.	
I consent to the use of my and my child's personal data for this study, as described in the information leaflet.	
I have discussed the child information leaflet with my child and I confirm that they have given their verbal assent (or written assent) to take part in the study.	

Patient Name (Block Capitals)   Participant Signature   Date

____

-- --

Witness Name (Block Capitals) Witness Signature Date

To be completed by the Principal Investigator or nominee.

I, the undersigned, have taken the time to fully explain to the above patient the nature and purpose of this study in a way that they could understand. I have explained the risks and possible benefits involved. I have invited them to ask questions on any aspect of the study that concerned them.

I have given a copy of the information leaflet and consent form to the participant with contacts of the study team.

(Signature)

____

Prof Ciaran Simms (Principal Investigator)/ Heather Curtin (Lead Researcher)

Head of School of Engineering/MSc Student

Date: __________________

| | |

2 copies to be made: 1 for participant, 1 for PI.

Child Assent Form

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

STUDY NAME: An exploration of the effect of mobility assistance dogs on activity levels, gait and quality of life in children with neurological and physical impairments.
Centre ID:
Identification Number for study:

Please ✓ tick the box if you agree. **Ask if you do not understand**	
1. General	**Tick box**
I have read the **Information Leaflet** for the above study. The information has been fully explained to me and I have been able to ask questions, and the answers were explained.	
I understand that this study it is my choice to do this study**.** I understand I can choose to not take part at any time. I understand that deciding not to take part will not affect my relationship with Dogs for the Disabled.	
I understand that all information will be kept private.	
I understand that I **will not be paid for taking part in this study**[10].	

I know how to contact the research team if I need to.	
I agree to take part in this research study having been fully informed of the **risks and activities involved** which are explained in the information leaflet which I have given.	
I agree to being contacted by researchers by phone/online as part of this research study.	
2. Data processing	**Tick box**
I understand that only Heather Curtin will have access to any of my details collected for this study, and that this will not be shared with anyone else.	
I understand this study will help understand further how mobility assistance dogs help children like me. I understand that **results from analysis of the information will not be given to me**.	
I understand that **I can stop taking part in this study** at any time without giving a reason and this will not affect my future services with Dogs for the Disabled.	
I will allow the use of my data for this study, as described in the information leaflet.	
My parents/guardians have discussed the information leaflet with me, and I consent to be being part of this study.	

Patient Name (Block Capitals) Participant Signature Date

---   --

Witness Name (Block Capitals)   Witness Signature   Date

To be completed by the Principal Investigator or nominee.

I, the undersigned, have taken the time to fully explain to the above patient the nature and purpose of this study in a way that they could understand. I have explained the risks and possible benefits involved. I have invited them to ask questions on any aspect of the study that concerned them.

I have given a copy of the information leaflet and consent form to the participant with contacts of the study team.

(Signature)

____

Prof Ciaran Simms (Principal Investigator)/ Heather Curtin (Lead Researcher)

Head of School of Engineering/MSc Student

Date

| | |

2 copies to be made: 1 for participant, 1 for PI.

Appendix F. Gait Analysis Cluster Protocol

Gait Analysis using the Codamotion Clusters and Pelvic Wand Protocol

Heather Curtin February 2022

Marker and Model Set

The full lower body gait analysis consists of 26 markers.

The position of clusters are described in figure 1 below.

The following table summarises marker identities:

Table F-1: Summary of marker identities

Name	Identity	Name	Identity	Name	Identity	Name	Identity
R.Thigh.0	5	R.Thigh.1	6	R.Thigh.2	7	R.Thigh.3	8
R Shank.0	9	R Shank.1	10	R Shank.2	11	R Shank.3	12
L Thigh.0	21	L Thigh.1	22	L Thigh.2	23	L Thigh.3	24
L Shank.0	25	L Shank1.	26	L Shank.2	27	L Shank.3	28
R. Foot.0	15	R. Foot.1	16	R. Foot.2	17	R. Foot.3	
L.Foot.0	18	L.Foot.1	19	L.Foot.2	20	L.Foot.3	
R. Sacral Wand	2	R.PSIS	13	R.ASIS	14		
L.Sacral Wand	1	L.PSIS	3	L.ASIS	4		

Once all markers have been placed onto the subject, it is important to check that they all are in the correct position. It is very easy to swap the markers identities on the feet by connecting the marker plug into the wrong marker drive box socket, or to place the right thigh cluster on the left thigh and vice versa. An easy way to check the marker placement is to ask the participant to stand in the middle of the field of view (in general on the force plate) and check the name of the markers in the 3D view, when the system is streaming the data on live mode.

Gait Analysis Workflow

Gait analysis must follow a specific workflow, where the different stages must be done in sequence. As well as capturing the gait data, the user will need to check a number of important parameters such as the placement of the different events (initial contact [IC], toe off [TO] and the end of the terminal swing phase [TSE]) or the foot assignment to the force plate. This guide outlines step by step how to perform a gait analysis, from the marker placement to the edition of the report.

The workflow of the protocol implies 5 stages:

1. System setup (Alignment, preparation of markers and testing wands)
2. Preparation of the subject (collect subject information, place wands and markers),
3. Input subject details into ODIN
4. Pointer Static acquisition
5. Dynamic trial acquisitions
6. Data processing

System Set Up

There are many key steps in collecting "routine" motion capture data. The first step consists of verifying the system itself. Firstly, make sure that the different systems are turned on. Then verify the position and orientation of the different sensors by performing an alignment (CX1 units, force plates …). Secondly, launch ODIN, choose the protocol "Coda-Sol_Gait.KK_LB_C.Ptr.P_1.00" and then connect ODIN to the hardware server. After performing an alignment (if required), check that the force plates are correctly identified in ODIN (check position and force vector). Perform a force offset if required. Thirdly, place the different clusters, pelvic wand and marker drive boxes on the floor in view of the Coda Units and check that they are visible by the system.

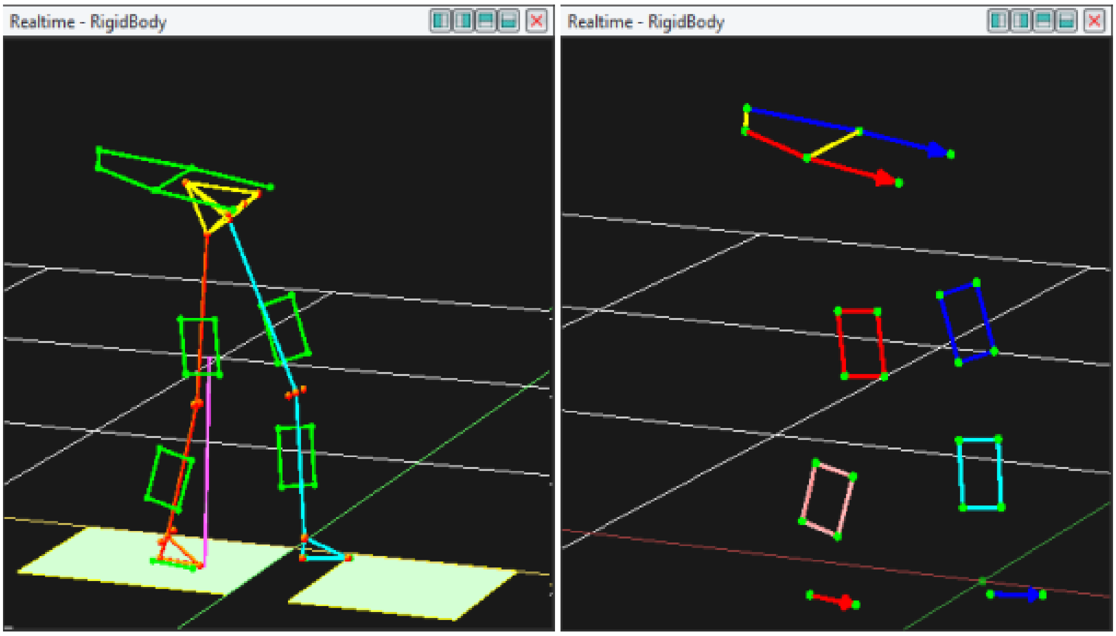
Preparation of the subject

Anthropometric data that is required by the software to create the human model is already collected from conventional gait model. The anthropometric measurements required are as follows: - Pelvic width (distance between the left and right ASIS) - Pelvic depth (distance between the ASIS and PSIS) - - Patient height (m) and weight (kg) Then prepare the patient with the relevant wearable systems (EMG, gait wands, pelvic wand and markers). Make sure the leg wands are correctly aligned. Clusters should be placed on the anterolateral aspect of the respective limb segment. Bands to hold clusters should be at the largest point of the muscle bulk to prevent slippage. Double sided tape can be placed on the inside of the cluster plates to prevent the cluster moving. All wires connected to the marker box should be tidied out of view of the LEDs. Colour coding of boxes with coloured tape may help with ease of use and reduce room for error.

Once all markers have been placed on the subject, it is important to do a real-time check, to see that they all are in the correct position. The stick figure should appear as shown in

Figure F-0-1. Use the Realtime - Rigid Body view in the “00a - Real-time Display” Layout to check the stick figure. It is very easy to swap the marker identities on the feet for example by connecting the markers to the wrong marker drive box socket or to swap the left and right foot marker drive boxes around for example.

Figure F-0-1: Real-time View Check



To check the marker placement, ask the patient to stand in the middle of the field of view (in general on the force plate) and check the name of the markers from the 3D view when the system is streaming the data in live mode. The “Realtime – Raw Markers” view is very convenient for this. The stick figure displays different sets of colours for the different devices. Arrows are also displayed to indicate which direction the device is orientated. The left femoral wand is indicated by a dark blue stick figure; the right femoral wand with a red stick figure; the left tibial wand with a turquoise stick figure; the right tibial wand with a pink stick figure; the left foot with a dark blue stick figure; the right foot with a red stick figure. All arrows are pointing anteriorly. If the patient is not able to stand in the field on their own for long enough for the experimenter to see, then data can be streamed for a short period of time. The stick figure will remain visible in the 3D view after streaming has been stopped.

Record subject details on ODIN.

Once the system and marker identities have been carefully checked, enter the subject details into the ambient ODIN workspace. The subject details are subject ID, patient gender, subject weight and height, pelvic width and depth, sacral offset, and knee and ankle widths.

Pointer and Static Acquisitions

The protocol contains 14 pointer landmarks which must be acquired before performing the acquisition of the walking trials. To do so, click on “hardware / Acquire Pointer ...”. A prompt window will appear displaying the name of the landmark that the experimenter needs to digitize. Once the landmark is digitized correctly, the name will change from yellow to green then the name of the next one will automatically appear on the display and the system will wait for it to be digitized. If an acquisition failed, ODIN would display the text in red and will inform the user of the failure reason. You can simply retry the acquisition and the name will turn green once it has successfully acquired the landmark. The protocol also contains one static acquisition, this is simply an acquisition of the position of all of the markers, it requires the experimenter to click the pointer trigger while the participant stands with all markers visible to the CX1 unit(s) until the static acquisition writing turns green.

Dynamic Trial Acquisitions

Capture the number of required trials for your experiment by clicking on the record button. The trials are automatically saved into the database. ODIN will automatically increment the repetition label for the next trial to be recorded. Not the quality and type of walk such as Fast/barefoot/AFOs etc on a capture sheet.

Processing the data

As mentioned previously, processing the data requires different steps which must be done in a specific order. The first step consists of checking which foot touched the force plate(s) Defining which foot touched the force plate ODIN has a python script which automatically assigns which foot touched the force plate (when force plates are used) however it is highly recommended to check the results in case the script didn’t assign left and right correctly. The script checks the position of the CoP (Centre of Pressure) and the position of the feet. If the force plate is touched by one foot at a time, then the script automatically determines that the foot which has touched the force plate is the foot closest to the CoP. The script will automatically set the foot as “unknown” if the force plate has been touched by two feet at the same time. In cases where the closest foot position is not above the force plate the foot will also be assigned automatically as “unknown”. To run the script, simply double click on the script called “01 Force Assignment” or right click on the “01 Force Assignment” and choose “Run Script ...” as shown in Figure F-0-2.

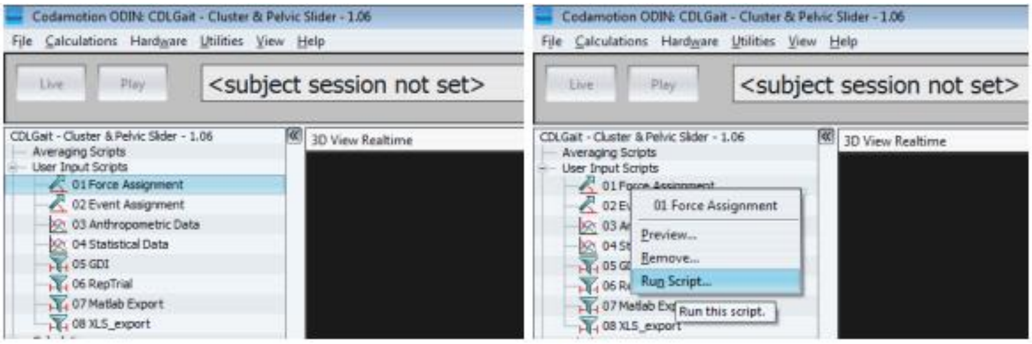


Figure 3: running the "Force" script

Figure F-0-2: Running of the “Force” script.

Defining the gait events

Once the force has been assigned to the left or right foot, the data can be used to automatically set the initial contact (IC) and the toe off (TO) events (when force plate(s) are used). To run the script, simply double click on the script called “02 Event Assignment” or right click on the “02 Event Assignment” and choose “Run Script ...” as shown below.

The script will only identify the IC and TO events using the force plate data therefore the end of Terminal Swing phase (TSE) needs to be manually inserted. In the same way, the user can decide to manually define a cycle where no force plate was involved in the cycle. In this situation, the calculated joint moments and powers will be wrong because no force data will be considered in the equation. However, the user can still use the joint angles and compare them with cycles where the force plate was touched by the right or left foot. As previously, the script will run on every trial present in the trial list. Once the script has run, select the next layout “02a – Left set gait events”. This layout is designed to help you to manually set all the remaining left events. Note that if the system only contains one force plate and if that force plate has been touched by the right foot therefore all three left events must be defined (IC, TO and TSE; see below). To define a left event, place the cursor at the correct position then right-click and navigate through “Create trial events / left” and choose the corresponding event (as shown below). Note that the stick figure can be moved and used to help the user to identify the events. Pressing on the “x” key when the stick figure is activated will set the stick figure projection view orthogonal and parallel to the sagittal plane. Once all left events have been defined on the first trial, select the next trial and define all remaining events and etc. Once all left events have been defined for all trial present in the trial list, select the next layout “02b – Right set gait events” and proceed to identify all remaining right gait events on every trial in the trial list in the same way as the left events.

Calculation of the Anthropometric parameters: The calculations of joint moments and power require a certain number of anthropometric data from the patient (length of the different segments and inertial properties: segmental centre of mass positions, segmental masses, radius of gyration). They are two different options /scripts for the calculation of the inertial properties in the protocol. Script 1: “03 Anthropometric Data [Auto]” By using the script “03 Anthropometric data”, Odin directly calculates the segmental lengths using the position of the different joint centres recorded during the walking trials. Then the inertial properties are calculated using the calculated lengths and the Jensen table (R. K. Jensen. “Changes in segment inertia proportions between 4 and 20 years.” J Biotech 22 (1989): 529-536). First select the next layout “03 Subject Data” and check that the following information is specified in every trial: Subject Height (m), Subject Weight (Mass in kg), Subject Gender.

This information is required to compute the inertial properties therefore the script will fail if it is launched without specifying the information. Once all the information has been specified for every trial, simply run the script “03 Anthropometric Data [Auto]”. Executing the script will compute the inertial properties and the results will be displayed on the different tables of the layout.
In some cases, the script can fail to compute the segment lengths (e.g. if the visibility of the pelvis in the cycle is poor). For such a case, we strongly recommend using the second script: “03 Anthropometric Data (manual setting of Segment Lengths)”. Script 2: “03 Anthropometric Data [manual]”. As previously mentioned, it might be possible that Odin can’t calculate the segment lengths using the marker data. In that case, the user can measure the segment lengths directly on the patient, then report them into the trials, and then run the script “03 Anthropometric Data [Manual]”. First select the next layout “03 – Subject Data” and check that the following information is specified in every trial: Subject Height (m), Subject Weight (Mass in kg), Subject Gender. To report the length of the segments, select the first trial of the list, and then fill table with the values as show below.

Once the values are set, save the file “file / save all” and open the bulk edit trial parameter function “File / Bulk Edit Trial Parameters” to copy the values to the other trials.

Select the six required parameters to copy “Footlight”, “RFootLength”, “LShankLength”, “RShankLength”, “Highlight”, and “RThighLength”. Please note that the parameters are sorted by “Name”. Then select the trials you want the value to be copied and click on “OK”. The values will be automatically copied to all selected trials.

The last step consists of running the script “03 Anthropometric Data [Manual]”. The inertial properties are calculated using the measured lengths and the Jensen table. The results will be displayed on the different tables of the layout.

Calculation of the Statistical Data The kinematic and kinetic data combined with events can be used to calculate statistical data such as steps or stride length / time or joint range of motion... Those data are calculated when running the script “04 Statistical Data” and the result can be visualised by selecting the next layout “04 – Statistical Data”. The results are displayed in different table as shown below:
Note that you must define the gait events on at least one cycle on each side. If not, the script will fail and because Odin tries to run the calculation on each trial in turn, starting at the top of the list (i.e., not just on the selected trial), if it fails on any trial, the sequence stops, and the calculation is not attempted on subsequent trials.

Chapter 2 Visualising the data Once the calculation of the statistical data has been performed the user is able to see all the different results by selecting different layouts. The layouts “05 – Sagittal Joint Angles” and “05b – All Sagittal Joint Angles” are dedicated to the visualisation of the hip, knee and ankle Euler angles. The first one shows the results of the current selected trial and the second one shows the results of all trials. The layout “06 – Sagittal Joint Moment”, “07 – Sagittal Joint Power” are used to display the hip, knee and ankle joint moment and power. Chapter 3 Generating a report 1. Generating a report with Odin A report can be generating in order to present all result in an editable word document. To generate a report, simply select “Utilities / Generate Report ...”

Then select the trial you want to use for generating the report, give a name to the report, select the template, and then click on “ok”. The generation of the report can take several seconds. A waiting message will pop up as shown below: Once the process finished the report is accessible in the “C:/Codamotion/Odin/reports/xxx” folder, where xxx refers to the report name chosen during the export process. The folder contains one Word document (“01 Cycle Symmetry - v1.0.docm”), one xml document (motionreport.xml) and many different pictures. Open the report by double clicking on the “01 Cycle Symmetry - v1.0.docm” word document. This document contains VBA macro therefore you might need to activate the macro in order to see the results. All fields and graph will correspond to the metadata and graph displayed in ODIN. The document contains an editable “medical section” that can be manually edited in the document. Odin is only capable of generating the pictures for a report of a single trial. A highly modular software has been developed for users who desire to create a multi-trials report. This software has been developed with python, making it easy to use and modifiable by the user. 2. Generating a report with the “Report Generator Software” As mentioned above, a highly modular python software has been developed for the users that wish to customise reports. This software comes with predefine template matching our own Word template, but the user can set their own. Documentation of the various python functions is available on request. For instructions on how to use this software, please refer to the user manual entitled “Report Generator Software’’.

Appendix G. Activity Monitor Validation

This section was completed as a subsection of Chapter 7. The activity monitor used in the study was validated for use in the cohort, for accuracy of step count, prior to use in the study.

Title

Criterion Validity of the Stepwatch Activity Monitor to measure step count accuracy in children with cerebral palsy.

Introduction

Cerebral palsy (CP) is a clinical diagnosis which describes a range of disorders due to injury to the developing brain often manifesting as difficulties with movement and posture [Rosenbaum 2007]. It is the most common cause of motor deficiency in young children and has been reported to occur in 2.1 per 1000 live births (Osko Ui et al., 2013). The severity of motor impairment is measured using the Gross Motor Function Classification Scale (GMFCS) ranging from level I-IV. Children with CP participate in significantly lower levels of physical activity than their peers, and less than recommended guidelines (Carlen et al., 2013). Knowledge of patterns of physical activity in children with CP may help healthcare professionals monitor activity levels. A number of activity monitors are available for this this purpose. Gait patterns in cerebral palsy include impairments in gait parameters such as a slow walking speed and short stride length. There are biomechanical differences from typical including transverse plane abnormalities such as in toeing gait, this may make it more difficult for some activity monitors to measure step count if there is a severely impaired pattern.

The most common methods used for assessment of physical activity in research are self-report instruments and movement sensors. Movement sensors using accelerometery measure ambulatory activity in a person's usual environment. Activity monitors are small unobtrusive microprocessors worn for continuous monitoring usually at one body site, which can be on the wrist, back or on a lower limb. . There are many devices available that are able to record data for extended periods, to provide an objective measure of a person's performance .The Stepwatch Activity Monitor (SAM) a is an example of an accelerometer-based activity monitor that has been used widely in different population groups. It is small (75x50x20mm) and lightweight (38g) and is worn at the ankle. The monitor contains a triaxial sensor that uses a combination of acceleration, position, and timing to detect steps. The Stepwatch is calibrated based on each person's height and gait pattern, and the threshold can be adjusted for patients with altered gait patterns.

Interventions, surgery, and rehabilitation strategies for children with CP are often focused on enhancing walking and functional ability (ref). Until recently, outcomes to capture the effectiveness of these interventions have been primarily measures of mobility that were collected within laboratory and clinical settings. Advances in accelerometery technology, transfer of data, and processing software now allow the clinician and researcher the ability to quantify walking and physical activity within the context of daily life.

Modus Healthcare's Stepwatch has been shown to be valid in some clinical populations and shows good reliability with other movement sensors (Bjornson et al., 2012). Although validation has been established in impaired gait, such as in a frail elderly population (McCullagh et al., 2017). The particular validation studies in children with CP were performed specifically in treadmill walking. Although the Stepwatch has been widely used in studies to measure physical activity in children with CP (Bjornson 2007, Nicholson 2018,)and described as accurate compared to other monitors, the device has yet to be clearly validated in overground walking in this population including those with severely impaired gait patterns (CAPIO 2010). The Stepwatch offers advantages over other monitors due to reported wearability and ease of use. However, validity must be established to use this monitor in children with CP across GMFCS levels in overground walking.
Stepwatch measures physical activity intensity as it counts the number of steps over a given time interval. It is worn on the ankle and may be used for long-term step monitoring. The data reflect both minute-by-minute variations in step activity and a cumulative measure of steps over a period of time.
The aim of the study is to determine accuracy of the Stepwatch for the measurement of step count compared to the gold-standard video/3-d motion analysis captured data, in children with CP while walking over ground.

Methods
The study is composed of a cross sectional study design. Ethical approval was obtained from the Central Remedial Clinic (CRC) ethical committee. Children with CP aged 4-18 and associated walking impairment attending for gait analysis were invited to take part in the study. The children's parents/guardians were given an information leaflet (see Appendix) about the study when they arrived for gait analysis. A convenience sample of 13 children was recruited. Informed parental consent and child assent was obtained for all participants. All children had a gait analysis according to the CRC Gait Laboratory protocol. Following routine 3D gait analysis, the Stepwatch activity monitor was applied above the lateral malleolus on the dominant limb. A ten-step verification was performed as described by the manufacturers. Participants wore their typical footwear including orthoses and used

their typical walking aids that they use for daily walking. The participant was instructed to walk at their self-selected speed along a 9 metre walkway 6 times with a 5 second rest in between each walk trial as previously described (Mudge et al., 2007). Video recording was used as a gold standard criterion of step count as previously described (McCullagh et al., 2017). Two researchers were involved in data collection and data analysis. Three-dimensional kinematic data were concurrently collected by a four camera Codamotion sensors (200hz). However, subsequently this data were not used as the 3d gait analysis data is processed for one stride only. The six laps of the 9m walkway would include an acceleration and deceleration at the ends of the walkway and therefore was not deemed comparable to the video data for step count of concurrent data. Percentage error is calculated using the following formula [(monitor step count – video step count/ video step count) x 100]. Video step count was correlated with Stepwatch step count. A positive value indicates overcounting by the Stepwatch and a negative value indicates undercounting.

Data were uploaded to IBM SPSS Statistics Version 28 (Armonk, NY: IBM Corp) for analysis. Pearson's correlation was calculated to assess the level of association between the Stepwatch and the criterion standard (video). A correlation coefficient of above 0.85 was deemed as acceptable (McCullagh et al., 2017; Mudge et al., 2007). For the purpose of calculating the video step count, a step was defined as "a definite foot displacement with movement of body mass into a new position", this would not include pivoting in turns or sliding the foot along the floor. Two researchers analysed the video recordings separately, beginning with the video recordings, and resolved any disagreements by analysing them together to reach a consensus. The video recordings were analysed first, when the researchers were blind to the motion sensors' measurements. The first researcher is a senior physiotherapist in the gait laboratory and the second researcher was a student physiotherapist. Data were tested for normality and parametric tests were used to analyse data.

Results

Thirteen children participated in the study; they are described in table 1.

Table G-1: Participant details, step count and percentage error

Participant no	Diagnosis	GMFCS	Leg SW worn	Aids used	Steps video	Steps SW	% error
1	CP spastic bilateral	III	R	PKW	93	93	0.0
2	CP unilateral right	I	L	none	65	63	3.1

3	CP spastic bilateral	III	L	PKW	116	119	-2.6
4	Central Core Myopathy	I	R	none	71	78	-9.9
5	CP Left unilateral	I	R	none	73	74	-1.4
6	CP spastic bilateral	IV	R	PKW	54	49	9.3
7	CP Spastic bilateral	III	R	PKW	59	59	0.0
8	CP right unilateral	I	L	none	75	75	0.0
9	CP left unilateral	II	R	none	76	81	-6.6
10	CP left unilateral	II	R	none	76	74	2.6
11	CP left unilateral	I	R	none	74	73	1.4
12	CP right unilateral	II	L	none	79	77	2.5
13	CP right unilateral	I	L	none	62	63	-1.6

CP: Cerebral Palsy PKW: Posterior Kaye Walker; GMFCS : Gross Motor Function Classification Scale. GMFCS levels: Level I: Walks without limitations; Level II: Walks with limitations; Level III: Walks using a handheld mobility device; Level IV: Self mobility with Limitations; May use Powered Mobility; Level V: Transported in a Manual Wheelchair (Palisano et al 2008).

Table 2 gives descriptive statistics of step count for the group.

Table G-2: Mean and SD for the group.

Descriptive Statistics

	Mean	Std. Deviation	N
Steps Video	74.85	15.837	13
Steps Stepwatch	75.23	17.162	13

For the group (n=13) Mean video step count was 74.9 (SD 15.8); mean Stepwatch step count was 75.2 (SD 17.2)

Table G-3: Correlation of Video and Stepwatch Step count

Correlations

	steps video count 2	Steps SW

steps video count 2	Pearson Correlation	1	.985**
	Sig. (2-tailed)		<.001
	N	13	13
Steps SW	Pearson Correlation	.985**	1
	Sig. (2-tailed)	<.001	
	N	13	13

**. Correlation is significant at the 0.01 level (2-tailed).

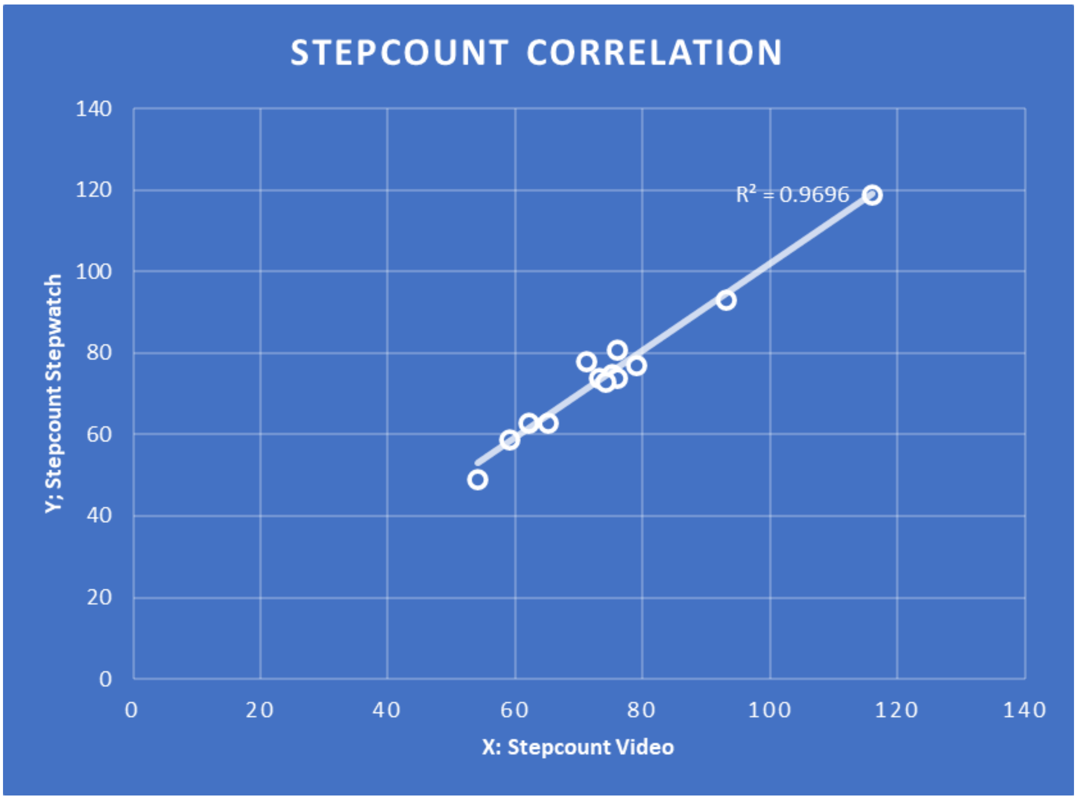


Figure G-0-1: Step count Correlation between Stepwatch and criterion video.

Discussion

This study shows that the gold standard criterion step count and Stepwatch step count are highly correlated in this group of children with impaired walking p<0.001. This agrees with previous validation studies in impaired overground walking where the Stepwatch was found to be a reliable tool to measure step count in pathological walking (McCullagh et al., 2017; Mudge et al., 2007). Anomalies in step count data may be due to some movement on turns not necessarily defined as a step on the video. Stepwatch appears reliable to measure step count in impaired walking in this cohort, more suitable than those worn at the thigh or pedometer due to small steps and slow pace of walking. Stepwatch parameters such as speed, stride length and cadence were not comparable with 3DGA parameters due to acceleration and deceleration on turns. Gait parameter data from the Stepwatch is based an average of one minute of walking and is not relatable to gait data based on one stride. These parameters would benefit from further validation.

Conclusions

Stepwatch appears reliable to measure step count in ambulant children with cerebral palsy in overground walking.

Appendix H. Activity Diaries

PT1201.

Code: [redacted] Week Starting: Jan 18th

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am	up out of Bed	Dublin	up out of Bed.	Bed	[redacted] has sore leg	up & Breakfast	up Breakfast
9am-10am	& Excited to meet	crc	No school as isolating to	appointment in Balbotay	today so	Good form today no	we walk around.
10am-11am	our new dog.	clinic.	go to Cork.	with splint	very little walking Today.	pain.	Leave for Cork
11am-12pm			Went for a small walk.				
12pm-1pm	Meet [redacted] our new	Drive				walking around	
1pm-2pm	dog.	Home.	Played at Home.			Playing outside.	
2pm-3pm	Took [redacted] for a walk		outside on quad.	we walk down the road.			
3pm-4pm			Dinner time.			Playing with toys	
4pm-5pm	Played with [redacted]						Arrive Cork
5pm-6pm	Played in House.			Playing with Play dough.		Packing our bag for cork.	we walk around new House.
6pm-7pm	Dinner						
7pm-8pm	& Bed.	Home Bed		Bed.		watching TV & Bed.	Dinner & Bed.
Barriers to exercise					Sore knee today swollen.		

Notes: Tuesday - did a good big walk today with [redacted] Had a great day.

Code: [redacted] Week Starting [redacted]

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am	up dressed	Weather Good	up dressed.	Hospital	up Dressed.	up Dressed	Up Dressed.
9am-10am	Breakfast	outside Play	Break Fast	walking at Hospital	Took [redacted] for walk.	Breakfast	Breakfast
10am-11am	outside Playing	Played in garden	Took [redacted] for	Left Hospital	Played on trampoline	outside Playing	Took [redacted] for walk.
11am-12pm	Go cart Quad	Break.	snack Time	Went to Playplace	went with walker	[redacted] for walk	went to Park.
12pm-1pm	Lunch time	walked around House	Played on quad.	Played climbed	Lunch.	Circus	Lunchtime
1pm-2pm	Took [redacted] for walk.	with [redacted]	Went to Park	Had loads of fun	Swimming	circus.	Played outside
2pm-3pm	Played on Trampoline	Played on quad.	Took [redacted] To Grannys	went to Park	swimming	played outside	Went to visit friends
3pm-4pm	Played in Paddin Pool	Played with toys	Played with [redacted]	Home	Back home outside	walked with walker	Took [redacted] for walk
4pm-5pm	Dinner Time	Beach.	outside	Dinner Time	Dinner time	Dinner time.	Played at Pool
5pm-6pm	played in garden.	Played in water	Dinner Time.	Outside to play.	Movie on couch	played with toys	Dinner time
6pm-7pm	Bath.	storytime	outside to Play	Bed	Played with toys	Took [redacted] for walk	Bath
7pm-8pm	Bed time	Bath + Bed	Bedtime	Time.	storytime	Bath & Bed.	Bed.
Barriers to exercise	[redacted] had a bad bug so was sick for a good few days.						

Notes: [redacted] walking still very bad so not as much as usual.

H[redacted] no sheet for the week
so made my own ☺

Plan for Week   Friday 3/6/22 to Thur 9th

Friday

Morning Time

Up dressed, played outside as school closed. Played inside for a we while & then outside on trampoline.

Afternoon Time.

Had lunch

Went swimming

Went to Grannies.

Evening [redacted]me

Took [redacted] for a we walk.

Played outside.

Got ready for bed & had bath

Saturday

Morning

up dressed breakfast & straight outside to play. Walked [redacted] around the house a few times

Afternoon

Had loads of fun outside, playing on his bike, tried so hard to peddal it & then played on quad.

Evening.

Went with Mammy to visit Granny & Granda & brought Nellie, Bath at home & Bed early..

[redacted] Tues 2nd June

Sunday
Morning
Up dressed breakfast & played outside
Took [redacted] for a big walk & had
a bath when we got home.
Afternoon
Played outside on his trike and did
a bit of walking around. then
walked with a walker for a while.

Evening
Played with ipad, back outside played
with [redacted], played in we pool ...
then played inside walked around

Tuesday
Morning
Up dressed brekfast, took [redacted] for a
walk today before school & then walked
around house a few times, sports day at
school so loads a steps today.
Afternoon
Home, lunch then outside & playing on
his quad and playing in his trampoline
and in for dinner.

Evening
Back outside played outside.
Bath Bed.

Wednesday
Morning
Really Bad weather, played with
[redacted] before school & ipad.

Afternoon
Came home from school, still bad
rain, did a we bit of walking
in house, then played ipad.

Evening
Chilled out as weather very
bad & seemed very tired today

Code: [redacted] Week Starting: June 20th

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am							
9am-10am	School	School	School	School	School		
10am-11am	" "	" "	" "	" "	" "		
11am-12pm	" "	" "	" "	" "	" "		
12pm-1pm	" "	" "	" "	" "	" "		
1pm-2pm	" "	" "	" "	" "	" "		
2pm-3pm	Home through	Home. Horse Riding	Home Swimming	Home trip [illegible]	Home + walk around		
3pm-4pm	walk with [redacted]	walk in Kwalker	walk with [redacted]	in K walker	estate with [redacted]		
4pm-5pm							
5pm-6pm	Critchy to get around House	Critchy to get around House	Critchy to get around House	Critchy to get around House	Critchy to get around Hous.		
6pm-7pm							
7pm-8pm							
Barriers to exercise							

Notes:

Code: [redacted] Week Starting: 31st may.

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am							
9am-10am							
10am-11am							
11am-12pm						Rain	
12pm-1pm							Ran Marathon with DAD Finish Line
1pm-2pm	Walking [redacted]					all day	
2pm-3pm							
3pm-4pm	Playing Ball			Walking [redacted]			
4pm-5pm							Rain all Day Didn't get out
5pm-6pm	out playing						
6pm-7pm							
7pm-8pm			Walking around House		Soccer Training		
Barriers to exercise							

Notes: Didn't Do much Walking outside Weather Wasn't great

Code: [redacted] Week Starting: Aug 2022.

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am							
9am-10am							
10am-11am	AT HOUSE RAINY DAY		AT A FRIENDS		TRAVEL TO [redacted]	IN HOUSE,	
11am-12pm	PLAYING AT HOME		LOW ACTIVITY	PLAYING AT HOME	SHOPPING TRIP USING WALKER	TIDYING AND WATCHING TV	WENT TO BEACH -
12pm-1pm	WENT OUT					VISITORS TO HOUSE	COULDN'T WEAR ANKLE
1pm-2pm	DRIVING - BIT OF WALKING					PLAYING AT HOME	BRACELET AS HAD WETSUITS ON
2pm-3pm	SWIMMING - NO ANKLE BRACELET						
3pm-4pm		CAR -		TV			
4pm-5pm		VISITING FAMILY		TV	RESTING		
5pm-6pm	WALK WITH [redacted]	RESTING	FELT TIRED	TV			
6pm-7pm	GAVE UP BECAUSE OF RAIN	RESTING	TV		Dinner		WALKED WITH [redacted]
7pm-8pm		DRIVING	WALKED WITH [redacted]	WALKED W [redacted]	Walked with [redacted] REST		REST
Barriers to exercise		TRAVELLED TO DUBLIN AND HOME TODAY	TIRED FROM YESTERDAYS TRAVELLING	DUE - HER PARENTS DID NOT HAVE TIME THIS AFTERNOON			REST

Notes:

Code: [redacted] Week Starting: 20th July 22.

Activity Diary

[redacted]

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am							
9am-10am	Breakfast	Breakfast	Breakfast	Breakfast	Breakfast		
10am-11am	walk	Trip to	walk with	Trip to	shower		
11am-12pm	to	the	Mimie	pitch +	and Balance		
12pm-1pm	grandmothers	Cinema		putt course	Board		
1pm-2pm	hos.						
2pm-3pm	Lunch	Balance	walk	played	out to		
3pm-4pm	walk	Board	in walker	video	restrant		
4pm-5pm	with	+ Hypervibe	and	games	for Dinner		
5pm-6pm	[redacted]	plate workout.	pool party		with [redacted].		
6pm-7pm							
7pm-8pm	Bed	Bed	Bed	Bed	Bed.		
Barriers to exercise							

Notes:

[redacted]

Code: ______ Week Starting: 11th April at 3pm monitor commenced. ①

Activity Diary

Time	18th Monday	12 Tuesday	13 Wednesday	14 Thursday	15 Friday	16 Saturday	17 Sunday
8am-9am	up at 9am	Up at 8am	Up at 7 30.	Up at 0745	Up at 9	Up at 9ish	Up at 8:30
9am-10am							
10am-11am	playing	at home in Dublin,	playing.	playing	Playing		
11am-12pm				out in wheelchair		playing	Playing
12pm-1pm		indoors as raining	Travelling Back to Cork.				
1pm-2pm	250 m walk				visiting		
2pm-3pm		no space in house					
3pm-4pm							
4pm-5pm	visiting		600 metre walk.	300m walk		refused walk.	
5pm-6pm					300 m walk		
6pm-7pm							
7pm-8pm	Bed at 9pm.	Bed at 8:30ish.	Bath				
Barriers to exercise			Bed at 9pm	Bed at 9pm	Bed at 9pm	Bed at 9.30pm.	Bed at 9am

Notes:

Code: [redacted] Week Starting: 28th March

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am	up dressed Breakfast	up dressed Breakfast	up Dressed Breakfast	up	No school		up Dressed
9am-10am	School	school	School	Hospital.	today		Breakfast
10am-11am	school	school	school		iPad	up out of Bed.	Played
11am-12pm	Break at school	school	school	Got 2 teeth out	TV	walking around	Took [redacted]
12pm-1pm	school	school	school		went for small walk.	Playing games	for a big walk but
1pm-2pm	school	school	school		TV	Visited a friend	realized
2pm-3pm	Home Rest	school	Doctors	Home from Hospital		out side Playing	we forgot the monitor.
3pm-4pm	TV	Took [redacted]	appointment	TV	Played outside	Back home	Back home monitor on
4pm-5pm	went to Park to Play	for a big walk. iPad		TV		Played on trampoline	Dinner played with [redacted]
5pm-6pm	Home Again	Played out Home	Back home played about			went for walk.	Played outside on trampoline
6pm-7pm	Playing	Trampoline	Went for walk with Nana, played outside	played toys with	very tired today	Played in House	walked around house
7pm-8pm	Bed.	Bed.	Bed.	story time		Trampoline	in iPad time
Barriers to exercise				2 teeth out today	Played outside still tired from Gas & Air.	iPad. Bed.	Bath + Bed.

Notes: [redacted] got 2 teeth out, was fine Thursday after But really tired on friday.

Code [redacted] Week Starting: 25/2/2022

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am	Stretches & floor work	Stretches & floor work					
9am-10am	School	School			off school sleep in.	sleep in.	
10am-11am	use stander	during school physio & stander					Swimming
11am-12pm						walking in walker.	
12pm-1pm					walking with walker		
1pm-2pm					10 mins with Havana.		
2pm-3pm	Home from school @ 3.	Home from school @3				off to a FOOTBALL MATCH FOR THE REST OF THE DAY.	
3pm-4pm					Chill evening with Granny.		
4pm-5pm	4 o'clock Drama class						
5pm-6pm							
6pm-7pm	30 mins walking 10 mins with Havana.	walking 30 mins walker & 10 mins Havana.					
7pm-8pm					stretches. AFO's off for the night		
Barriers to exercise			[redacted] was very sick with kidney infection	[redacted] was sick with kidney infection			Spent day visiting grandparents
Notes:							

Code [redacted] Week Starting: Monday 28th Feb.

(Rain) Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am	10 Min Walk at School.	5 mins with [redacted] P.E. in School.	—	—	—		
9am-10am			—	10 min Walk with [redacted]			—
10am-11am			—	—	around the House	10 Min Walk with [redacted]	—
11am-12pm			—	—	—	—	—
12pm-1pm			—	—	Playing Soccer with friend.	School Party	—
1pm-2pm			—	—	Out field with [redacted]	Trampoline Party.	Walking around House
2pm-3pm	10 min Walk With Mitch	10 Min Walk With [redacted]	10 mins With [redacted]	—	—	—	—
3pm-4pm				—	—	—	Walking [redacted] 15 mins
4pm-5pm	out in the green playing		around the House	—	around the House	—	—
5pm-6pm			—	—	—	—	—
6pm-7pm		Swimming	—	around the House		—	—
7pm-8pm				—	—	—	—
Barriers to exercise	P.E. Walk with School.						
Notes:							

Code: [redacted] Week Starting: 22/2/22

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday 24	Friday 25th	Saturday 26	Sunday 27th
8am-9am							
9am-10am							
10am-11am							walk in the woods with [redacted]
11am-12pm						walk with [redacted]	
12pm-1pm				walk in the woods	playdate		[redacted] wildlife park
1pm-2pm					"		"
2pm-3pm					"		"
3pm-4pm					"		
4pm-5pm	[redacted]	physioexercises 20mins	walk [redacted]		"		
5pm-6pm							
6pm-7pm	physio exercises						
7pm-8pm							
Barriers to exercise							

Notes:

Code: [redacted] Week Starting: [redacted]

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am	WALK INTO SCHOOL [redacted]	WALK INTO SCHOOL [redacted]	WALK INTO SCHOOL [redacted]	WALK INTO SCHOOL [redacted]	WALK INTO SCHOOL [redacted]		
9am-10am							
10am-11am			LATER DUE TO ORTHOTICS APPT			20MINS WALKING [redacted] VISIT GRANDPARENTS	
11am-12pm							20MINS WALKING [redacted]
12pm-1pm		BREAKS IN SCHOOL — USING WALKER					
1pm-2pm			PE - SOME DAYS				
2pm-3pm						PLAY FOOTBALL CYCLE ON TRIKE	
3pm-4pm					WALKING [redacted] 20MINS		WALK AT BEACH
4pm-5pm	WALKING [redacted]	WALKING [redacted]	WALKING [redacted]	WALKING [redacted]		PLAY	
5pm-6pm	GO TO SINGING						FRIEND OVER TO PLAY
6pm-7pm							
7pm-8pm		CUBS					
Barriers to exercise	HOMEWORK	HOMEWORK x OTHER ACTIVITIES	HOMEWORK	HOMEWORK	NONE	NONE	NONE.

Notes: WE ARE WORKING HARD TO PRIORITISE GETTING WALKING COMPLETED EVERY DAY. SOME TIMES ABOVE MAY NOT BE FULLY ACCURATE.

Code: [redacted] Week Starting: Wednesday 1st

Activity Diary

Time	Monday 6th	Tuesday 7th	Wednesday 1st	Thursday 2nd	Friday 3rd	Saturday 4th	Sunday 5th
8am-9am							
9am-10am						walk	
10am-11am						walk with [redacted]	
11am-12pm							
12pm-1pm							
1pm-2pm							
2pm-3pm							
3pm-4pm					walk with [redacted]		
4pm-5pm				walk w[redacted]			
5pm-6pm							
6pm-7pm			Gym				
7pm-8pm					walk with Mason		
Barriers to exercise	I work a long day	Storm					Dad away Mom sick

Notes:

Tuesday 7th - Storm

Wednesday 8th, 10-11am walk with [redacted]
2-3pm walk with [redacted]
6-7pm Gym

Thursday 9th 4-4:30 walk with [redacted]

Code: [redacted] Week Starting: Nov 21

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am	walk into school		physio session - walking			low	
9am-10am	school					low	low
10am-11am	breaks walking					low	low
11am-12pm	- moderate					stability day walking practice	low
12pm-1pm	to good					walking ✓	walking around the house
1pm-2pm	activity					low	
2pm-3pm						shopping	stability day walking 20 mins
3pm-4pm						low	
4pm-5pm	stability day walking practice 15 mins					low	cycling
5pm-6pm				- physio session		low	low
6pm-7pm	low	low	low				low
7pm-8pm							
Barriers to exercise							

Notes:

Code: [redacted] Week Starting: 15/10/2021

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am						Bed	Bed
9am-10am	School	School	School	School	School	"	
10am-11am	lunch.					shower	
11am-12pm		PE				lunch	Came home
12pm-1pm						Visit Grandparents	Visit
1pm-2pm						Visit Cousins.	other
2pm-3pm						Sleepover	Cousins.
3pm-4pm				Horseriding		at	
4pm-5pm						Cousins.	
5pm-6pm							
6pm-7pm							
7pm-8pm		Bed	Bed	Bed	Bed	Bed	Bed
Barriers to exercise							

Notes: Monday [redacted] fell and damaged both knees - needing plasters (happened in yard)

Code: [redacted] Week Starting: 20/9/21.

Activity Diary

Time	Monday 20	Tuesday 21	Wednesday 22	Thursday 23	Friday 17th	Saturday 18th	Sunday 19th
8am-9am							
9am-10am							
10am-11am							
11am-12pm							
12pm-1pm						Bocce [redacted]	
1pm-2pm							
2pm-3pm							
3pm-4pm		swimming					walk w[redacted]
4pm-5pm							outdoor play
5pm-6pm						Swim	" "
6pm-7pm		walk with	walk wi[redacted]	Athletics			" "
7pm-8pm	playing in the [redacted]	6:15-6:35	6:50-7:30				
Barriers to exercise	GAA pitch	~~playing on the GAA~~.			walk w[redacted]		

Notes:

Code: [redacted] Week Starting: 02/09/2021. Laurie.

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am	ready for school			09/09	up + getting ready school		
9am-10am	sick		school.	Home.		chill home.	chill home xBox
10am-11am		School	PE @ school.	away school.	School		
11am-12pm	sick.				school.	xBox.	
12pm-1pm					orthodontist (bracket off)	XBox.	swing basketball
1pm-2pm	Basketball				orthodontist	lunch	lunch
2pm-3pm	sick				car - lunch - Home		
3pm-4pm		Home - lunch. Basketball	Chill @ home. Extremely tired from PE!	Home from DFED 02/09	XBOX	soccer	swing basketball
4pm-5pm		neighbour + teacher in house			swing	basketball	walk with Maisie
5pm-6pm		played soccer + basketball		soccer	soccer.	swing	
6pm-7pm				Dinner.	Dinner	Dinner basketball	
7pm-8pm		Dinner + chill		swing + xbox swing + getting ready for bed	chill XBox - bed.	chilling before bed	
Barriers to exercise	[redacted] was feeling very sick today in his tummy.						MUM wasn't feeling well - severe back pain so not much activity
Notes:							

Code: [redacted] Week Starting: 6/9/21

Activity Diary

Time	6/9/21 Monday	7/9/21 Tuesday	8/9/21 Wednesday	2/9/21 Thursday	3/9/21 Friday	4/9/21 Saturday	5/9/21 Sunday
8am-9am	Up at 7.15	Up at 7.30	up at 7.30	Physio	up 7.30am	Up at 9am.	Up at 8.30
9am-10am	School stander	school stander	stander	school walk.	Physio session		
10am-11am	School walk	school walk	school walk	sports in school.	School walk at school 11ish		stander.
11am-12pm							
12pm-1pm					P.E. Class		
1pm-2pm							
2pm-3pm							
3pm-4pm	Home from school.	Home.	Home	monitor off.	Home from school 3pm.		
4pm-5pm	300m walk.			*monitor on.*		games / iPad.	350 m walk
5pm-6pm			off.				exercises stretches.
6pm-7pm	Bed.	Bed.		Leg stretches + massage			
7pm-8pm			forgot to reapply	Bed at 8/8.30	walk 250m.	physio + stretches	
Barriers to exercise							
Notes:		No walk done as exhausted from school + heat.	not much done again as exhausted. struggles a lot in 1st few weeks back to school.		forgot to reapply monitor after changing from school at 3.30ish to 7.30ish. Sorry! Was resting for afternoon so not much mo	No walk as raining heavily	Bed at 8ish.

Code: [redacted] Week Starting: Mon 13th September 2021

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am		Home + School bus	Home + bus	Home + Bus	Home + bus -	up 8AM	up 8Am
9am-10am							Yoga may Not have been done.
10am-11am	Appointment CRC						
11am-12pm		School	School	School	School.		Home I Dont believe they left the house
12pm-1pm	school						
1pm-2pm							
2pm-3pm	After School Club.	After School club.	yoga + physio exercises	yoga physio.		Some walking was done around Shops and a play ground (report from Daughter)	
3pm-4pm							
4pm-5pm			Home				
5pm-6pm				5:30pm walk			- home 5pm.
6pm-7pm	Home.	Home	bed.	Bed.	6:30pm to dads House for weekend Dont know activities.		
7pm-8pm	7.30pm bed.	bed.					7:30pm Bed.
Barriers to exercise							

Notes:

Code: [redacted] Week Starting: 13/9/21

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am		Stretching	stretching	stretching	stretching		
9am-10am		School.				Stretching	Stretching
10am-11am		+					
11am-12pm		P.E.		P.E			
12pm-1pm							
1pm-2pm		School	School	School	School		
2pm-3pm		school	School	School	school.		
3pm-4pm		Horse Riding.	Swimming	outdoor walk	outdoor walk		
4pm-5pm							
5pm-6pm		Playing	Playing	Playing	Playing		
6pm-7pm		+ Dancing					
7pm-8pm		T.V	T.V	T.V	T.V		
Barriers to exercise							

Notes:

Code [redacted] Week Starting: 10th of Sept (Friday) [redacted]

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am	ready for School	25 mins legs on motomed	30 mins legs on motomed.	Ready for School	Ready for school	Sleep in	
9am-10am				School	School	Sleep in	
10am-11am	stander in School 1hour	Stander in school 1hr.	stander in school 1hour.	Stander 1hour	School		
11am-12pm	school	GAA football in school.	PE	Rugby	School		
12pm-1pm	School		School	School	School	Half Marathon in Buggy.	
1pm-2pm	School		school.	School	School		
2pm-3pm	School		school	School	School	Finish Half Marathon	
3pm-4pm	Rest	Physio 1hr session	Rest.		Rest after School	Relax	
4pm-5pm	Rest	Relax	45 mins swim in Pool.		Walk outside 41mins	25 mins Walk	
5pm-6pm	Play		Rest.		Play time	relax	
6pm-7pm	25 mins walking (kaye walker)		Rest		Play time	relax	
7pm-8pm	ready for Bed.		ready for Bed.		Ready for Bed.	relax	
Barriers to exercise							[redacted]
Notes:							after Long day Saturday.

Code [redacted] Week Starting: [redacted] Started on 7.09.21

Activity Diary

Time	Monday	7 Tuesday	8 Wednesday	9 Sept Thursday	10 Friday	11 Saturday	12 Sunday
8am-9am							
9am-10am							
10am-11am							
11am-12pm							
12pm-1pm		cycling	school	school	school		
1pm-2pm							
2pm-3pm							
3pm-4pm							
4pm-5pm		Walk in the park					
5pm-6pm			Long walking training				
6pm-7pm							
7pm-8pm							
Barriers to exercise							
Notes:			Special walking training		forgot to put on	long walk 19-20:00	

13 14 15 16 different leg

school - 9-14:20

Code: [redacted] Week Starting: Tuesday

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am	/		/		/	/	/
9am-10am	/		Walking around House	/	/	/	/
10am-11am	/		/	/	/	/	/
11am-12pm	/		Kicking Ball 10 mins	Bouncing on Trampoline 15mins	/	/	/
12pm-1pm	/	School	/	/	/	/	/
1pm-2pm	/		/	Walk From Car park to Car 10mins	Walk From Car to McDonnell's 10 mins	/	/
2pm-3pm	/		Kicking Ball 15 mins	/	/	out playing Ball 45 mins	/
3pm-4pm	/		/	/	/	/	Walk 10 mins
4pm-5pm	/		Walking around House	Kicking Ball 10 mins	Kicking Ball 15-20mins	15 mins playing outside	/
5pm-6pm	Playing Ball 20 mins	15 mins playing outside	(out playing 1 Hour) with friends	/	/	Walking around House.	/
6pm-7pm			/	/	/	/	Playing outside 20 mins
7pm-8pm	/		/	/	/	out playing for 30mins	/
Barriers to exercise							

Notes: A lot of the Blank spaces are Walking around the House not always Sitting Down.

Code: [redacted] Week Starting: July 12th 2021

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	12-07-21	13-07-21	14-07-21	15-07-21	09-07-21	10-07-21	11-07-21
8am-9am	Breakfast	Breakfast	Breakfast	Breakfast	TV	TV	TV
9am-10am	July provision	July provision	playing outside	—	Breakfast	Breakfast	Breakfast
10am-11am	July provision	July provision	July provision	Beach/swim	Short walk	15mins exercise	GAA pitch
11am-12pm	July provision	July provision	" "	Beach	Home	outside play	outside play
12pm-1pm	—	lunch	" "	TV	"	lunch	Dinner
1pm-2pm	Home	walking in Cork	lunch	lunch	"	[redacted] gardens	[redacted]
2pm-3pm	playing outside	" "	swimming lesson	Appointment	"	[redacted] Gardens	
3pm-4pm	" "	" "	—	Appointment	"	[redacted] Gardens	
4pm-5pm	" "	Athletics	playing outside with friend	Appointment	"	Home	
5pm-6pm	TV	Athletics	" "		"	Home	Home
6pm-7pm	TV	Tea	" "		~~outside~~ "	MASS	outside play
7pm-8pm	GAA pitch	swim/Beach	Beach/swim		"	TV	TV
Barriers to exercise			—		Raining all day		

Notes:

Code: [redacted] Week Starting: 14/06/2021

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am		Getting up + dressed	up - go to school	up + go to school	up - go to school	up. chilling	up. chilling
9am-10am		Playing XBox	school	school	school	swimming	XBox - swimming
10am-11am		Playing XBox	School	school	school	chill	chill
11am-12pm		Resting	School	school	school	soccer in garden	chill.
12pm-1pm		Resting	school	school	school	walk in town.	lunch
1pm-2pm		Lunch	School	school	school	lunch	swing.
2pm-3pm		in-House Acting	Home from school	Home from school	Home from school	chill	
3pm-4pm	in car	Goal Practice in House	soccer in garden	on swing	swing in garden.	in car	soccer
4pm-5pm	in car	Sedentary games	X Box	playing soccer in garden.	in car	in car.	soccer.
5pm-6pm	in car	Dinner	soccer X Box	TV + XBox + swing	in West Cork - Dinner	XBox	XBox swimming
6pm-7pm	Dinner	Dinner	car Dinner	Dinner.	Dinner	XBox	Dinner
7pm-8pm	Bed-time	goal practice Bed time.	chill time BED	Chill time - BED	chill time.	Dinner.	chill - Bed-time.
Barriers to exercise	Travelling from Dublin						

Notes:

played soccer @ school.

Swimming quite a lot which involves him moving in one area or his feet.

Code: [redacted] Week Starting: 08/04/2022.

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am	chill					chill	chill
9am-10am		chill				chill.	chill
10am-11am	XBox	Birthday party				soccer.	XBox
11am-12pm	soccer					B'fast.	soccer in garden.
12pm-1pm	lunch	bowling.				travel to Cork.	
1pm-2pm							lunch.
2pm-3pm	Birthday party						
3pm-4pm	tubing + soccer.					XBox	family birthday party
4pm-5pm		XBox Soccer.			Trampoline	XBox	soccer
5pm-6pm					soccer.	soccer.	
6pm-7pm					Dinner	soccer	
7pm-8pm						Dinner. XBox	XBox. BED
Barriers to exercise							

Notes:

Code: [redacted] Week Starting: 3/6/21.

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	7/6/21	up at 7·30	up at 7·30	3/6/21	4/6/21	5/6/21	6/6/21
8am-9am							
9am-10am	Up at 7am.				Up at 7·30	up at 9am	Up at 9am
10am-11am		School	School		School		
11am-12pm	Birthday	100m walk			walk in school ?100m.	Walk roughly 400m	
12pm-1pm			tour.				
1pm-2pm					School		Beach
2pm-3pm		School		Monitor applied.			
3pm-4pm	walk 400ml.						
4pm-5pm				Drive home.	at home.		
5pm-6pm		exhausted				walk 300m roughly	
6pm-7pm	7pm						
7pm-8pm	left off as in hot tub ~ shower replaced. 7·30ish		walk 350 metres	400metre walk in walker taking approx 35 mins			walk 100m gravel path.
Barriers to exercise		Bed at 8:30	Bed at 8·30ish	Bed at 8:30pm.	Bed at 9pm	Bed at 9·45pm.	Bed at 9·30pm.

Notes:

Code: [redacted] Week Starting: May 2021

Activity Diary

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
8am-9am		Breakfast					
9am-10am		School	School	School.	School	In House	Played in
10am-11am						In House	Garden.
11am-12pm							
12pm-1pm							
1pm-2pm			Walking with SNA in School				
2pm-3pm						At home.	[redacted]
3pm-4pm							Cycle Pier.
4pm-5pm				Guitar.			Got Ice Cream.
5pm-6pm	Dinner.						
6pm-7pm		Went for cycle.	At home.				
7pm-8pm							
Barriers to exercise							

Notes:

[redacted]

Code: [redacted] Week Starting: 18 May 2022

Activity Diary

	23 Monday	24 Tuesday	18 Wednesday	19 Thursday	20 Friday	21 Saturday	22 Sunday
Time							
8am-9am							
9am-10am	School	School	School	School	School		
10am-11am							
11am-12pm						walk to	
12pm-1pm						Grandparents	Cycle in
1pm-2pm	School	School	School	School	School	in [redacted] with [redacted]	[redacted] with [redacted]
2pm-3pm							
3pm-4pm	at home						Cinema+Pizza [redacted]
4pm-5pm				[redacted]			
5pm-6pm							
6pm-7pm		walk to grandparents					
7pm-8pm		in [redacted] with [redacted]	Walk around Block with [redacted]		walk to Grandparents in [redacted] with [redacted]		
Barriers to exercise		[redacted] refused he had a sore foot so we reduced his walking time					
Notes:							

Appendix I. Semi-structured Interview Guides

Interview 1: Pre mobility dog provision - Parent Interview draft

Decision to get a mobility assistance dog

- Can you tell me about your decision to get a mobility assistance dog for your child?
- How did you hear about Dogs for the Disabled?
- What was it about having a mobility assistance dog for your child that interested you?
- Tell me about your child's involvement in this decision.
- Have you had other pets/dogs in your home?
- Do you know any other families who have a mobility assistance dog? Can you tell me Guides about this?

Expectations of getting the dog

- Can you tell me about your expectations for what it will be like when you get the dog?
- Can you tell me about what you think your child's expectations are of having the dog?
- How to do you think it might benefit your child?
- Have you any concerns/fears about the process or about having the dog?

Child's activity levels and walking ability

- How would you describe your child's walking ability? What are their strengths in relation to walking currently? What are their challenges?
- How would you describe their current activity levels? How active are they? Which moving tasks do they find challenging? Generally, how much time do they spend active in a weekday? At the weekends?

Child's participation in activities in and outside the home

- Can you tell me about your child's general week?
- *What activities do they take part in within the home?*
- Are they involved in any activities outside the home?
- If so, can you tell me about these? How do they generally spend their time at the weekends?
- Can you tell me a little out where you live in general (no specifics but town or city or countryside, footpaths, no footpaths, areas to walk safely, shops close by)?

- How would you describe your child's quality of life at the moment? Can you tell me more about this?

COVID related questions

- Since COVID has your child's level of activity changed? Can you describe this?
- Has their participation been more or less restricted (for example less opportunities to be out and about or more opportunities with family etc)

General

- Is there anything else you would like to tell me about in relation to getting the mobility assistance dog/your child?

Interviews 2 and 3

Parent interview draft for 1 month and 3 months post

At 1 month

- Can you describe to me the process of getting the mobility assistance dog for your child?
- What were the early days of your child having the dog like?

General

- Can you tell me about how your child and your family are getting on with the mobility assistance dog?
- Can you describe how your child has transitioned to having the dog?
- What do you think are the positives if any for your child – describe?
- What do you think have been the challenges – describe?
- How has it been fitting the dog into your lives and your home?
- Can you describe your child's walking and movement now?
- Is there anywhere that your child can walk with the dog that they couldn't before? Can you describe?
- Have you noticed any changes to your child's quality of life? If yes, can you tell me a little more about these?
- Can you tell me what your child's activity levels are now? Describe.
- Has COVID had any impact on your child's activity levels and participation? If yes, can you tell me about what might be different without COVID.
- Is there anything else that you think is relevant that you would like to tell me about?

Interview 4

Six months post – Parent Interview Draft

Looking back on the last 6 months, what can you tell me about having the mobility assistance dog?
Can you tell me about your child's walking ability now?
Can you tell me about your child's levels of activity?
Can you tell me about your child's participation and engagement in activities and people outside their home?
Can you tell me about your child's quality of life?
Have you noticed any changes in any of these areas now with the mobility assistance dog?
Can you describe this?
How did your child find the transition to having a mobility assistance dog?
How was this transition for the family?
Was there anything about the process or about getting the dog that surprised you?
Can you think of any things that it would be useful for someone else to know who is getting a mobility assistance dog?
What did you find particularly helpful during the process?
Were there things that you or your child found challenging? If yes, can you describe?
Is there anything else that would be helpful for someone else getting a dog?
Do you think COVID-19 has influenced your experiences and that of your child? If yes, can you describe this?

The research component

- What was this research process like for you? Can you explain?
- Were there parts that were difficult? Can you explain?
- Is there anything that would make the process easier for future participants?

Child Interview Questions:

Pre-Dog

- Why do you want to get a mobility dog?
- How do you feel it will help you?
- What is your walking like now?

Post Dog 1 month, 3 months

- How are you getting on with your dog?
- Can you tell me about activities you do with your dog?
- How does walking with your dog make you feel?
- Is there anywhere you can go now that you couldn’t before you had your dog?

Post Dog 6 months

- What would you tell another child who was waiting for a dog?
- How is your life different now that you have a dog?

Appendix J. Manual Muscle Testing

Hip Abduction Control

Subject Position: Side lying, pelvis in line with trunk and thigh in a neutral position in terms of flexion/extension.

Examiner Position: Standing behind subject and at the level of the subject's pelvis. Plinth adjusted to appropriate level. One hand stabilising the pelvis and preventing it from rolling backwards. The other hand should bring the upper most limb (being tested) into full abduction.

Figure J-0-1: Manual Muscle Testing: Hip Abduction

Action: With the uppermost leg held in abduction, the therapist should ask the subject to hold the limb in this position while support is slowly removed. If this is possible, progressive resistance should be applied by the therapist (hand above knee). If the subject is unable to hold the leg in abduction, the test should be repeated with the knee flexed (and it should be recorded that the lever of the thigh was reduced). If the subject is still unable to generate sufficient power, active movement should be tested in supine (gravity eliminated). The therapist should then use the modified Oxford scale (above) to grade the subject's strength.

Hip Extension Control

Subject Position: Comfortable prone lying over end of bed.

Examiner Position: At end of plinth and at the level of the subject's mid femur. One hand should be placed on the pelvis to stabilise that region. The other hand should be used to lift the limb off the plinth.

Figure J-0-2: Manual Muscle Testing: Hip extensors

Action: The subject should then be asked to hold the leg off the bed as support is removed from it. If they can comply with this request, progressive manual resistance should be applied against the hip extensors and the subject should continue to be verbally motivated to keep the leg up in the air. If the subject is unable to resist gravity alone, the test may need to be repeated in side-lying. Generally, this test is performed with the knee extended which assesses all hip extensors. If isolation of gluteal muscles is desired, then the test can be repeated with the knee held in passive flexion which can be difficult sometimes to achieve.

Hamstring Control:
Subject Position: Comfortable prone lying.
Examiner Position: Standing at the level of the subject's mid femur.
Action: The subject is asked to actively flex the knee. If they can comply with this through full ROM, then progressive resistance should be applied at the level of the ankle. If they are unable to move through full ROM the therapist should repeat the test in side-lying.

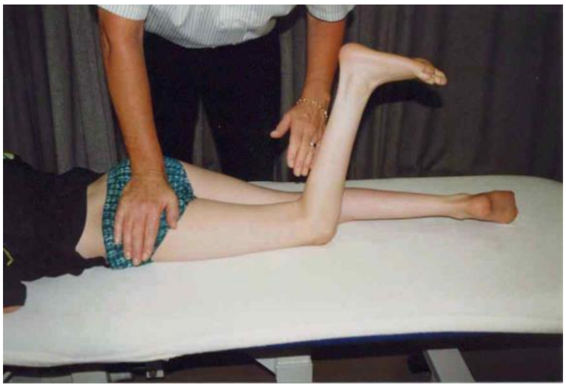


Figure J-0-3: Manual Muscle Testing: Hamstring strength

Quadriceps Control:
Subject Position: Sitting.
Examiner Position: Standing/sitting on the side that is to be tested. Plinth adjusted to appropriate height. One hand may be placed on the shoulder or trunk of the subject to stabilise this region. The other hand should be used to lift the shank into knee extension.

Action: The subject should be asked to hold the knee straight while support for the limb is removed. If they can maintain knee extension, then slow progressive pressure should be applied at the level of the proximal ankle. If they are unable to maintain knee extension against gravity the test may need to be repeated in side-lying.

Figure J-0-4: Manual Muscle Testing: Quadriceps strength

Abdominal Control:

Subject Position: Supine on plinth.

Examiner Position: Standing at the shoulder level of the subject.

Action: Ask the subject to sit up.

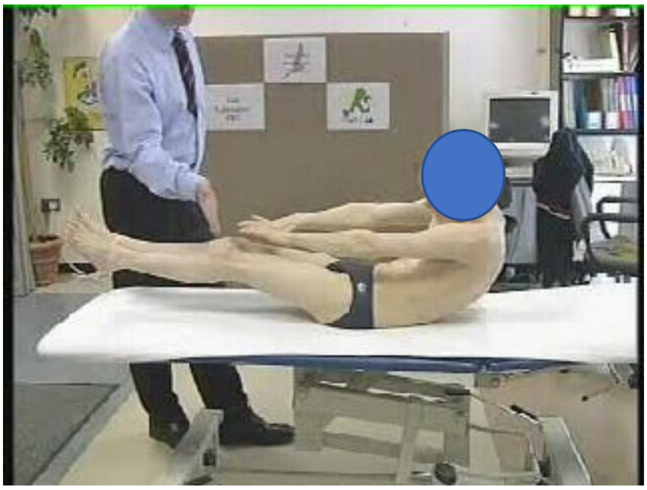
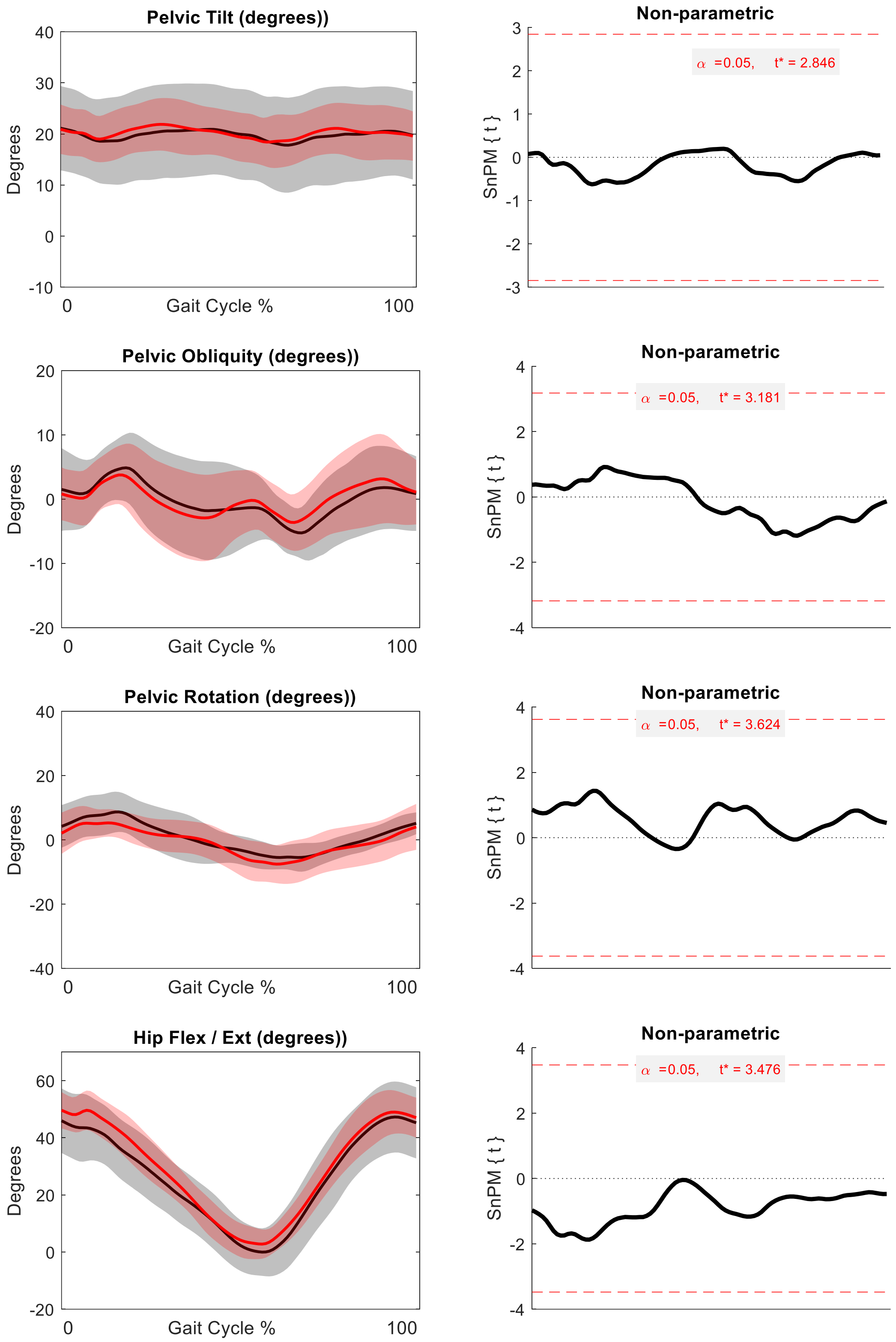
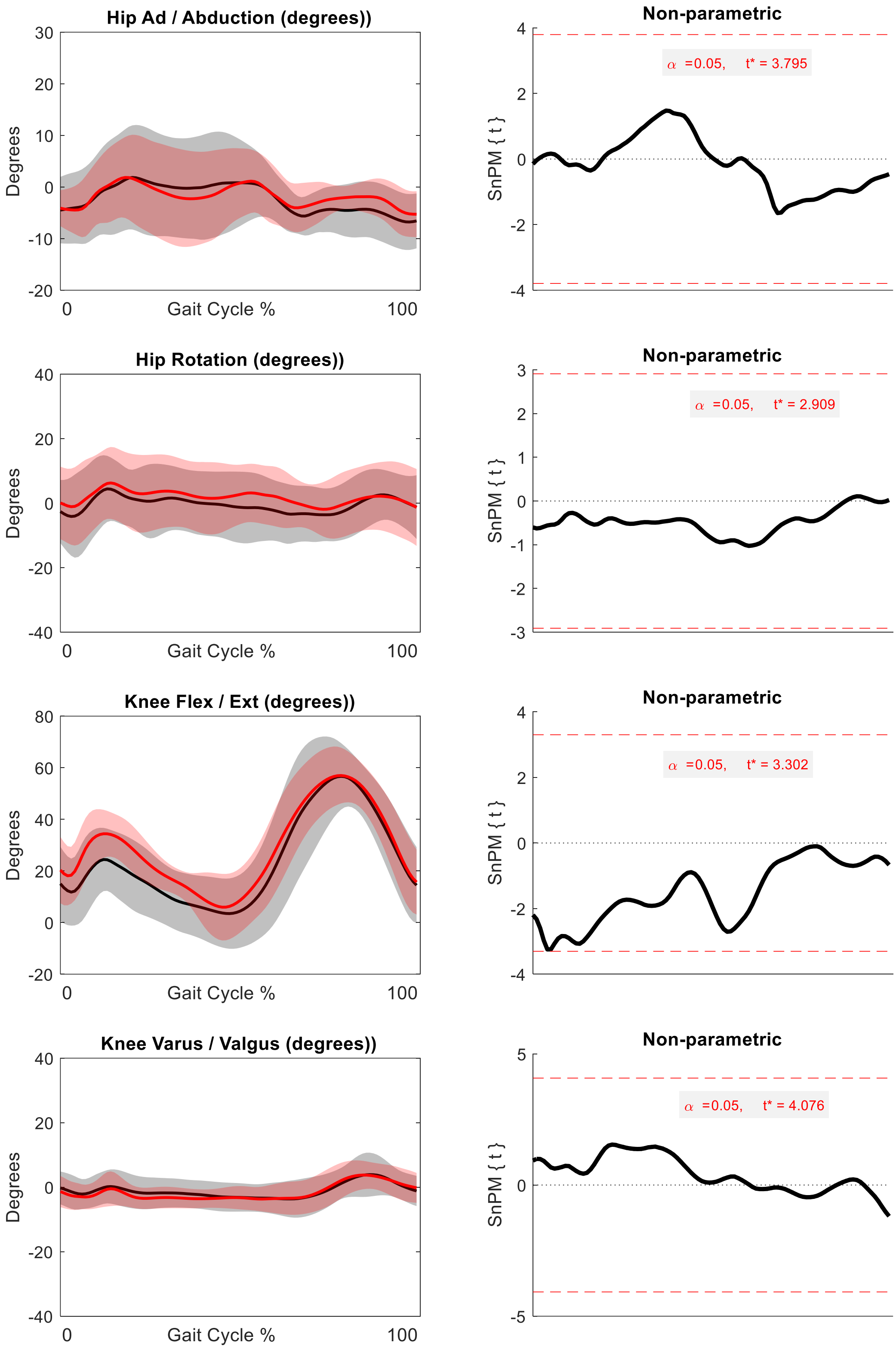


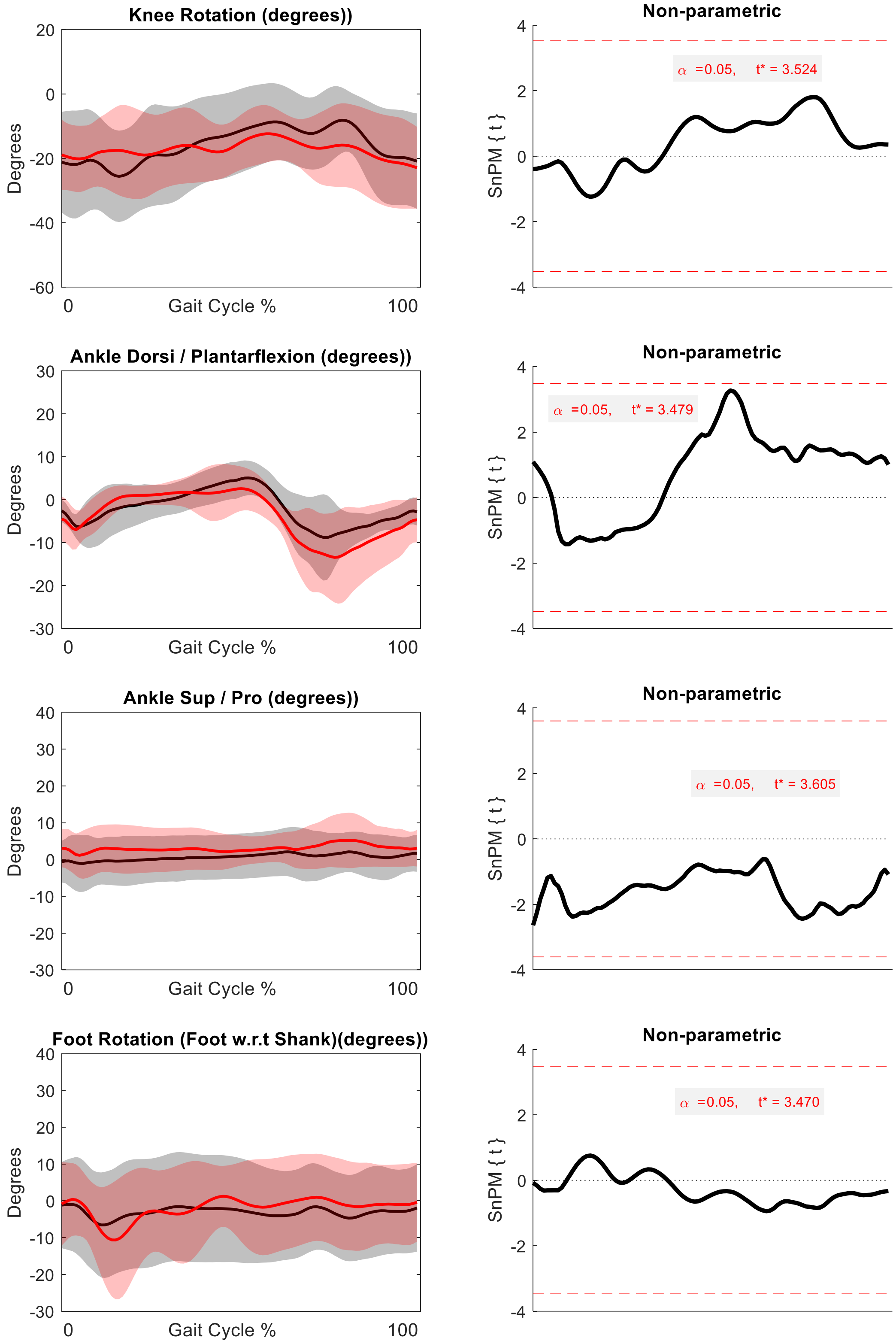
Figure J-0-5: Manual Muscle Testing: Abdominal strength

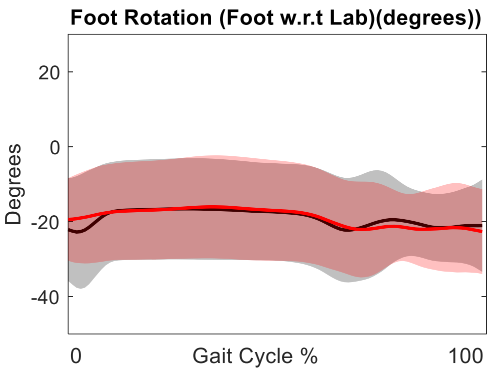
Appendix K. SnPM graphs for all planes of motion

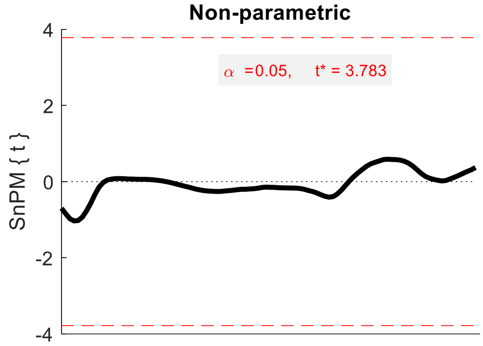
Group A SnPM graphs for all planes of motion and Random Theory Field Test (right column)



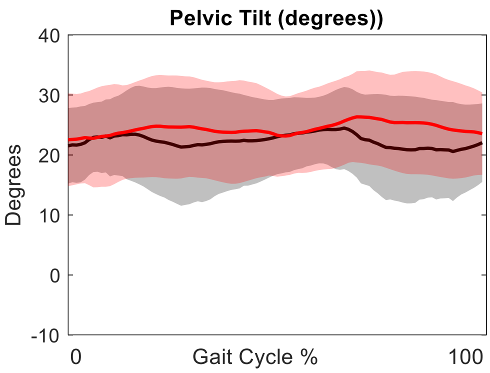

Hip Ad / Abduction (degrees))
Non-parametric
α =0.05, t* = 3.795
Hip Rotation (degrees))
Non-parametric
α =0.05, t* = 2.909
Knee Flex / Ext (degrees))
Non-parametric
α =0.05, t* = 3.302
Knee Varus / Valgus (degrees))
Non-parametric
α =0.05, t* = 4.076
Degrees
Gait Cycle %
SnPM { t }

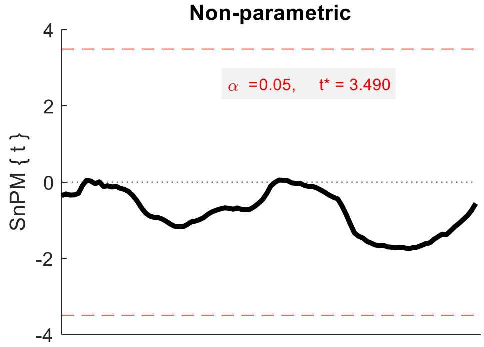

Knee Rotation (degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.524
Ankle Dorsi / Plantarflexion (degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.479
Ankle Sup / Pro (degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.605
Foot Rotation (Foot w.r.t Shank)(degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.470

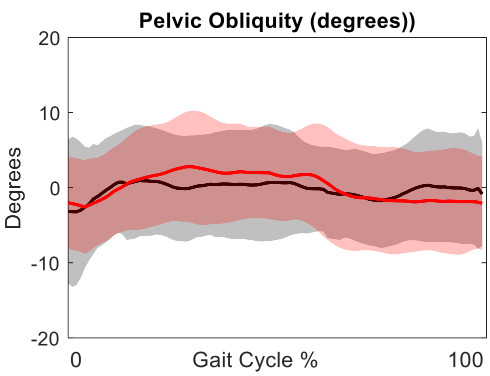


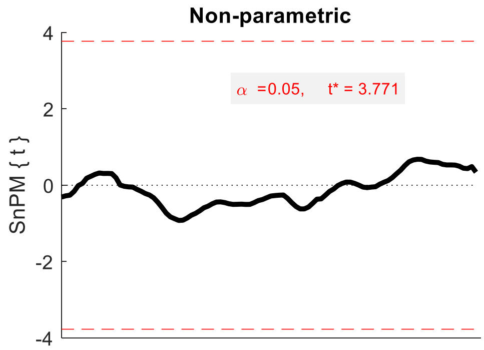


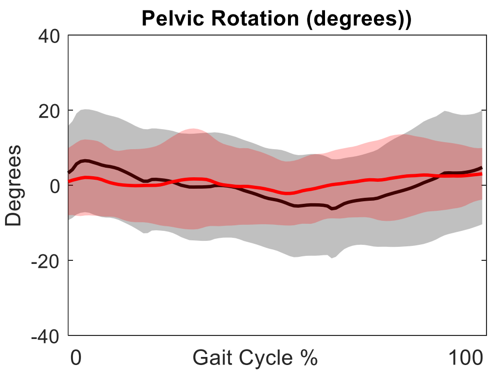
Group B SnPM graphs for all planes of motion and random theory field test (right column)

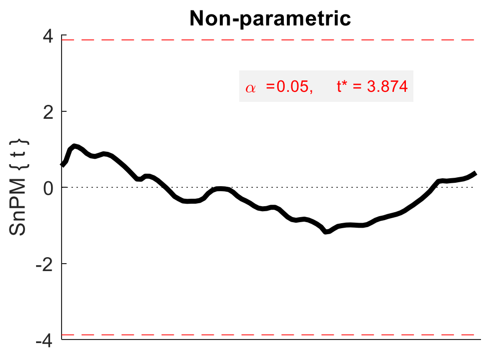


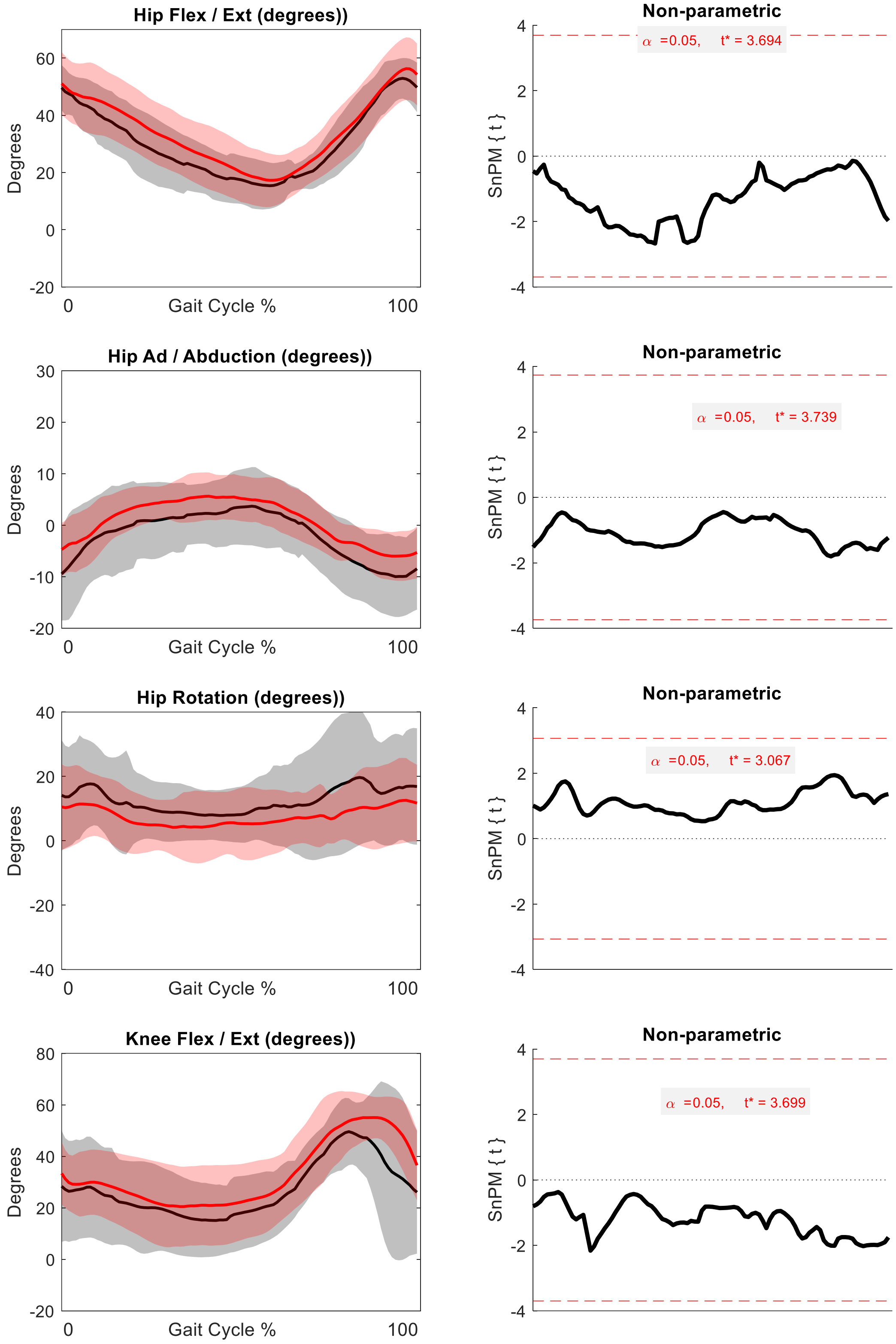




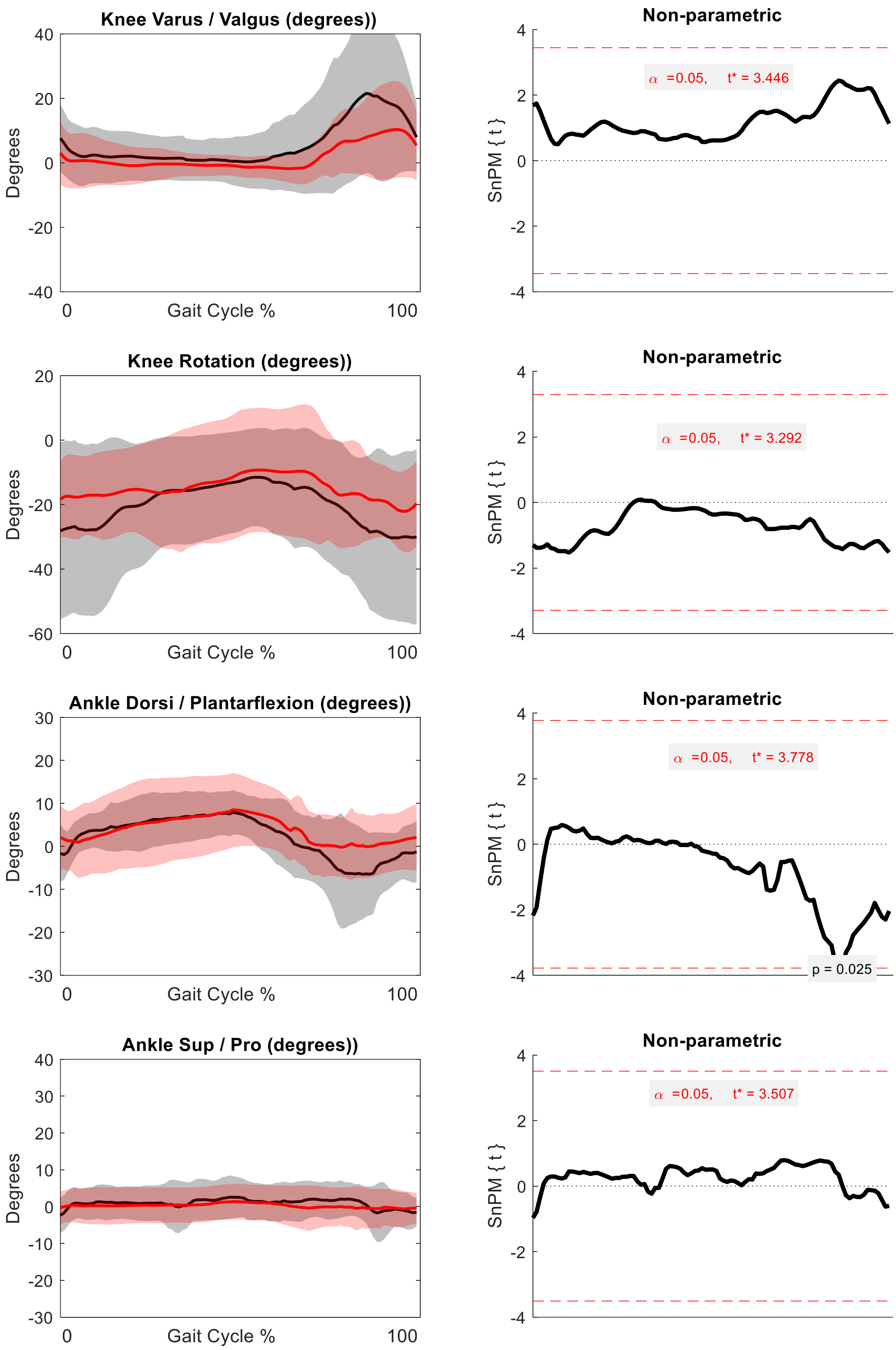


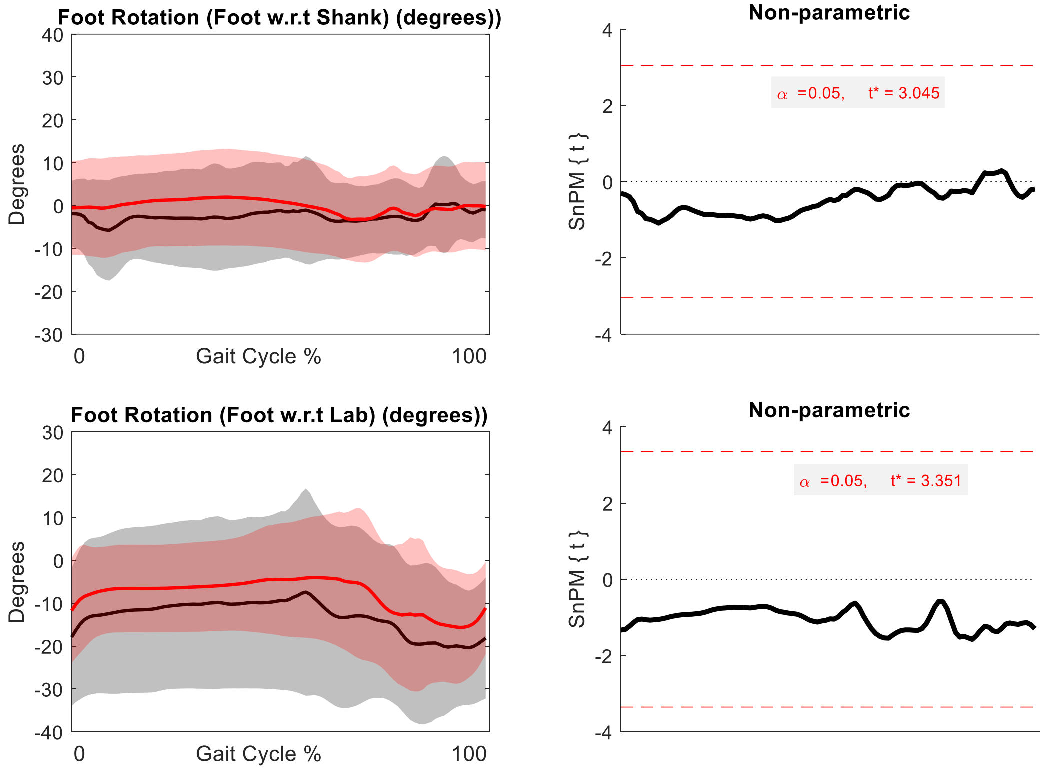






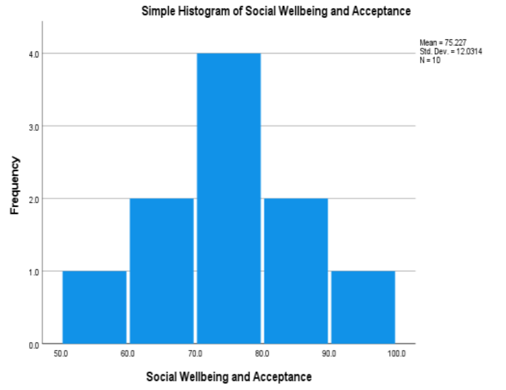
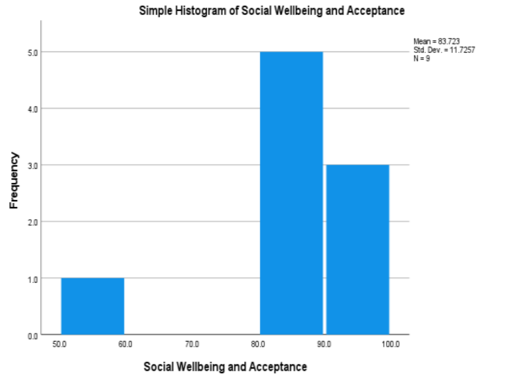
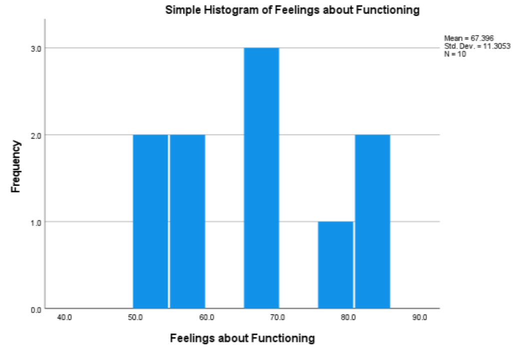
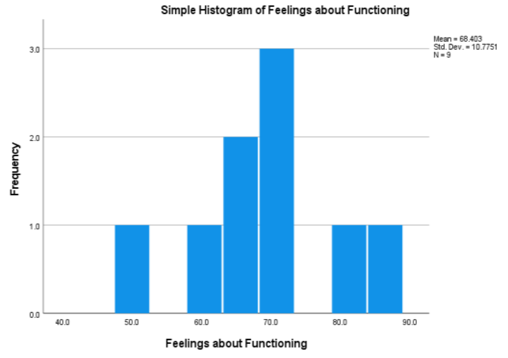
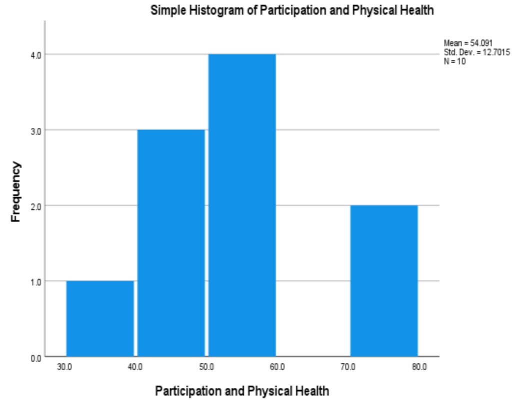
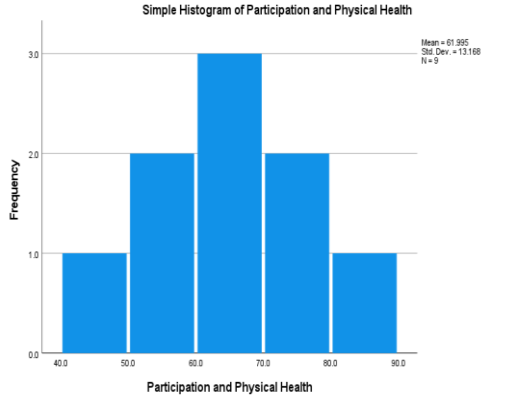
Hip Flex / Ext (degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.694
Hip Ad / Abduction (degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.739
Hip Rotation (degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.067
Knee Flex / Ext (degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.699

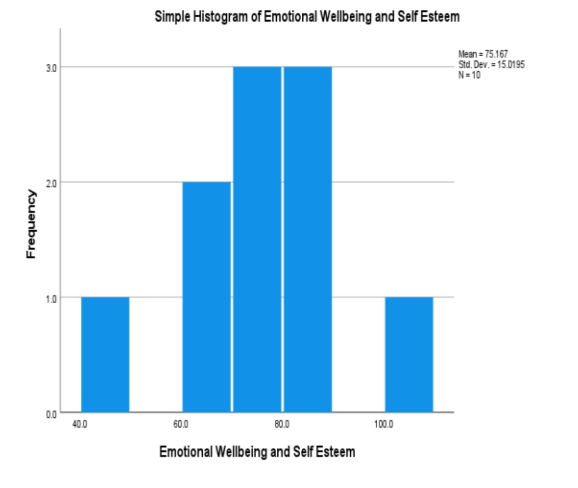

Knee Varus / Valgus (degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.446
Knee Rotation (degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.292
Ankle Dorsi / Plantarflexion (degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.778
p = 0.025
Ankle Sup / Pro (degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.507

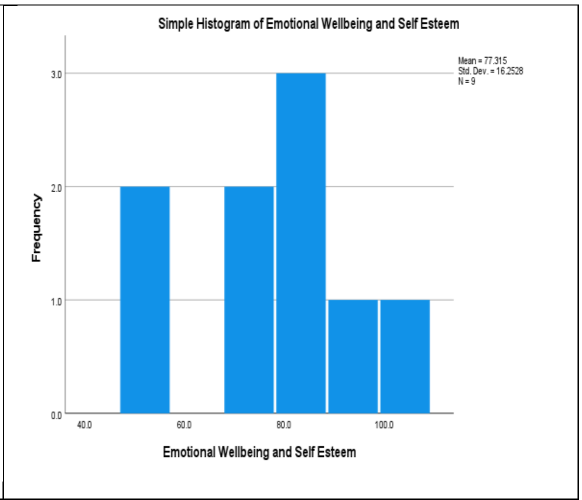


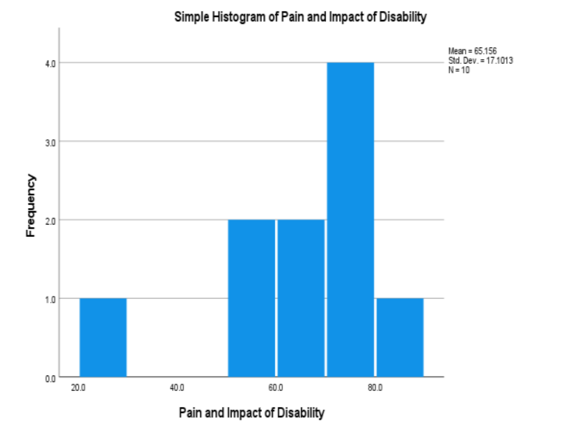
Foot Rotation (Foot w.r.t Shank) (degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.045
Foot Rotation (Foot w.r.t Lab) (degrees))
Degrees
Gait Cycle %
Non-parametric
SnPM { t }
α =0.05, t* = 3.351

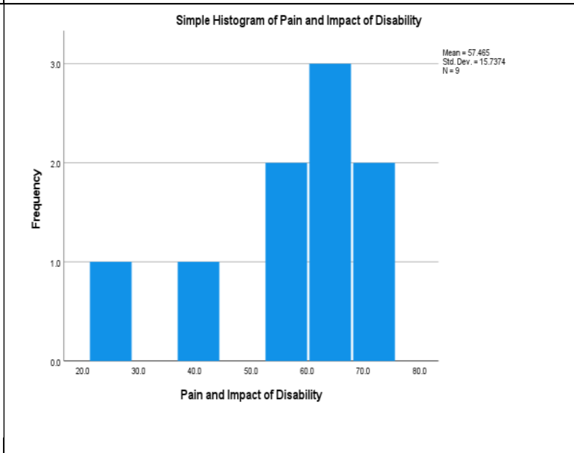
Appendix L. Histogram to analyse distribution of data for choice of statistical test in CPQoL

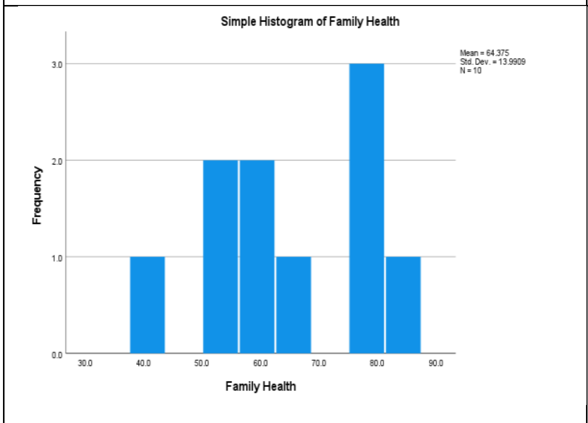
<table>
<tr><th>Pre Dog Data Distribution</th><th>One month Data Distribution</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

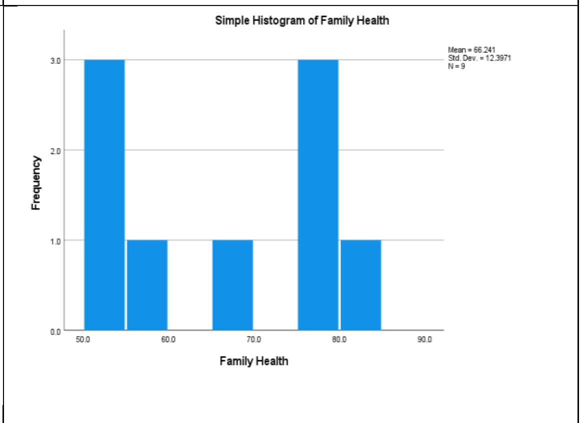






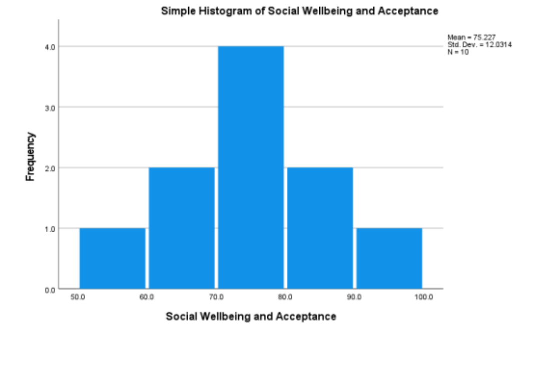


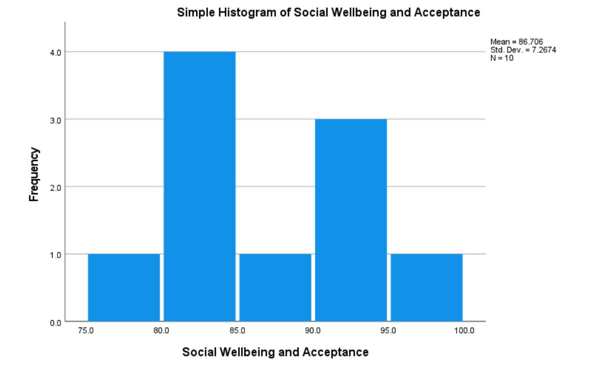


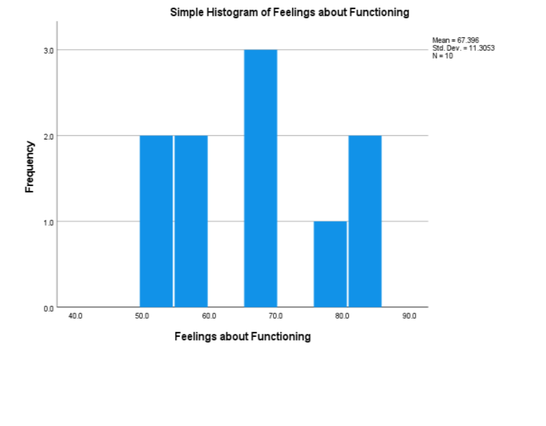


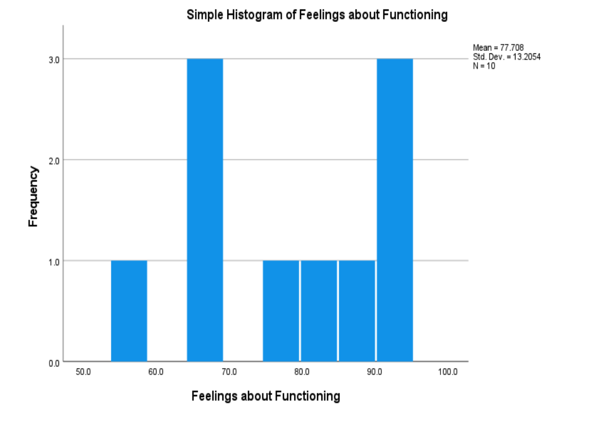
Access to Services	

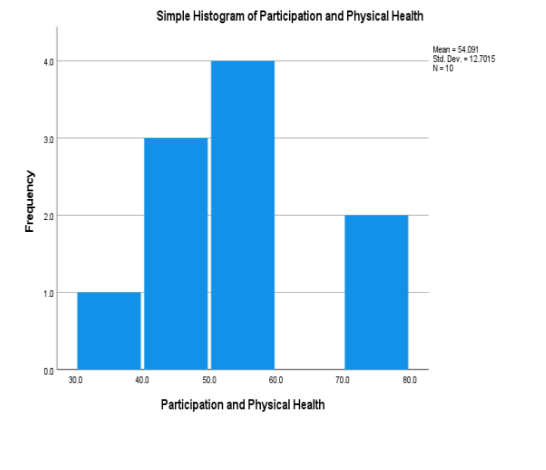
Pre Dog	6 month follow up

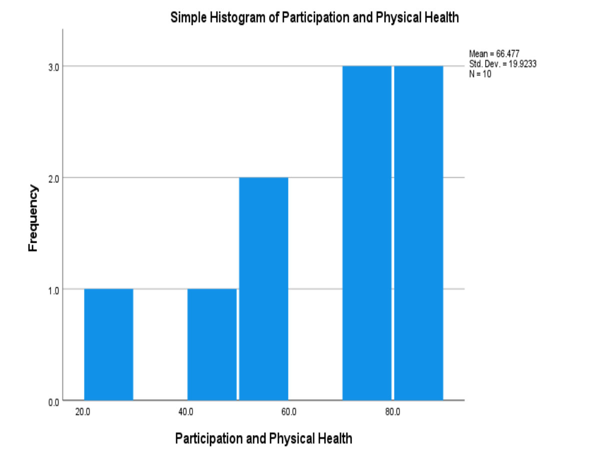

Simple Histogram of Social Wellbeing and Acceptance
Mean = 75.227
Std. Dev. = 12.0314
N = 10
Frequency
Social Wellbeing and Acceptance

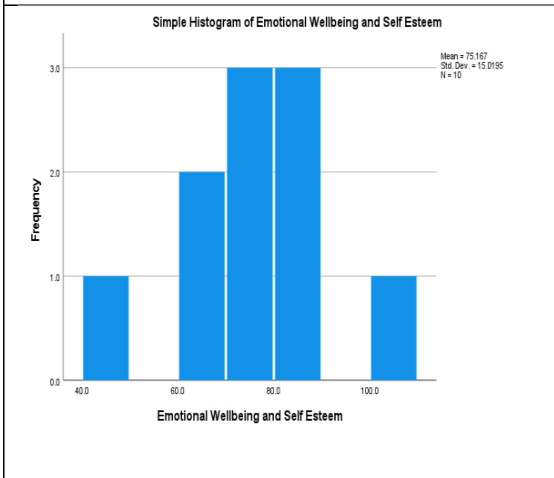

Simple Histogram of Social Wellbeing and Acceptance
Mean = 86.706
Std. Dev. = 7.2674
N = 10
Frequency
Social Wellbeing and Acceptance

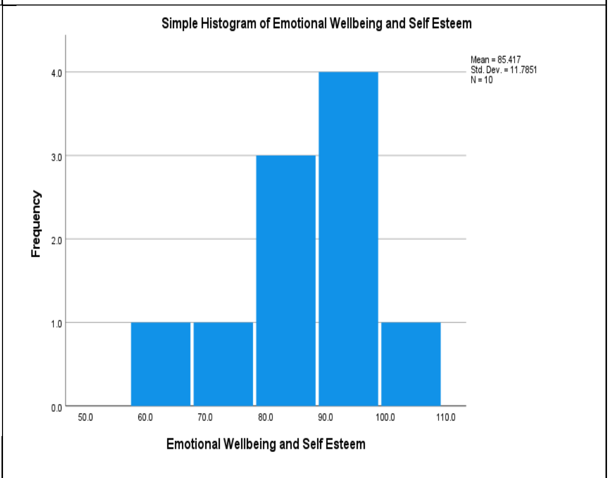

Simple Histogram of Feelings about Functioning
Mean = 67.396
Std. Dev. = 11.3053
N = 10
Frequency
Feelings about Functioning

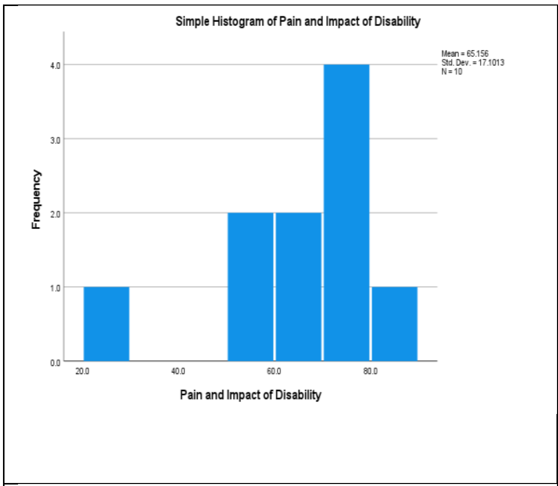

Simple Histogram of Feelings about Functioning
Mean = 77.708
Std. Dev. = 13.2054
N = 10
Frequency
Feelings about Functioning

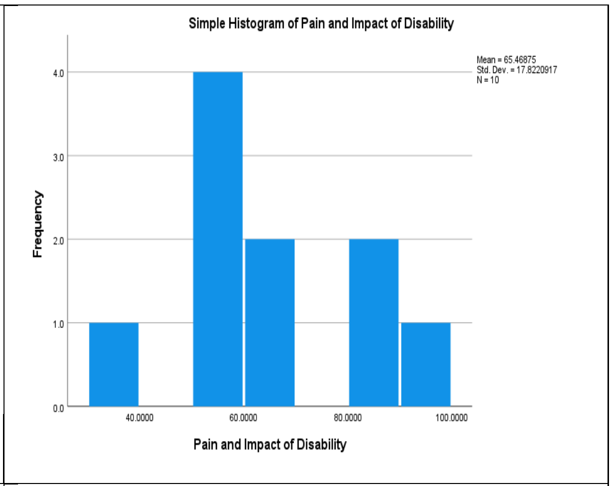

Simple Histogram of Participation and Physical Health
Mean = 54.091
Std. Dev. = 12.7015
N = 10
Frequency
Participation and Physical Health

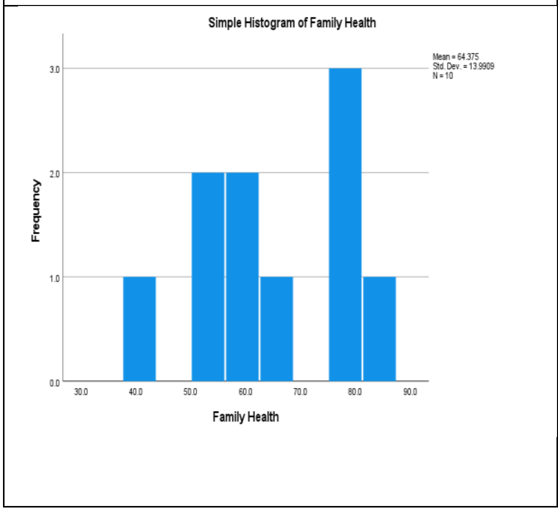

Simple Histogram of Participation and Physical Health
Mean = 66.477
Std. Dev. = 19.9233
N = 10
Frequency
Participation and Physical Health

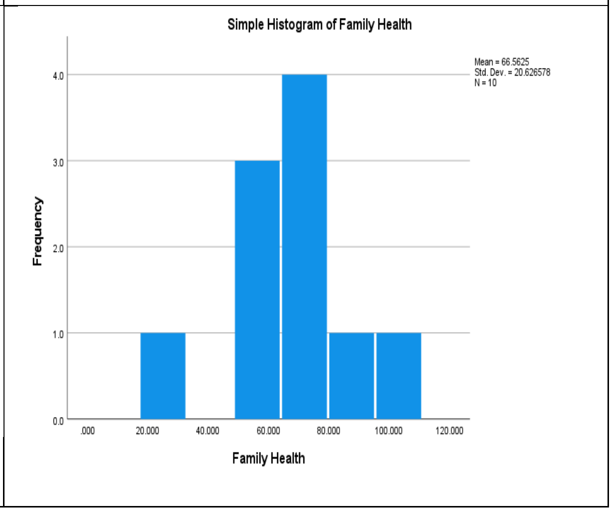

Simple Histogram of Emotional Wellbeing and Self Esteem
Mean = 75.167
Std. Dev. = 15.0195
N = 10
Frequency
Emotional Wellbeing and Self Esteem


Simple Histogram of Emotional Wellbeing and Self Esteem
Mean = 85.417
Std. Dev. = 11.7851
N = 10
Frequency
Emotional Wellbeing and Self Esteem


Simple Histogram of Pain and Impact of Disability
Mean = 65.156
Std. Dev. = 17.1013
N = 10
Frequency
4.0
3.0
2.0
1.0
0.0
20.0
40.0
60.0
80.0
Pain and Impact of Disability

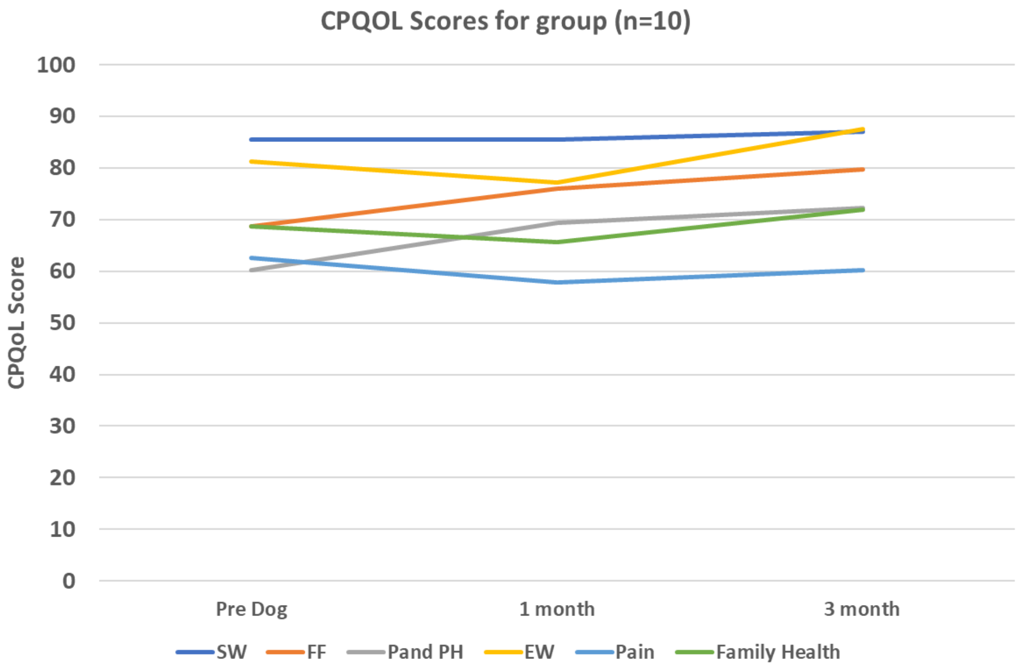

Simple Histogram of Pain and Impact of Disability
Mean = 65.46875
Std. Dev. = 17.8220917
N = 10
Frequency
4.0
3.0
2.0
1.0
0.0
40.0000
60.0000
80.0000
100.0000
Pain and Impact of Disability

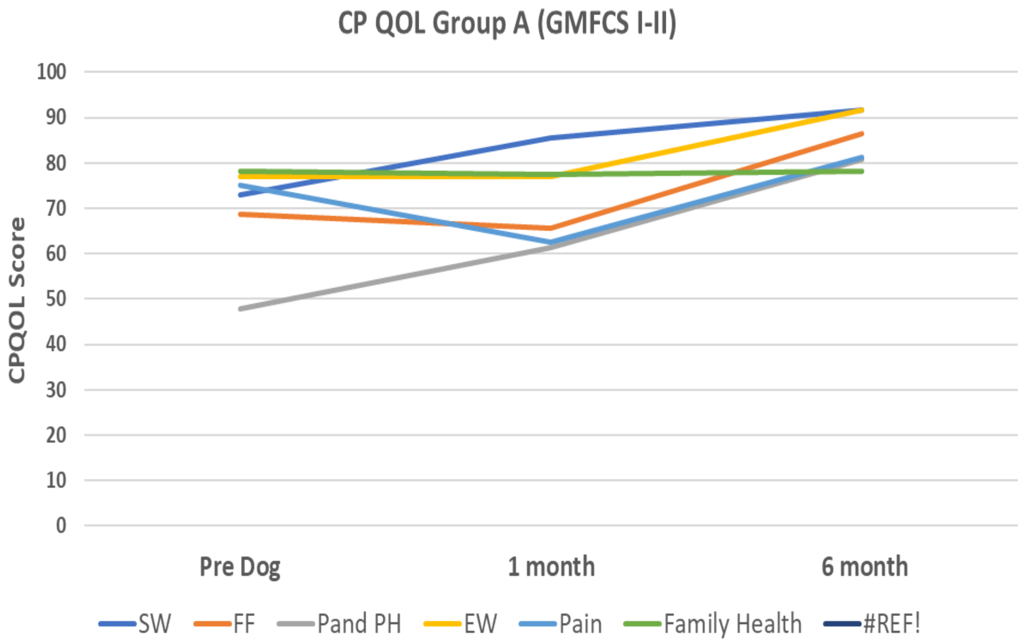

Simple Histogram of Family Health
Mean = 64.375
Std. Dev. = 13.9909
N = 10
Frequency
3.0
2.0
1.0
0.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
Family Health

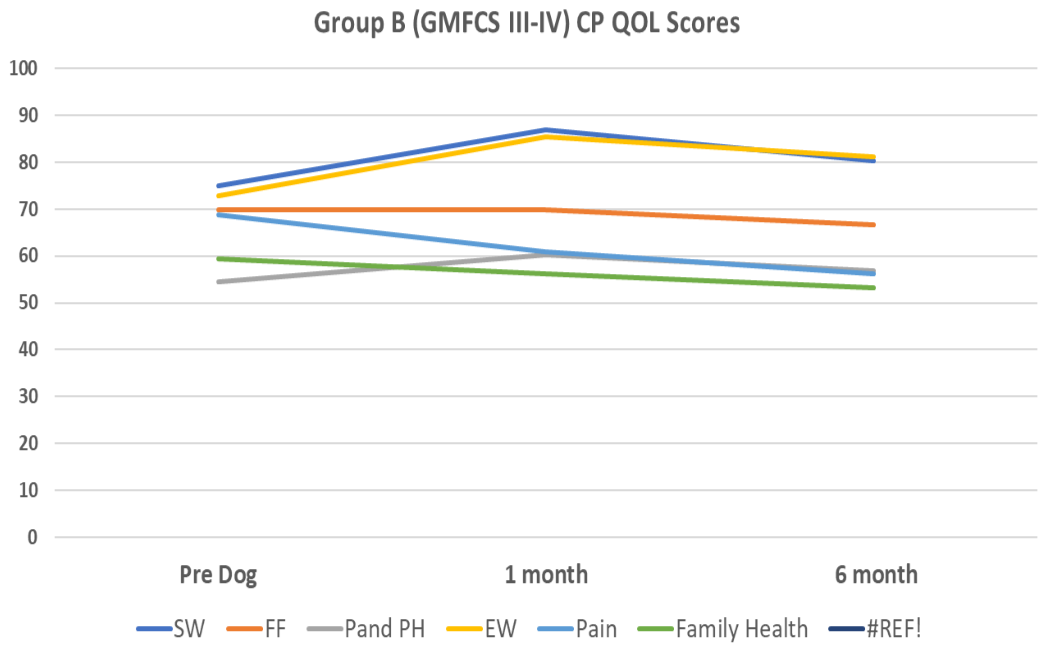

Simple Histogram of Family Health
Mean = 66.5625
Std. Dev. = 20.626578
N = 10
Frequency
4.0
3.0
2.0
1.0
0.0
.000
20.000
40.000
60.000
80.000
100.000
120.000
Family Health

Appendix M. CPQoL data across timepoints

CPQol Data across timepoints for the group (n=10), group A (n=5) and group B (n=5)




CP QOL Group A (GMFCS I-II)
CPQOL Score
100
90
80
70
60
50
40
30
20
10
0
Pre Dog
1 month
6 month
SW
FF
Pand PH
EW
Pain
Family Health
#REF!


Group B (GMFCS III-IV) CP QOL Scores
100
90
80
70
60
50
40
30
20
10
0
Pre Dog
1 month
6 month
SW
FF
Pand PH
EW
Pain
Family Health
#REF!