THE HEALTH BENEFITS OF RACERUNNING FOR THOSE WITH A MODERATE-TO-SEVERE NEURODEVELOPMENTAL DISABILITY.

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THE HEALTH BENEFITS OF RACERUNNING FOR THOSE WITH A MODERATE-TO-SEVERE NEURODEVELOPMENTAL DISABILITY.

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Declaration

I declare that the work in this thesis was carried out in accordance with the regulations of the University of Gloucestershire and is original except where indicated by specific reference in the text. No part of the thesis has been submitted as part of any other academic award. The thesis has not been presented to any other education institution in the United Kingdom or overseas.

Any views expressed in the thesis are those of the author and in no way represent those of the University.

Signed

Date

16.12.2022

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Abstract

Introduction: Neurodevelopmental disabilities can cause restrictions in mobility, increasing the risk of individuals developing secondary health conditions. For individuals with moderate-to-severe neurodevelopmental disabilities, it can be difficult to find activities which improve physical health and reduce this risk. RaceRunning is a developing disability sport designed specifically for individuals with moderate-to-severe disabilities, enabling them to move independently with the potential to improve physical health outcomes.

Aim: The present study aims to investigate the effect of RaceRunning on physical health in individuals with moderate-to-severe neurodevelopmental disabilities.

Method: Five males and 4 females with neurodevelopmental disabilities (18.1 ± 9.8y) completed a 12-week intervention consisting of a 1-hour RaceRunning session per week. Sessions involved a warm-up section, a skills section and a cool down. At baseline and 12 weeks, resting heart rate, blood pressure and thigh and calf circumference were measured. Isometric strength in both legs were also recorded. Cardiorespiratory response to RaceRunning was assessed via a 6-minute RaceRunning test and kinematics of running technique were recorded and analysed during the test.

Results: Significant decreases in resting heart rate were observed post intervention ($p = 0.038$) with no changes in blood pressure (systolic = $p = 0.242$) (diastolic = $p=0.846$). No significant differences were observed in thigh (left = $p=0.922$, right = $p =0.404$) or calf circumference (left = $p = 0.377$, right = $p = 0.310$). Knee flexion isometric strength was significantly higher in both left ($p = 0.021$) and right ($p = 0.006$) legs but only significantly higher in the left knee for knee extension ($p = 0.018$). Plantarflexion saw no significantly different (left = $p = 0.139$, right = $p = 0.075$) changes in isometric strength. There was no significant change in the 6-minute RaceRunning test and kinematic changes were only observed in the knee following 12 weeks of RaceRunning.

Conclusion: This preliminary evidence suggests there may be some health benefits of RaceRunning to those with neurodevelopmental disabilities. Recruiting a larger cohort and assessing other measures of health may better reflect these changes.

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List of Abbreviations

6MRT	-	6-minute Racerunner Test
ADLs	-	Activities of Daily Living
BP	-	Blood Pressure
CP	-	Cerebral Palsy
CoV	-	Coefficient of Variance
DB	-	Drawback
KE	-	Knee Extension
KF	-	Knee Flexion
GMFCS	-	Gross Motor Function Classification System
HP	-	Heel Plant
HIT	-	High Intensity Training
HR	-	Heart Rate
IC	-	Initial Contact
MST	-	Midstance
MSW	-	Mid-swing
NDD	-	Neurodevelopmental Disabilities
QoL	-	Quality of Life
RHR	-	Resting Heart Rate
TD	-	Typical Developing
TO	-	Toe-off
WHO	-	The World Health Organisation

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Chapter 1 – Introduction

Approximately 6% of the UK population have some form of neurological motor disorder that affects participation in a range of daily activities (Shafizadeh et al., 2019). Neurodevelopmental disabilities (NDD) encompass a highly heterogenous group of diseases that have a wide range of neurological problems (Shevell, 2010; Moreno-De-Luca et al., 2013). The etiology of NDD that negatively affects neurodevelopment include genetic predispositions, brain lesions and material/environmental exposures which can occur congenitally or be acquired during childhood (Whitney et al., 2020). It can result in neurological functioning and/or processing impairments involving cognition, communication, behaviour and motor functioning (Moreno-De-Luca et al., 2013; Whitney et al., 2020). Typically, NDD is clustered into developmental skill domains: gross and fine motor, speech and language, personal-social cognition, and activities of daily living (ADLs) (Shevell, 2010). Many individuals will possess more than one impaired developmental domain (Miller et al., 2013; Arim et al., 2017). These impairments can manifest into variables such as muscle weakness, reduced muscle size and impaired gait (Van der Linden et al., 2018; Shafizadeh et al., 2019). This in turn can lead to further complications such as restricted mobility, reduced cardiovascular responses and an overall reduction in physical health (Liptak et al., 2001; Jacobson, 2020).

The neurodevelopmental changes that occur in individuals with NDD have been linked to a reduction in physical activity (Jacobson, 2020; Whitney et al., 2020). Children with cerebral palsy (CP) have been reported to have excess body fat, lower levels of physical activity and underdeveloped musculoskeletal systems (Liptak et al., 2001; Stevenson et al., 2006; Whitney et al., 2020). Childhood obesity rates have been shown to be disproportionately higher by at least 38% in individuals with NDD compared to typically developed peers (TD) (Irby et al., 2012). This can link to an increased risk of developing secondary comorbidities in adulthood (Sukal-Moulton et al., 2022). Concerns over health problems across a 10-year period have been shown to increase amongst this population (29 to 54%, p=0.008), with restrictions in ADLs increasing by 26% (p=.002) (Benner et al., 2017). This could be reduced or slowed by participating in physical activity.

Approximately 70-75% of individuals with a disability do not participate in physical activity and have reduced habitual activity levels up to 30% below the recommended guidelines (Carlon et al., 2013; Verschuren et al., 2016; Kwon et al., 2019; Shafizadeh et al., 2019). Across a 7-year period, individuals with CP saw a reduction in walking by up to 20%, with further increases in fatigue and the intensity and frequency of pain (Opheim et al., 2009). Furthermore, individuals with NDD spend 63% more time being sedentary, with less time doing physical activity compared to TD peers (Ryan et al., 2014). This is exhibited in individuals with Spina Bifida, with reports of spending more time being sedentary per hour (49.5 ± 5.78min/hr) compared to TD peers (41.0 ± 5.76min/hr, $p = 0.001$) but also spending less time doing light ($p = 0.003$) or moderate ($p = 0.001$) physical activity. Prolonged bouts of sedentary activity increase cardiometabolic risk factors such as increases in abdominal obesity and elevated blood pressure (BP) (Ganz et al., 2021). This can increase the risk of developing secondary health conditions such as cardiovascular disease, ischemic stroke, type II diabetes mellitus, obesity and cancers (Kwon et al., 2019; Whitney et al., 2020). Furthermore the reduced level of physical activity in individuals with NDD can lead to a cycle of deconditioning, impairing multiple bodily systems and causing further subsequent reductions in physical activity (Durstine et al., 2000).

To prevent secondary health conditions and the reduction of quality of life (QoL) in those with NDD, there is a need to develop physical activities that are adapted for individuals with participation limitations and restrictions (Meester-Delver et al., 2007; Dahan-Oliel et al., 2012). Physical activity has been reported to have numerous health benefits in TD children, with improvements in cardiopulmonary health, strength, flexibility and endurance (Van Schie et al., 2022). However, due to problems in mobility, individuals with NDD may struggle to access activities which promote health benefits (Dolk et al., 2010; Rimmer et al., 2017; Van Schie et al., 2022; Sukal-Moulton et al., 2022; WHO, 2022). Interventions that are designed for NDD populations are often focussed on addressing the underlying developmental impairments such as poor muscle tone, decreased attention span, poor dexterity or difficulties with perceptual concepts (Dahan-Oliel et al., 2012). Interventions such as cycling, resistance training and strengthening programmes are available for individuals with NDD with

improvements in aspects such as muscular strength (Park & Kim, 2014). Swimming, walking and functional exercises are also available for individuals with NDD and have been shown to improve cardiorespiratory endurance (Verschuren et al., 2016). However, whilst these activities do provide both physical and psychological benefits, they are not always catered to severe conditions, presenting a big gap in participation (Wright et al., 2019; Van Lindert et al., 2023). In group activities, individuals with moderate-to-severe conditions are more dependent on others to help them to participate compared to more mild and ambulant severities (Wright et al., 2019). This can present a barrier to participation as many individuals wish to be independent in group-specific activities (Jaarsma et al., 2015; Wright et al., 2019). Whilst facilities may offer opportunities for participation in sports, the sports themselves may be deemed too physically challenging for individuals with more severe disabilities (Jaarsma et al., 2015). This presents the ongoing issue amongst NDD populations regarding access and availability of facilities, with the impairments associated with their condition resulting in many individuals being inactive.

One suggested intervention to overcome these barriers could be the sport of RaceRunning. RaceRunning is a sport that provides social and physical benefits to NDD participants (Sukal-Moulton et al., 2022). RaceRunning is a niche, developing disability sport designed specifically for individuals with moderate to severe impairments (gross motor function classification system [GMFCS] IV and V) (Kristjánsson, 2018; Shafizadeh et al., 2019; Kossakowski et al., 2021). Initially developed in Denmark, there are around 2000 bikes used worldwide which consist of a chest plate, handlebars, a saddle with thoracic support and a belt that securely fastens the individual into position as they manoeuvre (Figure 1.) (Kristjánsson, 2018; Shafizadeh et al., 2019). The sport is recognised on an international scale with a proposal of the sport for inclusion in the Paris 2024 Paralympic programme (RaceRunning.org, 2020, May 5). Currently, there are 13 clubs across England, Scotland and Wales (Quest, 2020, June 2). Whilst the sport is predominantly for individuals with CP and is governed by CP Sport, it is not exclusive to this group (CPISRA, 2021). It provides individuals with a variety of disabilities the opportunity to be active, with the frames being suitable from 5 years of age through to adulthood (CPISRA, 2021; Van der Linden et al., 2022). RaceRunning

can enable a population that have limited opportunities to take part in traditional sports (Kristjánsson, 2018; Johnson, 2021).

This links to the ‘F words (2001) in childhood disability’, a conceptual foundation designed by the International Classification of Functioning, Disability and Health (ICF) (Rosenbaum & Gorter, 2012; Soper et al., 2019). It consists of 6 categories: function, family, fitness, fun, friends and future, which contribute towards participation in physical activity within a broader socio-ecological context (Rosenbaum & Gorter, 2012; Soper et al., 2019). The implications of all ICF ‘F’ words can play a role in the care and QoL of individuals with disabilities (Rosenbaum & Gorter, 2012; Soper et al., 2019; Kerem-Günel et al., 2023). Function and fitness involve an individual’s body and structure in relation to their ability to participate in activities and tasks within a given environment, as often their impairments present challenges (Kerem-Günel et al., 2023). Fun refers to the personal factors of participation, with individuals with disabilities having lower rates of involvement in activities compared to able bodied individuals, due to activities not being as adaptive or as enjoyable (Rosenbaum & Gorter, 2012). Family and friends relate to the basic environment of the individual in terms of social interactions and an overall family-centred service as both often influence the wellbeing of the individual (Kerem-Günel et al., 2023). Future encompasses all aspects of the ‘F’ words in relation to the impact their condition has on their future development and in turn their overall QoL (Rosenbaum & Gorter, 2012). Overall, it is aimed towards providing a family-centred, strengths-based and holistic approach to child health and development (Cross et al., 2022). Engaging in these areas is important as it believed to provide a greater understanding of childhood disability, placing the emphasis on what an individual can do as opposed to their restrictions (Soper et al., 2019).

RaceRunning is a platform for inclusion amongst individuals with disabilities and could provide the opportunity for them to adopt an entirely different schema (Kossakowski et al., 2021). This can be through creating greater autonomy over their lives, promoting positive behavioural changes (Walkeden & Walker, 2015: Hartley 2019; Kossakowski et al., 2021) and encouraging a greater participation in physical activity for individuals with moderate-to-severe NDD (Bauman et al., 2006; Ryan et al., 2020b). Whilst RaceRunning is predominantly an individual sport, the formation of clubs across the UK

(Quest, 2020, June 2) enables individuals with NDD to form a community, building into the family and friends aspect of the ICF ‘F’ words. The physicality of RaceRunning itself targets both the function and fitness categories as the sport requires individuals to propel themselves forward and run, which studies have investigated further in relation to fitness outcomes such as cardiovascular fitness (Hjalmarsson et al., 2020). As the sport is specifically for individuals with disabilities, it is gives them the opportunity to enjoy participating in sport and be active (Van der Linden et al., 2022), which encompasses both fun and future aspects of the ‘F’ words as RaceRunning could lay the foundation to more activity and a better lifestyle.

Physical and psychological wellbeing is an important aspect of QoL, with physical activity being considered the most influential in improvements regarding autonomy and independence (Dahan-Oliel et al., 2012; Zhang & Chen, 2019). Whilst resistance exercises have been shown to produce the greatest physical benefits, teaching movements and sport skills provide both physical and psychosocial health benefits (Kapsal et al., 2019). In a recent survey, 93% of RaceRunning athletes reported improvements in self-confidence as a result of RaceRunning (Van der Linden et al., 2022). This is supported by Johnson (2021), as they investigated the psychological impact of RaceRunning, with athletes reporting the sport has improved their confidence, with a sense of inclusion and belonging being a big part of their social development (Johnson, 2021). Furthermore, they determined that these improvements in psychological wellbeing translated to greater positive QoL and health outcomes. This emphasises the importance of introducing RaceRunning to individuals with NDD.

Available research into RaceRunning have found improvements in QoL and overall wellbeing due to RaceRunning participation have been determined amongst surveys, whilst pilot and full-scale studies have reported improvements in bone health, competency using the racerunner (Johnson, 2021; Sukal-Moulton et al., 2022; Van der Linden et al., 2022; Van Schie et al., 2022), muscular thickness (9%) and cardiovascular and aerobic fitness (34%) (Donnell et al., 2010; Bryant et al., 2015; Phillips et al., 2017; Hjalmarsson et al., 2020). Locomotor adaptations, muscle fatigue and the influence of lower limb impairments on performance such as spasticity, poor voluntary motor control and reduced passive knee extension have also been assessed

within RaceRunning research (Kristjánsson, 2018; Van der Linden et al., 2018; Shafizadeh et al., 2019; Van der Linden et al., 2022). Although these findings are positive, due to NDD being a lifelong condition (Palisano et al., 2017), it is important to consider outcomes over a prolonged period. Overall, the research surrounding RaceRunning is very limited, with only a few studies focussing on the long-term effects of the sport on health.

RaceRunning is a sport that allows individuals with a wide variety of conditions the opportunity to participate in sport however, the high prevalence of individuals with CP that participate in RaceRunning often results in other NDD being excluded from research (Hjalmarsson et al., 2020; Kossakowski et al., 2021). Encouraging RaceRunning research to include a variety of disabilities and disorders would benefit the sport by spreading awareness. Researchers have stated that due to the specificity and technical requirements of RaceRunning, only individuals with CP can access the potential benefits (Kossakowski et al., 2021)**.** The limited research available causes speculation and a need for investigation to determine the extent of potential benefits across multiple NDD conditions. This underlines the importance of investigating the health benefits to RaceRunning on a population of those with NDD that have limited opportunities for physical activity.

Figure 1. RaceRunning frame example taken from the side and rear. Cushioning is added to the chest plate and saddle to provide comfort. The RaceRunning frame is adjusted to a comfortable setting. Helmets are worn throughout training and competition. Permission was granted by the participant and parent to use these images.

1.1 Aims

This study is part of a multicentred feasibility trial in partnership with Queen Margaret University. This feasibility study aims to investigate the effects of RaceRunning on measures of physical health in individuals with moderate-to-severe NDD.

Measures include resting HR and BP, thigh and calf circumference, knee flexor and extensor strength, ankle plantarflexion strength, and the distance travelled during the 6-minute RaceRunning test at baseline and 12 weeks.

Kinematic gait analysis via sagittal joint angles will also be measured at and between the stance and swing phases in the ankle, knee and hip pre and post 12 weeks.

1.2 Hypothesis

The study hypothesis is that there will be a significant difference in measures of physical health between baseline and 12-weeks of RaceRunning training.

The study null hypothesis is that there will be no significant differences in measures of physical health between baseline and 12-weeks of RaceRunning training.

Chapter 2 – Literature Review

2.1 Neurodevelopmental Disabilities

Neurodevelopmental Disabilities (NDD) refers to a diverse group of conditions that can impact affected individuals throughout their whole life (Dahan-Oliel et al., 2012). It affects approximately 2% of the general population, with cognitive, physical and emotional impairments of varying degrees (Angriman et al., (2015). Conditions include cerebral palsy (CP), congenital anomalies, intellectual disabilities, genetic syndromes and neurological disorders etc (Jones et al., 2007; Shevell, 2010; Rosenbaum et al., 2007; Dahan-Oliel et al., 2012; Thapar & Rutter, 2015; Whitney et al., 2020). CP remains the largest single cause of childhood physical disability within the developed world, with a prevalence around 2.0-2.5 per 1000 live births (Surman et al., 2009). Defined as a movement and posture disorder, it is used to describe motor syndromes that are caused by nonprogressive contusions, lesions or malformations during the early stages of the developing brain (Rosenbaum et al., 2007; Kristjánsson, 2018; Noorkoivet al., 2019; Jacobson, 2020). Congenital anomalies or more commonly referred to as birth defects, are structural or functional deviations that develop prenatally and may be identified before, at birth or later in life (WHO, 2022). Neurological disorders are structural, biochemical or electrical anomalies within the brain, spinal cord or other nerves throughout the body that result in a variety of symptoms (Siuly & Zhang, 2016). Research demonstrated that often these clinical manifestations and/or symptoms will change over time (Rosenbaum et al., 2007; Kvarnung & Nordgren, 2017; Gulati & Sondhi, 2018). The severity of the functional impairment can also alter due to a variety of factors (Hjalmarsson et al., 2020). It is therefore important to understand the various limitations associated with the condition severity as whilst some conditions are considered nonprogressive, the nature and severity of their disability may change over time.

2.1.1 Muscle Weakness

Understanding whether muscular strength can be developed or maintained by RaceRunning is of interest due to individuals with moderate-to-severe NDD having a reduced ability to weight bear, limiting their mobility and independence (Van der Linden et al., 2018; Ryan et al., 2020b). In general, individuals with physical disabilities may

present with muscle weakness due to inactivity, which can elevate the prevalence of secondary health conditions and complications such as reduced bone density and further reductions in muscular strength (Okuyama & Oka, 2009; Van der Linden et al., 2018; Shafizadeh et al., 2019; Whitney et al., 2020). In individuals with CP, muscle weakness can occur due to lesions within the brain, impairing cortical innervation of descending pathways, resulting in secondary adaptations such as smaller muscle size and reduced muscle activation (Hussain et al., 2014). Reports show a 30-35% decrease in muscular strength within the dorsiflexors and plantar flexors in individuals with CP, when compared to TD peers (Burdea et al., 2012). Decreased knee extension strength in adolescents is associated with further increases in disability in adulthood (Henriksson et al., 2019; Fraser et al., 2021). This is primarily due to the gradual deterioration of muscular function if left untreated (Boström & Ahlström, 2004). As individuals with severe impairments have a wide variation in motor control capacity and restricted mobility, determining muscle strength could be an important consideration. The combination of muscular weakness and reduced aerobic fitness are important risk factors that can cause subsequent disability (Henriksson et al., 2019). This can lead to a cycle of inactivity, increasing muscular weakness and potentially accelerating the progression of their condition (Durstine et al., 2000; Boström & Ahlström, 2004). This highlights the importance of developing interventions that promote muscular growth and strength, to reduce the overall deterioration of their condition.

Poor selective control of the ankle dorsiflexors and spasticity and muscle weakness of the plantar flexors can cause the foot to drop, increasing the incidence of tripping and falling (Mathewson & Liebar, 2015; Moll et al., 2017). Defined as an abnormal muscle contraction, spasticity is characterised by an increased velocity dependent tonic stretch reflex, in combination with exaggerated tendon jerks resulting from stretch reflex hyperexcitability (Jones et al., 2007; Etoom et al., 2018; Lindén et al., 2019). It can impair the full range of motion of a joint through a shorter muscle-tendon-complex length (Mockford & Caulton, 2010; Mathewson & Liebar, 2015; Jacobson, 2020). Within a normal muscle bundle, the composition of a muscle consists of 95% of muscle fibres (Lieber et al., 2003). Spastic muscles have been found to consist of 40% of muscle fibres with increases in intramuscular fat and connective tissue (Lieber et al., 2003;

Mockford & Caulton, 2010). In cross section, spastic muscle exhibits abnormalities such as fibre size variability, increased rounded and ‘moth-eaten’ fibres and in some instances, increased extracellular space (Lieber et al., 2003; Foran et al., 2005; Mockford & Caulton, 2010). This contributes towards the abnormal contractions often observed in individuals with spasticity (Jones et al., 2007; Etoom et al., 2018; Verschuren et al., 2018; Lindén et al., 2019). In combination, muscle weakness, spasticity and poor selective motor control can inhibit mobility, which subsequently worsens due to inactivity.

2.1.2 Reduced Muscle Size

Abnormal or reduced muscle tone is an underlying developmental impairment often observed within this population resulting in associated complications (Dahan-Oliel et al., 2012). In individuals with CP, muscle volumes have been found to be reduced up to 50% in the lower limbs compared to TD peers, particularly in the paretic limb (Shortland, 2009; Dahan-Oliel et al., 2012; Hussain et al., 2014). Children with NDD may appear weak due to the alterations within the myosin expression and potential structural abnormalities during the perinatal period (Mockford and Caulton, 2010). These include sarcomere length, fibre size, whole muscle length and cross-sectional area and viscoelastic properties (Theis et al., 2016; Mockford & Caulton, 2010). Gastrointestinal problems, growth, malnutrition and inactivity have also been shown to contribute towards decreased muscle size in individuals with NDD (Liptak et al., 2001; Sullivan, 2008; Opheim et al., 2009; Guleti & Sondhi, 2018; Kristjánsson, 2018; Jacobson, 2020). This can be related to the prevalence of sedentary behaviour, with increases in condition severity being associated with greater healthcare days and missed social activity opportunities (Stevenson et al., 2006). These limitations on opportunities for physical activity may lead to physical deterioration and further health complications.

Small muscle size can be associated with spasticity and limited activity, with a link towards cardiovascular and coronary diseases (Heitmann & Frederiksen, 2009; Chen et al., 2018). In relation to function, a study of 38 children with CP saw those with more severe impairments showed greater indications that decreases in muscle thickness linked to decreased functional capacity (Mockford & Caulton, 2010). This is due to reduced selective motor control in individuals with CP being unable to reflect the forces

produced during physical activity (Noble et al., 2019). It is therefore important to consider both muscle control and muscle size when conducting research on individuals with moderate-to-severe NDD to more accurately explain RaceRunning outcomes.

2.1.3 Gait/Kinematics

Restricted mobility in NDD populations is a key influence on physical health due to the limited opportunities to be active. Difficulties in maintaining an ankle isometric contraction within the fascicles and poor selective control of dorsiflexors can lead the foot to drop (Moll et al., 2017; Noorkoiv et al., 2019). This reduces walking efficiency, resulting in a higher consumption of oxygen, increasing heart rate and greater levels of fatigue (Almuhtaseb et al., 2014). Reduced knee and hip joint extension are also associated with inefficiency of gait in NDD populations, as 50% of the energy expenditure is utilised to lift the centre of mass (Dallmeijer et al., 2017; Noorkoiv et al., 2019; Hjalmarsson et al., 2020). The increased energy expenditure and fatigue can often influence decisions regarding physical activity participation (Mockford & Caulton, 2010; Mathewson & Liebar, 2015; Smith et al., 2019; Johnson, 2021). Furthermore, the inefficiency in walking gait plays a considerable role in the reduction of mobility, adding both physical and psychological factors towards inactivity within the NDD population (Ong et al., 2019). This can be through decreases in confidence when balancing and a greater perceived limitation in walking ability (Nogueira et al., 2013). Individuals reported ‘unwanted attention’ due to their gait, using walking aids as a result of dysfunctional gait, increased energy demands and overall, a reduced functional capacity (Gjesdal et al., 2020)**.** It is therefore important to investigate the different avenues of potential improvement in walking gait, kinematic values and overall mobility. As RaceRunning enables individuals with moderate-to-severe NDD to be more independent and active (Kristjánsson, 2018; Shafizadeh et al., 2019; Kossakowski et al., 2021) and there being limited research surrounding the topic (Shafizadeh et al., 2019; Maas & Vanwanseele 2022), understanding the kinematics of RaceRunning could help further develop the sport and encourage future research.

2.2 Reduced Physical Activity and Secondary Health Problems

Individuals with NDD have a high prevalence of health disparities with the associated risk often being attributed by condition severity (Jeon et al., 2015; Whitney et al., 2020).

Restricted functional mobility and increased sedentary behaviour have been shown to increase the risk of developing secondary health conditions and/or comorbidities (Carlon et al., 2013; Lauglo et al., 2016; Noorkoiv et al., 2019). Comorbidities refers to a list of relevant diseases, disorders or illnesses that coexist with another condition (Hall, 2006; Sethi, 2010). Physical activity has been shown to alleviate health-related problems, but is often dependent on the individual's ability to be active on a regular basis (Shafizadeh et al., 2019; Jacobson, 2020; Shirazipour et al., 2020; Johnson, 2021). However, approximately 70-75% of individuals with a disability do not participate in any physical activity, with habitual activity levels being 30% below recommended guidelines (Carlon et al., 2013; Shafizadeh et al., 2019). It has also been shown that immobility has been independently predictive of low levels of physical activity ($p = 0.007$) (Finlayson et al., 2009). Due to many individuals with moderate-to-severe NDD being unable to be active as a result of their condition, it is important to distinguish the consequences of inactivity within this population, with the potential of utilising RaceRunning to reduce these associated risks.

2.2.1 Cardiovascular Responses

Cardiovascular disease are the leading cause of mortality worldwide, with reduction in physical activity contributing towards this associated risk (Mc Namara et al., 2019). This is particularly prevalent amongst NDD populations due to restricted mobility (Whitney et al., 2020). Heart rate (HR) and blood pressure (BP) are widely used to assess health statuses and cardiovascular risk, with a resting heart rate (RHR) between 60-80bpm and a BP of 120/80 mmHg being deemed to be healthy amongst the general population (Cook et al., 2006; Ryan et al., 2015; Guo et al., 2019; Osibogun et al., 2020; Reedman et al., 2022). In conditions such as CP, they have a less efficient autonomic mechanism at rest and are less adaptive to exercise compared to TD peers (Gąsior et al., 2020). This is an important consideration to the study as NDD is a diverse population, adaptations such as reduced RHR may not be apparent across all participants.

When an injury occurs within the cerebral cortex and/or the cerebellum on either side, it can cause a central dysregulation of the sympathetic and parasympathetic outflow to the cardiovascular system, increasing HR (Shanks & Herring, 2013; Shaffer & Ginsberg, 2017; Findling et al., 2020). Individuals with CP have a higher average RHR (104.34 ±

20.30) compared to TD peers (84.17 ± 13.27) (Ferreira et al., 2011). Due to the nature of NDD conditions, the abnormal RHR places them at a greater risk of a cardiac event (Tadic et al., 2018). Studies have determined that individuals with a RHR of above 80bpm have a 47% increased risk of haemorrhagic stroke, 38% for ischaemic stroke and 65% of an unclassified stroke compared to a RHR of below 65bpm (Tadic et al., 2018; Mills et al., 2020). The prevalence of cardiovascular risk within NDD population emphasises the importance of engaging in physical activity to regulate and improve cardiovascular health.

Measuring RHR through heart rate monitors has proven to be a repeatable and valid method of assessing cardiac health amongst the general population (Engström et al., 2012; Chow & Yang, 2020). Engström et al., (2012) did this through determining a correlation coefficient of 0.97 – 1.0 in relation to an ECG machine for validity. For repeatability, they expressed the coefficient of repeatability variation in percent with the mean ECG measurements being 9% and the polar measurements at 11% and reported no significant differences. This is supported by Waninge et al., (2013), as they stated that the validity of the Polar monitors in recording heart rate had been tested against a variety of electrocardiograms. They also utilised the devices in their study whereby individuals with profound intellectual and multiple disabilities were assessed. Ge et al., (2016) also supports the accuracy of chest strap heart rate monitors as it produces a more accurate reading than other portable heart rate equipment. This endorses the use of the devices within current research and in future studies where individuals with disabilities are involved.

High levels of sympathetic activity are associated with increasing cardiovascular risks such as hypertension (Mancia et al., 2021). This can result from a dysregulation of afferent input and central integration of autonomic balance (Shanks & Herring, 2013). Hypertension is defined as a systolic BP above 140mmHg and/or a diastolic BP above at 90mmHg (Mills et al., 2020). Utilising non-invasive BP monitors is a common clinical practice amongst researchers as it is an easy and repeatable measure of collecting resting BP (Marshall et al., 2002). An investigation into the validation of non-invasive central BP devices was conducted, concluding that following the correct protocol, the BP monitors can be considered a reliable and valid method of assessing BP (Sharman

et al., 2017). These include listing the manufacturer model, defining, and using appropriate cuff sizes, familiarisation of the testing procedure to the participants and performing multiple tests with the removal of outliers if needed. Additional influences should also be considered when collecting BP measurements as whilst familiarisation of testing procedures is key for reducing psychological influences, the “white coat” effect has been reported in previous studies to increase systolic and diastolic BP (Kallioinen et al., 2017; Buljina et al., 2022). Research has shown that significant increases in systolic and diastolic pressure during the first 10 seconds of cuff inflation ($p<0.05$) (Gazzola et al., 2018). These findings outline the psychological influences associated with increased BP and should be made aware when utilising this method. In a study conducted by Jung et al., (2015), they evaluated the accuracy and validity of home blood pressure monitors, concluding that validated machines were 85.4% accurate. There were also reports of significant differences in accuracy in validated versus non-validated devices ($p = 0.017$). This highlights the importance of utilising validated BP monitors in addition to following correct procedures to increase the likelihood of valid and reliable data collection.

Restricted functional mobility and sedentary behaviours have been shown to cause vascular remodelling as blood vessels narrow, increasing the risk of hypertension (Carlon et al., 2013; Lauglo et al., 2016; Caruso et al., 2017; Noorkoiv et al., 2019; Song et al., 2020). Physical activity at a high intensity has been shown to be a key influence on the improvement of cardiovascular health (Lauglo et al., 2016; Van Biljon et al., 2018), however, in individuals with mobility or cognitive impairments, this may not be possible (Johnson, 2021). This is particularly apparent amongst more severe conditions, due to the added mobility restrictions associated with their condition (Liptak et al., 2001; Jacobson, 2020). As RaceRunning is often implemented at a high intensity (Donnell et al., 2010; Hjalmarsson et al., 2020), it is possible for cardiovascular changes to occur. However, this possibility has yet to be investigated, highlighting the importance of determining the potential for RaceRunning to improve cardiovascular health.

2.2.2 Cardiorespiratory Fitness

Cardiorespiratory fitness is reflective of cardiovascular, metabolic and functional health (Butler et al., 2010; Billinger et al., 2012). Individuals with NDD have been shown to

have poor cardiorespiratory fitness compared to TD individuals due to higher oxygen uptakes and lower physical work capacities (Butler et al., 2010; Ryan et al., 2015; Bricout et al., 2018; Hjalmarsson et al., 2020). In addition, it is important to consider the type of condition an individual has as well as the level of severity when assessing cardiorespiratory fitness. For instance, individuals with Morquio syndrome have been shown to have deformed thoracic cages, which in combination with paralysis of the respiratory muscles and the deposition of mucopolysaccharides in the soft tissues, can result in respiratory issues (Savci et al., 2006). In CP, differences in respiratory function can be related to condition severity, with reports that individuals with GMFCS level III having worse pulmonary capacity and weaker respiratory muscles compared to lower GMFCS classifications (Kwon & Lee, 2014). This can be attributed to reductions in walking efficiency, resulting in higher oxygen consumption, increasing fatigue and cause a cessation in physical activity (Almuhtaseb et al., 2014). Overall, this can hinder their ability to perform activities of daily living (ADLs), reducing independence and impairing multiple systems (Durstine et al., 2000). This can lead to a cycle of deterioration, deterring the individual from participating in ADLs (Ryan et al., 2015; Johnson, 2021).

Improvements in cardiorespiratory fitness can produce physiological adaptations that can improve the efficiency of the circulatory and respiratory transport system, providing numerous health benefits (Cairney et al., 2017). Furthermore, high habitual physical activity levels have also been shown to reduce arterial stiffness, lower aortic media thickness and improve endothelial function (Haapala et al., 2017). However, the combination of mobility restrictions and decreased cardiorespiratory fitness in individuals with NDD, makes it challenging for them to meet the recommended exercise guidelines (Carlon et al., 2013; Shafizadeh et al., 2019). Research has determined that the sedentary times amongst young people with CP was twice the maximum amount recommended (Carlon et al., 2013). This places them at greater risk of developing further health complications (Liptak et al., 2001; Carlon et al., 2013; Shafizadeh et al., 2019; Jacobson et al., 2020; Johnson, 2021). This stresses the importance of engaging in physical activities that have a cardiorespiratory element that is suitable for participation in NDD populations. As RaceRunning can be associated with cardiorespiratory fitness (Hjalmarsson et al., 2020), it could provide individuals with

moderate-to-severe conditions the opportunity to reduce secondary health risks, improve their ability to perform ADLs and reduce the deterioration of their condition. The limited research available that investigates this potential improvement from RaceRunning it highlights the need to explore cardiorespiratory fitness further within the present study.

2.2.3 Quality of Life

Individuals with NDD present an important public health issue due to the impact of their condition on the QoL of the affected individual and their family (Dolk et al., 2010). Individuals with mobility difficulties report lower health related QoL scores compared to TD peers as a result of reduced mobility, as it can restrict their accessibility to physical and social environments (Block et al., 2005; Liang et al., 2011; Lampousi et al., 2020). Links between loneliness and mental health problems in children with NDD have been established which may impact and extend into adulthood (Kwan et al., 2020). This can lead to social isolation, which is an objective lack of interactions or withdrawal from friends, relatives or the wider community (Freeman et al., 2020). Social isolation occurs more frequently in individuals with disabilities due to their special needs, demands and restricted ability to socialise (Block et al., 2005; Freeman et al., 2020). Low habitual activity can have a detrimental effect on physical, psychological, behavioural and emotional health (Ryan et al., 2015). Researchers often strive to improve QoL within NDD populations, with some research determining some of the psychological benefits of RaceRunning (Johnson, 2021; Van Schie et al., 2022). Sport can provide a variety of psychosocial benefits such as increased self-esteem, wellbeing, QoL and reduced anxiety (Barak et al., 2016). This was demonstrated by Kapsal et al., (2019), determining the largest effect sizes were associated with psychological outcomes ($g = 0.754$), behavioural outcomes ($g = 0.986$) and social outcomes ($g = 0.723$), with a 5.7% between-study variance. Developing and delivering effective intervention can provide physical and psychological benefits that can enable a better QoL for individuals with NDD.

Parents of children with NDD often experience a considerable burden from the need to attend specialty medical and allied health services such as neurology paediatrics and physiotherapy (Shevell, 2010; Novak-Pavlic et al., 2022). This can lead to greater

feelings of life dissatisfaction, with worse self-reported health statuses and health behaviours (Froehlich-Grobe et al., 2016). This can increase with condition severity due to having multiple health-related problems resulting in more days of social participation days missed (Boyle & Cordero, 2005; Froehlich-Grobe et al., 2016; WHO, 2022). The considerable burden placed on the individual and their support network demonstrates the need for effective and efficient long-term interventions (Carroll, 2019; Mitrushina & Tomaszewski, 2019) to improve overall wellbeing and health.

2.3 Interventions Available to Improve Physical Activity

Encouraging individuals with NDD towards physical activity can present a multitude of barriers (Shirazipour et al., 2020). Factors such as lack of facilities, transport limitations and a lack of inclusivity have been shown to be some of the main issues regarding physical activity participation (Rimmer, 2005; Jaarsma et al., 2015; Rimmer et al., 2017; Gagnon, 2020). This was demonstrated by Rimmer (2005) who determined that within indoor facilities, accessibility was restricted due to difficulties opening doors, smaller facilities and equipment such as cardiovascular machines being on different floors with no access apart from stairs. The outdoor environment can also be restricted due to the streets not having curbs, poorly lit facilities and the terrain being too difficult for individuals with disabilities to manoeuvre (Rimmer 2005; Rimmer et al., 2017). Similarly, whilst in the UK the curriculum contents are intended to provide students with disabilities the opportunity to participate in physical activity, it is often not applied, excluding them from such activities (Tant & Watelain, 2016). Healthcare practitioners and researchers are continuing to implement interventions to maintain physical activity and mobility (Park & Kim 2014; Kalkman et al., 2019), with an emphasis on the importance of designing interventions for their specific needs.

2.3.1 Established Interventions

There are a variety of interventions that promote the integration and participation in physical activity in individuals with NDD despite limitations due to impairments (Shevell, 2010). Functional electrical stimulation is used to stimulate impaired motor control muscles, causing the muscle to contract (Moll et al., 2017; Armstrong et al., 2020). After 8 weeks of functional electrical stimulation, cycling combined with goal-directed training and adapted cycling training, gross motor function (GMFM-88) significantly improved

from 52.8 to 62.6 in individuals with CP (GMFCS levels II – IV) (Armstrong et al., 2020). These interventions can result in specific muscular strength changes being observed, through improvements in active dorsiflexion angle, strength and overall selective motor control, balance and gait kinematics following a systematic review on functional electrical stimulation (Moll et al., 2017). Through a meta-analysis of cycling, resistance training, functional electrical stimulation and strengthening programmes, it was established that 40–50-minute sessions three times per week was the most optimal for muscular strength improvements (Park & Kim, 2014). This demonstrates that regardless of intervention type, improvements in muscular strength can be improved if conducted for a set time over a prolonged period.

Endurance training interventions have been shown to reduce RHR (Van Biljon et al., 2018), with positive correlations between RHR-decreasing effect and initial RHR (Reimers et al., 2018). Van Biljon et al., (2018) demonstrated that across 5-weeks, improvements in RHR were observed through high intensity interval training (92.0 ± 14.1 bpm to 79.2 ± 10.2 bpm), moderate-intensity continuous training (87.2 ± 10.6 bpm to 82.6 ± 12.8 bpm) and/or a combination of both (92.7 ± 13.3 bpm to 80.3 ± 10.3 bpm). High intensity interval training is often utilised in conjunction with endurance training to improve cardiorespiratory responses. Studies have determined that short-term cardiorespiratory training (approximately 2-4 months), increased aerobic fitness by 18-22% whereas long-term training (approximately 8-9 months) improved by 26-41% (Butler et al., 2010). Similar results were presented by Lauglo et al., (2016), as across 24 high intensity interval training sessions (2 – 4 sessions per week), there was a significant increase in VO2max of 10% and a decline in percent utilisation of VO2max (48.8 vs 39.4). High intensity interval training has been shown to reduce C-reactive protein (CRP) ($p=0.016$) an indicator for arterial inflammation, reducing the risk of developing coronary heart disease (Casas et al., 2008; Van Biljon et al., 2018). These physiological alterations could aid an individual in the improvement of cardiovascular and cardiorespiratory health, reducing the overall risk of the development of secondary health conditions. This emphasises the importance of long-term interventions to improve cardiovascular and cardiorespiratory health.

2.3.2 Interventions for moderate-to-severe conditions

Whilst many interventions promote an increase in physical activity, some inclusive programmes available may not be appropriate for everyone with a disability (Shields & Synnot, 2016). This is applicable in individuals with moderate-to-severe NDD (GMFCS III – V) as they have difficulties weight bearing and are more reliant on mobility aids than those with milder severities (GMFCS I – II) (Van der Linden et al., 2018; Shafizadeh et al., 2019). Limited access to adapted physical activities for moderate-to-severe conditions can prevent them from being active, making them more susceptible to additional health consequences (Surman et al., 2009; Ryan et al., 2020b). This is important to establish, as whilst interventions may be available, due to the severity of their condition they may not be physically able to participate, further restricting their opportunities to be active.

2.3.2.1 Boccia

Boccia is one of the most popular adapted sports for individuals with severe musculoskeletal disorders (Faria et al., 2014). A minimum of two players will compete, with the aim of throwing their ball closest to the target ball, 'the Jack' (Barack et al., 2016). It provides an opportunity for individuals with disabilities to integrate with a variety of people, reducing the feelings of social isolation and improving QoL (Łosień et al., 2018). In a longitudinal Boccia study across a 4-month period, psychological QoL saw improvements up to 29% (Barack et al., 2016). However, whilst it does provide many psychological benefits, there is little physiological benefit from participation that could reduce the risk of secondary health conditions due to the low cardiorespiratory demand (Carlon et al., 2013; Faria et al., 2014; Łosień et al., 2018; Hjalmarsson et al., 2020). The demand for sports and interventions to be developed that provide physiological and psychological benefits is prevalent amongst individuals with moderate-to-severe NDD.

2.3.2.2 Adapted Football

It has been established that in many instances, opportunities to participate in sport is often not applicable for individuals with more severe disabilities due to it being too physically challenging for them to engage (Jaarsma et al., 2015). Adapted sports such as powerchair football is a sanctioned sport available to individuals with severe mobility

impairments (Barfield, Newsome & Malone, 2016). It is one of the fastest growing UK disability team sports, involving adapted electric wheelchairs for mobility and an enlarged football from which they play with (Muscular Dystrophy UK, 2015; Barfield et al., 2016). However similar to Boccia, whilst it the sport provides many psychological benefits including improved QoL (Jeffress & Brown, 2017), reports of physical benefits are limited. This still places them at risk of developing secondary health conditions.

2.3.2.3 RaceRunning

RaceRunning is a sport discipline based on strength and stamina that can enable those with moderate-to-severe NDD to be active (Kossakowski et al., 2021). Training sessions are designed towards developing the basic skills in using the RaceRunning frame, to progress onto a moderate-to-vigorous exercise intensity (Reedman et al., 2022). Many research articles have focussed on the psychological aspects of RaceRunning, with improvements exhibited in QoL, psychosocial aspects of life and overall health and wellbeing (Bryant et al., 2015; Johnson, 2021; Van der Linden et al., 2022). Physical benefits have also been investigated however available research is very limited.

Through ongoing research within RaceRunning, the 6-minute RaceRunning test (6MRT) was developed to enable researchers assess the physical capabilities of RaceRunning (Bolster et al., 2017; Hjalmarsson et al., 2020). Some researchers have stated that the 6MRT appears to be not exhausting enough, with some implications regarding cardiorespiratory fitness and experienced fatigue (Kristjánsson, 2018). The reliability and construct validity of the 6MRT was assessed by Bolster et al., (2017), via calculating the intraclass correlation coefficient (ICC), standard error of measurement (SEM) and the smallest detectable differences (SDD) of the test. They determined that the ICC of the test was 0.89 amongst GMCS level III and 0.91 for GMFCS level IV, supporting the use of the 6MRT as a reliable and repeatable method. Furthermore, they validated the test by comparing the two groups, finding that lower GMFCS levels translated to better 6MRT performances on two separate occasions, with a mean distance covered was 413 metres in GMFCS III and 239 metres in GMFCS IV after the second set of testing. This is important as the 6MRT could be used to track initial progress when first using the racerunner, which can be applicable to the present study (Johnson, 2021). Studies have utilised the 6MRT as a means of investigating the long-

term effects utilising 6MRT over a prolonged period (Sperl, 2018; Hjalmarsson et al., 2020; Sukal-Moulton, 2022) achieving mixed results, emphasising the demand for more research to be conducted utilising the test as a means of cardiorespiratory assessment.

Limited research has been conducted on the potential muscular adaptations from a prolonged RaceRunning intervention. In a 12-week RaceRunning study, medial gastrocnemius thickness increased by 9% proposing that the combination of low daily exercise and a low starting point, stimulated the hypertrophic response (Hjalmarsson et al., 2020). Measuring muscle thickness though anthropometric measurements such as muscle circumference has been utilised to estimate appendicular muscle mass, particularly calf circumference (Santos et al., 2019). This is beneficial as the NDD population reportedly have smaller muscles and increased muscular atrophy compared to TD populations (Verschuren et al., 2018). Thigh circumference is also used as a determinant of health, due to a low thigh circumference being associated with increased risk of cardiovascular mortality (Chen et al., 2020). In combination with restricted mobility, this could increase the risk of further health complications.

Utilising a tape measure has been a reliable method of recording muscle circumference, with minimal modifications (Kennedy et al., 2022). An investigation into the reliability of tape measurement assessments was conducted, determining the reliability coefficient of measures being 0.996 (Labs et al., 2000). Previous studies have utilised the anthropometric measurements as a basis for assessing the validity and reliability of other new established methods, with supportive findings in terms of reliability but varying degrees of validity depending on the participants recruited (Xia et al., 2019; Kennedy et al., 2022). In a validity study by Layec et al., (2014), they determined that whilst anthropometric measurements often overestimated muscle volume, it was proportional to the volume determined by MRI with close correlation scores between the two (r^2 = 0.89 in the thigh and 0.98 in the lower limb). They also stated that these results confirmed anthropometric measurements provide a valid index for muscle volume and with appropriate corrections, could be applicable for individuals with severe muscle atrophy. Following the guidelines (Labs et al., 2000), anthropometric measurements provide repeatable and cost-effective methods that although time-consuming, can be produced on a large scale. It is important to understand the various reliability, validity

and repeatability of selected methods in order to gage the potential limitations associated within the intended study.

As muscle weakness is one of the main symptoms associated with individuals with NDD (Lindén et al., 2019; Ryan et al., 2020b), studies have been conducted using isometric strength tests to determine RaceRunning classifications (Van der Linden et al., 2021). Isometric strength has not been conducted in relation to health and the potential long-term effects of RaceRunning. Furthermore, whilst these interventions are beneficial, they utilise individuals with experience within the sport. It is important to understand the extent of RaceRunning on inexperienced individuals, as it gives researchers a greater overview of the sport as a potential therapeutic treatment intervention. Considerations for hand-held dynamometry such as accounting for reported measurement error, separating muscle groups into impaired and less impaired, and reporting strength in relation to body weight or as a torque measurement were reported when assessing individuals with CP (Crompton et al., 2007). When muscle groups are stabilised, the hand-held dynamometer is a valid source as compared to an isokinetic dynamometer, with strong positive correlations between the two for both flexor ($r = 0.72$) and extensor isometric strength ($r=0.82$) (Muff et al., 2016). Furthermore, reproducibility saw a coefficient of variation to be 3.2 - 4.2%. An investigation into the reliability of the handheld dynamometer in individuals with CP was conducted determining that correlation coefficient values of single use being between 0.7 and 0.9 across all lower limb muscle groups (Willemse et al., 2013). Furthermore, additional testing reduced the smallest detectable change from 9% to 14%. Overall, utilising hand-held dynamometers has been determined to be a valid and reproduceable method of assessing isometric strength in individuals with NDD (Crompton et al., 2007; Willemse et al., 2013; Muff et al., 2016).

Due to the limited research available on RaceRunning, it is important to explore other avenues that can be developed and contribute towards future research. Physical activity interventions such as RaceRunning are being designed with the aim to improve mobility and functionality (Ryan et al., 2020b; Johnson, 2021). Researchers have established five different RaceRunning styles that were dependent on disability type (Mac Cann, 2018). Shock absorption patterns have also been established in RaceRunning, with

resemblances to forefront runners without disabilities as characterised by an active peak during the initial stance phase (Shafizadeh et al., 2019). This emphasises the importance of identifying kinematic values on a variety of individuals and the potential of determining gait kinematic values in motion across a prolonged period.

When collecting kinematic values, research has been conducted in a variety of ways. In a 12-week of RaceRunning training intervention it was established that in the less-affected side, passive hip flexion significantly increased ($p= 0.015$) whilst on the more-affected side, passive ankle dorsiflexion significantly decreased ($p = 0.026$) (Hjalmarsson et al., 2020). Although these measures were collected through a physical examination at rest, the findings provide useful information in terms of the potential use of kinematic values in a RaceRunning intervention. An investigation of 2-dimensional video analysis determined it to be an accurate measurement tool when recorded within the camera's measurement plane with less than a 2° of measurement error when held in a fixed position error (Peebles et al., 2021). Furthermore, researchers found no clear trend on optimal kinematic parameters determining a better validity and reliability when categorising movement patterns rather than quantifying specific angles (Hensley et al., 2022). This is important as it ensures an appropriate selection of methods, with considerations to measurement parameters and categorising movements.

2.4 Summary

In conclusion, NDD populations are at risk of developing secondary health conditions and further health complications due to restricted mobility. This increases with severity as individuals classified as moderate-to-severe are unable to participate in physical activity on a regular basis. This is due to a multitude of barriers, of which one is the limited adaptability of sport. This creates a cycle of deterioration, with the subsequent cessation of physical activity. Whilst there are some sports available such as Boccia and Powerchair Football that provide individuals with moderate-to-severe disabilities the opportunity to participate and provide psychological benefits, there is little to no cardiorespiratory demand. It is therefore important to establish sports and interventions that can provide physiological benefits in addition to psychological. RaceRunning is a new and developing sport with reports of physiological improvements over a short and prolonged period. However, the research available is very limited, highlighting the need

for additional studies to focus on reproducible practices but also introduce aspects of RaceRunning that have not previously been considered.

Chapter 3 – Methods

3.1 Participants

Based on previous research (Hjalmarsson et al., 2020), an observed power of 0.8 and an effect size of 0.426, sample size calculations revealed an initial recruitment aim of 10 participants. 20 individuals with NDD who had been taking part in RaceRunning for <1 month were approached for the study. Participant recruitment was staggered across the year due to the timings of training sessions and the locations of the RaceRunning clubs. 15 individuals gave consent, 6 withdrew after baseline testing as they were not regularly attending RaceRunning sessions. The remaining 5 males and 4 females (18.1 ± 9.8y) completed the 12-week study. Participants were recruited across three RaceRunning clubs based in Cardiff (n = 3), North Devon (n = 3) and Gloucester (n = 3). Exclusion criteria consisted of no lower limb surgery within 12 months and no musculoskeletal injury within the last 6 months. Ethical approval was obtained from the University of Gloucestershire Research Ethics Committee. Information sheets and written and verbal informed consent was gained from participants (Appendix 1.2 and 1.4) and parents/guardians (if under the age of 18 y) (Appendix 1.3 and 1.4) prior to the commencement of the study.

3.2 Study Design

Participants were assessed at baseline (0 weeks) and 12 weeks. At each point, participants completed a series of tests measuring resting HR and BP, isometric strength of the knee and ankle, cardiorespiratory fitness, muscle circumference and running technique. Each week throughout the study period, participants took part in a 1-hour RaceRunning session led by an experienced coach who had attended a RaceRunning coaching course. Training generally consisted of a warm-up, skills that were dependent on the aims of the session and a cool down (Johnson, 2021). Coaching style of each location slightly differed, with the location in Gloucester focussing on competitive elements, Cardiff was recreationally based, and North Devon was a combination of both. All participants adhered to between 75-90% of all sessions and the results were collected at baseline and at 12-weeks. Due to the limited research

available in RaceRunning and the study being a feasibility study, there was no control group.

3.2.1 Ethical Principles

As the study recruited individuals that are within the vulnerable population category, ethical principles are especially important when conducting this intervention. To ensure non-maleficence and beneficence, participants always had a parent, carer or coach with them throughout testing procedures. To ensure autonomy, participants and parents were reminded that up to the point of submission, the individual was allowed to withdraw at any time. The principle of justice was upheld by treating the participants equally and fairly, ensuring that they understood the given tasks. Consent was given by the individual and from the parent/guardian if they were under the age of 18 either in writing or verbally. Confidentiality and anonymity were ensured by anonymising all data collected, removing any key identifiable features. All data collected will be held in a secure location for up to 5 years after the intervention from which it will be disposed of. A pilot study was also conducted to ensure the tests ran smoothly but also to reduce the risk of harm to the participants.

3.2.2 Pilot study

A pilot study was conducted prior to the main intervention. One participant separate from the main intervention group, completed the initial testing for all measures within the study. This ensured that the measures were suitable for the population and that the tests were conducted correctly. Any issues with tests were amended prior to the main intervention. This enabled the tests to be run smoothly and ensure the safety of the participants.

3.3 Procedures

Demographic information (Table 1.) was gathered prior to the commencement of this study. At each visit, measures of HR, BP, muscle circumference, isometric strength, cardiorespiratory fitness and running technique were taken.

3.3.1 Heart rate

HR monitors and ultrasound gel were applied and attached to the chest. Participants were asked to sit for five minutes prior to recording. Heart rate readings were then

recorded for a minute using the Polar H7^{TM} HR monitors (Models Fs3c, FT1, 610i, 810i, RS800CX, RCX5, FT7, Polar, Electro Oy, Kempele, Finland).

3.3.2 Blood pressure

A BP cuff was placed on the middle upper left arm (Omron M3 Intellisense device, Omron Healthcare, Kyoto, Japan) however if readings could not be obtained then BP was measured at the wrist (Omron RX-M, HEM-628-E, Omron Corporation, Kyoto, 600-8530, Japan). In total three participants did not record BP readings due to equipment failure or not giving consent for this section of the study.

3.3.3 Circumference

Thigh circumference was measured using an anthropometric tape measure (Silverline Tools Ltd, Yeovil, UK) at 50% of the line from the anterior superior iliac spine to the superior part of the patella whilst calf circumference was measured at the most prominent part of the muscle belly (Ryan et al., 2020b) to represent muscle size. As some conditions do not have an affected side, measurements were labelled as 'left' and 'right' for later analysis. Due to all tests being conducted outdoors, participants wore clothing appropriate for the weather conditions but wore the same for both baseline and 12-week testing periods. This ensured that the thickness of the material did not interfere during the anthropometric measurements. Three measures at each landmark were taken and averaged.

3.3.4 Strength

For the isometric strength tests, a handheld dynamometer pad (Lafayette Manual Muscle Test System, Model 01163, Lafayette Instrument Company, Lafayette, IN, USA) was placed on a circumferential line of the lateral malleolus (ankle) for knee flexion and extension (Fosang & Baker, 2006). Whilst sitting down, the leg remained in a neutral position (with the knee flexed at approximately 90 degrees) whilst the handheld dynamometer was placed on the anterior (front) surface of the leg for extension (left coefficient of variation [CoV] = 16.74%, right CoV = 17.39%) and posterior (back) surface for flexion (left CoV = 12.38%, right CoV = 13.94%). For plantarflexion strength, the knee remained in full extension, with the handheld dynamometer positioned on the metatarsal head (left CoV = 9.88%, right Cov = 12.61%). The researcher assisted in

moving the foot into the initial position (approximately 90 degrees or ‘neutral’) before the handheld dynamometer was placed, followed by stabilising the leg throughout the movement. Both left and right legs were assessed. For all strength assessments, the movement was demonstrated. Participants were instructed to perform three maximal trials for each movement which was recorded and averaged. Each trial consisted of a maximal isometric contraction for five seconds, with a 30 second rest in between to minimise variability due to fatigue. Verbal encouragement was given throughout.

3.3.5 6-minute run test

The 6-minute RaceRunning Running test (6MRT) is a reliable method of assessing cardiorespiratory fitness in this population (Bolster et al., 2017; Hjalmarsson et al., 2020). Participants began with a warm-up. Participants were asked to run for 6 minutes around a track and to cover as much distance as possible in that time. The distance covered was recorded as well as average speed over the 6 minutes. Verbal encouragement was provided throughout. Due to the intensity of 6MRT and the gradual increase in fatigue, this test was conducted on a separate occasion to all other tests. This ensured that participants could perform to the best of their ability.

3.3.6 Kinematic analysis

Reflective tape was placed on the participant’s greater trochanter, lateral femoral epicondyle, lateral malleolus and fifth metatarsal on the right side of the body. To record the kinematic changes during running, a 2D Camera (Canon Inc., Tokyo, Japan) on a tripod was placed 5 metres back, perpendicular to the running track and triangulated to two cones 5 metres apart. This ensured the optical axis of the camera was aligned with the centre of the capture area on the track. Pan, roll and tilt were also adjusted. Height and zoom of the camera were also adjusted in accordance with the hip, knee and ankle.

Video recordings of the participant’s gait were taken during the first initial stages of the 6MRT. It was then uploaded and analysed using Quintic Biomechanics version 26 (Quintec, Sutton Coldfield, UK). Speed across the 5-metres was also calculated. Analysis of hip knee and ankle were conducted in the sagittal plane, focussing on flexion-extension of the hip and knee. In the ankle, angles are in the sagittal plane and focus on dorsiflexion-plantar flexion. Reference points in the ankle throughout gait

include initial contact, mid-stance and toe-off during the stance phases and drawback, mid-swing and heel plant (Klaewkasikum et al., 2022). Four participants did not consent to be filmed and therefore were not included.

3.4 Data Analysis

Descriptive statistics (mean and standard deviation) were calculated for all tests using Excel (Version Excel 365). IBM SPSS (Version 28) was used for data analysis. The data collected was tested for normal distribution and differences between 0 and 12 weeks were assessed using a series of paired samples t-tests or Wilcoxon tests in the case of non-parametric data. An alpha level of $p \leq 0.05$ was set for all statistical tests. The effect size calculated was referenced to Cohen's D, which sees small effect sizes around 0.2, medium effects around 0.5 and larger effect sizes around 0.8 (Goulet-Pelletier & Cousineau, 2018). Due to performing multiple t-tests, it does increase the possibility of a type 1 error whereby the null hypothesis is rejected (Banerjee et al., 2009) and so it should be considered when reviewing the results of the intervention.

Chapter 4 – Results

The study investigated a variety of areas through a series of t-tests and Wilcoxon tests to determine whether RaceRunning would improve initial scores, with mixed results. Table 1 illustrates the demographics of the recruited participants. Specific results have been discussed below, with interests in RHR, isometric strength and kinematic values.

Table 1. Demographic information within this study.

	Description of participants (n=9)
Age (y)	18 ± 10
Sex	
Male	5
Female	4
Primary Diagnosis	
Ataxic CP	2
Diplegia CP	1
Dyskinetic (Dystonic) CP	1
Spastic Diplegia	1
Progressive Ataxia	1
Spina Bifida + CP	1
Morquio Syndrome	1
Undiagnosed	1

4.1 Heart Rate and Blood Pressure

There was a significant reduction in RHR (0 weeks: 84 ± 22 bpm, 12 weeks: 74 ± 15 bpm) ($z = -2.079$, $p = 0.038$) (Figure 2) with an observed power of 0.541 and a medium effect size of 0.53. However, there was no significant change in resting systolic BP (0 weeks: 137 ± 18 mmHg, 12 weeks: 144 ± 19 mmHg) and diastolic BP (Figure 4) (0 weeks: 93 ± 10 mmHg, 12 weeks: 95 ± 28 mmHg) (systolic: $t = -1.32$, $p = 0.242$; diastolic: $t = -0.846$, $p = 0.846$). Within systolic BP, the observed power was 0.278 and effect size was 0.38 whilst diastolic BP resulted in an observed power of 0.70 and effect size of 0.10.

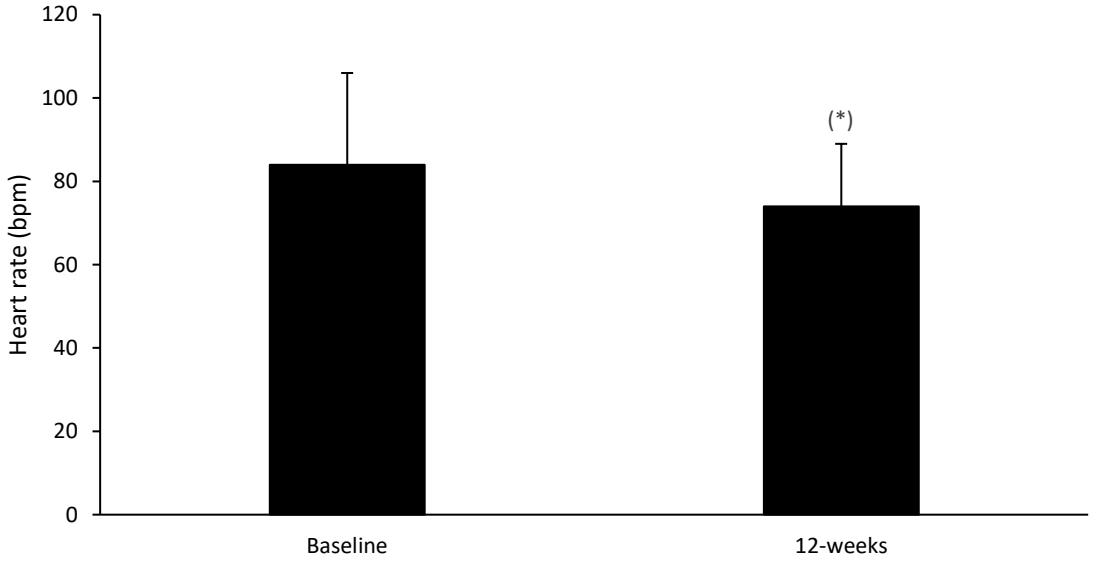

Figure 2. Differences in resting Heart Rate between baseline and 12-weeks of RaceRunning training, $p = 0.038$ (*).

4.2 Circumference

There was no significant change in thigh circumference in the left (0 weeks: 43.4 ± 10.6 cm, 12 weeks: 43.5 ± 11.2 cm) ($t = -0.101$, $p = 0.922$) or right legs (0 weeks: 44.1 ± 11.2 cm, 12 weeks: 43.1 ± 10.9 cm) ($t = 0.882$, $p = 0.404$) after 12 weeks of RaceRunning. For thigh circumference, the left observed power was 0.51 compared to the right which was 0.122. A small effect size of 0.01 in the left and 0.09 in the right was reported.

No significant changes were reported in calf circumference in the left (0 weeks: 32.9 ± 8.1 cm, 12 weeks: 31.6 ± 6.1 cm) ($t = 0.943$, $p = 0.377$), or right legs (0 weeks: 30.9 ±

6.38 cm, 12 weeks: 31.7 ± 6 cm) (t = 1.094, p = 0.310). For calf circumference, the left observed power was 0.130, whilst the right was 0.158. A small effect size of 0.17 in the left and 0.14 in the right was reported.

4.3 Knee and Ankle Isometric Strength Test

There was a significant increase in knee flexion (KF) strength in both the left (45.2 ± 44 Nm to 64.5 ± 48.8 Nm) (z = -2.310, p=0.021) and right legs (41 ± 29.8 Nm to 71.1 ± 51.1 Nm) (z = -3.743, p = 0.006) following 12 weeks of RaceRunning (Figure 8.). Observed power was 0.679 in the left and 0.904 in the right. A medium effect size of 0.42 on the left side was calculated, whilst on the right there was a large effect of 0.61.

Significant improvements were also demonstrated in knee extension (KE) strength in the left leg (87.8 ± 53.7 Nm to 110.8 ± 63.7 Nm) (t = -2.967, p = 0.018) with an observed power of 0.739 and a medium effect size of 0.39. In the right leg non-significant results were reported (90.6 ± 53.1 Nm to 106.1 ± 52.8 Nm) (t = -2.079, p = 0.071) (Figure 9) with an observed power of 0.448 and a small effect size of 0.29.

No significant changes were found in plantarflexion strength observed after 12 weeks of RaceRunning in the left (56.3 ± 42.3 Nm to 74.2 ± 39.9 Nm) (t = -1.518, p=0.167) and right legs (44.7 ± 32.5 Nm to 62.1 ± 33 Nm) (z = 1.779, p=0.075). Observed power was 0.268 in the left and 0.508 in the right. Medium effect sizes of for both left (0.43) and right (0.53) was reported.

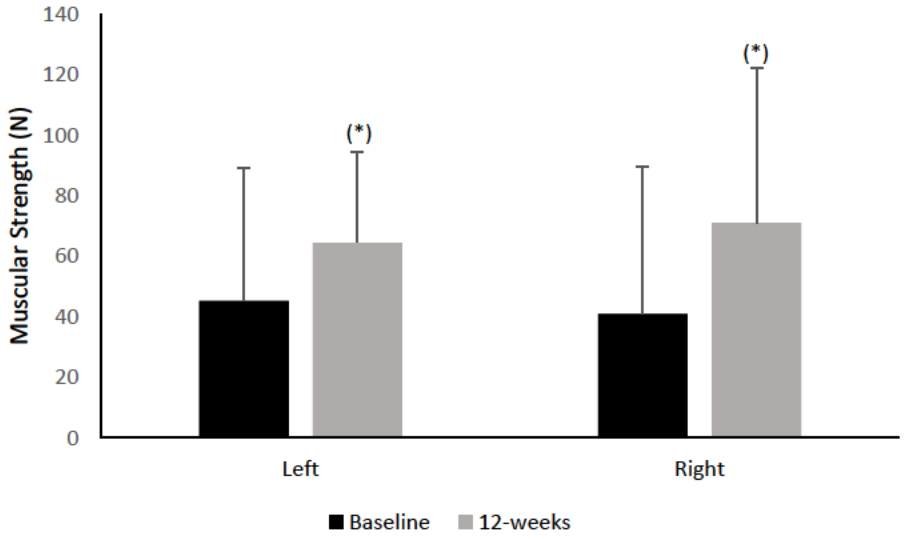

Figure 3. Differences in knee flexor strength for the left and right legs between baseline and 12-weeks of RaceRunning training, p<0.05(*).

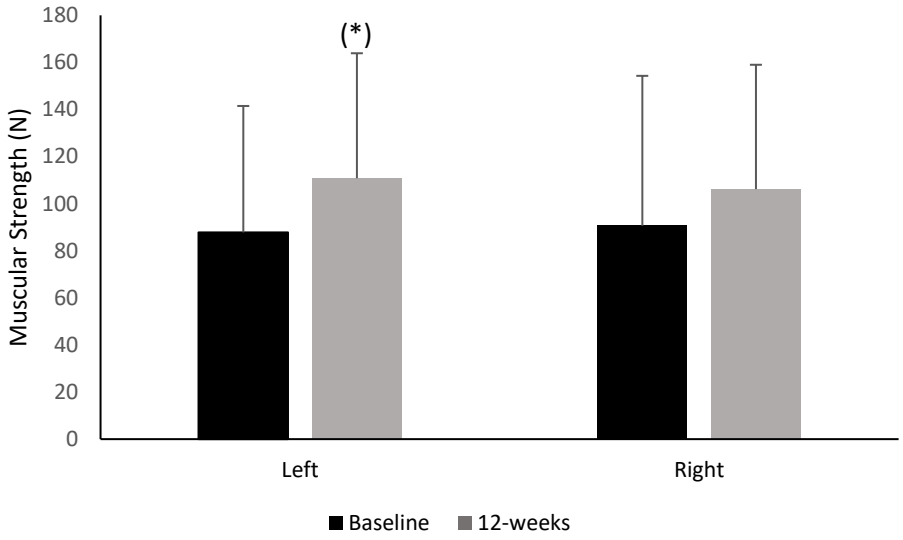

Figure 4. Differences in knee extension strength for the left and right legs between baseline and 12-weeks of RaceRunning training, left - $p<0.05$(*), right - $p>0.05$.

4.4 6-minute RaceRunning Test

There was no significant change in distance covered over the 6-minute test between baseline (802 ± 412 m) compared to 12 weeks (722 ± 392 m) ($t=1.672$, $p=0.155$). Observed power was 0.275 with a small effect size of 0.20.

There was also no significant change in average speed over the 6 minutes at baseline (2.2 ± 1.2 m/s) and 12 weeks (2.0 ± 1.1 m/s) ($t = 1.671$, $p = 0.156$), with an observed power of 0.253 and a small effect size of 0.20.

4.5 Kinematic Values and Speed

There was no significant change in 5m running speed after 12 weeks of RaceRunning (0 weeks: 3.2 ± 2.1 m/s, 12-weeks: 2.3 ± 1.3 m/s) ($t = 1.711$, $p = 0.148$), with an observed power of 0.275 and medium effect size of 0.55.

No significant changes in ankle angle (Table 2) or hip angle (Table 4) throughout the gait cycle were observed after 12 weeks of RaceRunning. At the knee, there was a significant decrease in the amount of knee flexion from toe-off to drawback phase ($t = -2.966$, $p=0.041$), drawback phase ($z = -2.023$, $p = 0.043$) and drawback to mid-swing phase ($t = -7.598$, $p = 0.002$), after 12 weeks of RaceRunning (Table 3).

Table 2. Average and SD of ankle kinematic values at baseline and 12-weeks

	Baseline (°)	12-Weeks (°)	Significance (p value)	Observed Power	Effect size
Ankle					
Initial Contact	-2.5 ± 15.47	-0.16 ±10.82	0.829	0.054	0.18
IC -> MST	1.26 ± 14.98	0.13 ± 9.78	0.874	0.052	0.09
Midstance	7.36 ± 14.11	6.6 ± 12.25	0.893	0.053	0.06
MST ->TO	3.4 ± 12.14	1.55 ± 7.22	0.500	0.085	0.19
Toe-off	-9.77 ± 12.19	-15.62 ± 9.68	0.463	0.097	0.53
TO -> DB	-28.06 ± 13.80	-22.52 ± 10.21	0.391	0.117	0.46
Drawback	-21.32 ± 8.99	-18.46 ± 14.60	0.768	0.057	0.24
DB -> MSW	-6.28 ± 8.89	-7.56 ± 7.01	0.571	0.077	0.16
Mid-swing	12.82 ± 15.40	17.3 ± 3.82	0.674	0.072	0.40
MSW -> HP	5.64 ± 15.11	6.63 ± 8.12	0.871	0.052	0.08
Heel plant	-1.53 ± 9.38	3.62 ± 12.17	0.193	0.228	0.47
HP ->	-7.49 ± 9.93	1.01 ± 13.24	0.167	0.255	0.73

Negative values represent dorsi flexion. Positive values represent plantarflexion

Table 3. Average and SD of knee kinematic values at baseline and 12-weeks.

	Baseline (°)	12-Weeks (°)	Significance (p value)	Observed Power	Effect Size
Knee					
Initial Contact	-5.94 ± 8.19	-.0.26 ±10.49	0.363	0.126	0.60
IC -> MST	-5.64 ± 11.14	0.5 ± 11.52	0.124	0.321	0.54
Midstance	-0.78 ± 17.26	0.1 ± 22.09	0.782	0.56	0.04
MST ->TO	0.71 ± 14.10	3.25 ± 18.61	0.520	0.086	0.002
Toe-off	17.69 ± 5.18	14.66 ± 16.83	0.686	0.065	0.24
TO -> DB	24.55 ± 8.17	15.57 ± 10.06	0.041*	0.610	0.98
Drawback	45.52 ± 21.58	26.96 ± 11.34	0.043*	0.765	1.07
DB -> MSW	53.52 ± 17.87	27.27 ± 11.06	0.002*	1.000	1.77
Mid-swing	49.65 ± 24.99	33.08 ± 6.93	0.287	0.159	0.70
MSW -> HP	33.82 ± 23.64	18.28 ± 12.82	0.296	1.000	0.82
Heel plant	11.49 ± 19.70	-0.08 ± 11.99	0.349	0.131	0.70
HP ->	3.89 ± 12.00	-1.23 ± 12.52	0.686	0.077	0.42

*p<0.05. Negative values represent extension. Positive values represent flexion

Table 4. Average and SD of hip kinematic values at baseline and 12-weeks

	Baseline (°)	12-Weeks (°)	Significance (p value)	Observed Power	Effect size
Hip					
Initial Contact	9.18 ± 14.38	6.1 ± 14.42	0.489	0.092	0.21
IC -> MST	3.31 ± 16.65	7.89 ± 14.04	0.393	0.116	0.30
Midstance	-5.2 ± 19.83	1.76 ± 24.52	0.261	0.174	0.31
MST ->TO	-14.28 ± 19.08	-6.28 ± 21.06	0.250	0.181	0.40
Toe-off	-18.62 ± 16.05	-12.12 ± 19.37	0.247	0.183	0.37
TO -> DB	-17.49 ± 9.83	-8.95 ± 20.76	0.062	0.187	0.53
Drawback	-3.64 ± 14.54	-11.18 ± 13.59	0.241	0.187	0.54
DB -> MSW	8.0 ± 7.96	-3.35 ± 16.37	0.80	0.495	0.88
Mid-swing	28.54 ± 18.50	18.12 ± 18.37	0.148	0.281	0.57
MSW -> HP	28.97 ± 15.51	19.49 ± 24.40	0.144	0.287	0.46
Heel plant	28.5 ± 17.41	15.74 ± 13.78	0.076	0.443	0.81
HP ->	25.44 ± 14.17	15.3 ± 13.54	0.065	0.485	0.73

Negative values represent extension. Positive values represent flexion.

Chapter 5 – Discussion

Individuals with moderate-to-severe NDD have reduced levels of physical activity, increasing the risk of secondary health-related problems (Van Biljon et al., 2018; Jacobson, 2020; Whitney et al., 2020). Finding ways in which these individuals can access physical activity capable of improving physical health outcomes is a priority amongst researchers (Carlon et al., 2013; Kristjánsson, 2018; Sukal et al., 2022). The purpose of this study was to investigate the effect of 12-weeks of RaceRunning training on physical health amongst individuals with moderate-to-severe NDD. Overall, there were no significant changes in resting BP (systolic 137 ± 18 mmHg versus 144 ± 19 mmHg and diastolic 93 ± 10 mmHg versus 95 ± 28 mmHg, $p > 0.05$), thigh (left 43.4 ± 10.6 cm versus 43.5 ± 11.2 cm, $p = 0.992$, right 44.1 ± 11.2 cm versus 43.1 ± 10.9 cm, $p = 0.404$) and calf circumference (left 32.9 ± 8.1 cm versus 31.6 ± 6.1 cm, $p = 0.377$, right 30.9 ± 6.38 cm versus 31.7 ± 6 cm, $p = 0.310$), 6MRT (802 ± 412 m versus 722 ± 392 m, $p = 0.155$), plantarflexion strength (56.3 ± 42.3 Nm versus 74.2 ± 39.9 Nm, $p = 0.167$) and the majority of kinematic values ($p>0.05$) over 12 weeks. Only RHR (84 ± 22 bpm versus 74 ± 15 bpm, $p = 0.038$), knee flexion strength (left 45.2 ± 44 Nm versus 64.5 ± 48.8 Nm, $p = 0.021$, right 41 ± 29.8 Nm versus 71.1 ± 51.1 Nm, $p = 0.006$) knee extension strength on the left leg (87.8 ± 53.7 Nm versus 110.8 ± 63.7 Nm, $p = 0.018$) and knee kinematic values during toe-off, toe-off to drawback and drawback to mid-swing phases ($p<0.05$) demonstrated significant changes following 12-weeks of RaceRunning. Overall, the findings of the study demonstrated the overall acceptance of the null hypothesis.

One consideration that should be acknowledged is the statistical analysis used in the present study. When conducting analysis on data, it is important to identify whether the variable being compared between data collection groups is normally distributed (Sedgwick, 2015). This is due to there being differences in the specific hypotheses being tested. The null hypothesis of a two-sample t-test (parametric) is that the mean of the two groups is equal; whereas the null hypothesis of the Wilcoxon test (non-parametric), is that the probability distributions of the two groups are equal (Goldstein-Greenwood, 2022). Whilst it is accepted amongst researchers to utilise both methods of

analysis (Sedgwick, 2015; Goldstein-Greenwood, 2022), it is important to recognise these dissimilarities when determining the outcome of the present study.

5.1 Heart Rate and Blood Pressure

One important finding was the significant reduction in resting heart rate (RHR) of participants from 84 ± 22bpm to 74 ± 15bpm (p=0.038) over the 12 weeks. RHR is a significant determinant of cardiovascular health (Cook et al., 2006; Ryan et al., 2015; Guo et al., 2019; Jensen, 2019; Reedman et al., 2022), with research showing that individuals with a RHR between 70-79bpm have a greater cardiovascular health outlook than those with RHR above 80bpm (Osibogun et al., (2020). It has been widely reported that training at a heart rate close to 70-80% of the maximum heart rate can bring about positive changes in RHR (Sylta et al., 2014; Lauglo et al., 2016; Van Biljon et al., 2018), however it is not clear if these thresholds also apply to those with NDD. Children with CP have been shown to have an average RHR of 104 ± 20bpm compared to the average in TD peers of 84 ± 13bpm (Ferreira et al., 2011). In individuals with Morquio syndrome, their lower left ventricular dimensions, lower stroke volumes and smaller left ventricular mass in addition to higher wall thickness and higher work index, makes it difficult for them to maintain cardiac output (Hendriksz et al., 2015; Kampmann et al., 2016). This results in increases in RHR of up to 21% (94.5 ± 2.7 bpm) compared to TD peers (Kampmann et al., 2016). This associated risk increases the likelihood of developing a cardiometabolic morbidity, with research determining that individuals with CP or spina bifida, have a significantly higher (41.5%) risk compared to those without either condition (30.6%) (Peterson et al., 2020). It is therefore important to find activities capable of inducing a cardiovascular response to lower RHR (Piepoli et al., 2014). Hjalmarsson et al., (2020) determined the average heart rate throughout RaceRunning training sessions was 136bpm or 69% of estimated heart rate max. Despite heart rate not being measured during training in the present study, the previous research coupled with reductions in RHR found in this study, demonstrates that RaceRunning could induce a positive cardiovascular response.

Despite the positive change in RHR, there was no significant change in resting blood pressure (BP). Moderate-to-vigorous physical activity has been associated with reductions in cardiometabolic diseases risk factors such as elevated BP (Theis et al.,

2021). Sustained changes in resting BP have been shown to be affected by duration, intensity and frequency of training sessions (Lee et al., 2010). Previous physical activity trials that have shown improvements in resting BP, have tended to include longer intervention periods and higher intensities (Johnson et al., 2007; He et al., 2018; Van Biljon et al., 2018). An investigation into the effects of 8 weeks of high intensity interval training, twice weekly on health and fitness on individuals with disabilities was conducted (Zwinkels et al., 2019), determining a significant reduction in systolic (pre = 123 ± 14.0bpm, post 20 ± 12.8bpm, p = 0.008) and diastolic (pre = 7.8 ± 10.3bpm, post = 65.4 ± 8.5bpm, p = 0.022) BP. This supports and challenges the present study, due to the timeframe of their investigation (Zwinkels et al., 2019) being shorter but had an increase in frequency of sessions. In a RaceRunning specific intervention, Hjalmarsson et al., (2020) monitored the intensity of training sessions and stated participants were encouraged to have a high work rate. This bears similarities to the present study, as due to the nature of the data collection being from 3 different RaceRunning clubs and each offering varying levels of training, the intensity of sessions was not controlled. This can make it difficult to determine whether the present intervention needed to have a higher frequency of training sessions and an extended period of monitoring, or whether the RaceRunning training itself does not elicit positive changes in BP. Establishing the timeframe threshold and dosage could be useful in future RaceRunning research.

The methods of collecting BP in those with NDD can also introduce error within the measurement. For example, incorrect BP cuff size has been reported to influence systolic and diastolic BP, with discrepancies as large as 30 mmHg (Palatini & Asmar, 2018). Cuff sizes deemed too large saw a 10-30 mmHg decreases in BP whilst cuff sizes deemed too small resulted in increases in BP levels by 2-8 mmHg in obese people and around 30 mmHg in individuals of a healthy weight (Tolonen et al., 2015). In individuals with a shorter arm length relative to circumference such as those with NDD, proper cuff fit can be problematic (Palatini et al., 2020) leading to inaccurate results. One further variable with the potential to influence results was the environmental impact of weather and temperature on BP readings. Testing sessions were staggered over June-December and were often taken outside at the track where participants trained. Exposure to cold temperatures has been shown to increase systolic BP (5-32 mmHg)

and diastolic BP (4-23 mmHg) (Kallioinen et al., 2017) through activation of the sympathetic nervous system. This elevates angiotensin II levels (protein hormone that causes blood vessel narrowing) and stimulates the release of the neurotransmitter norepinephrine, activating the renin-angiotensin system and increasing BP (Zhang et al., 2014). Thus, it is possible that methodological factors influenced the change in BP recorded from baseline to post intervention.

Whilst reductions in BP were not demonstrated in the present study with RaceRunning, the selection of participants could have played a role in this outcome. A significant correlation was found between disability type and severity with the occurrences of hypertension ($p < 0.001$) (Lin et al., 2012). In addition, when adjusting for demographic variables, there were higher instances of hypertension in physical disabilities compared to other disabilities (Wu et al., 2021). Researchers have stated that most studies often focus on hypertension in the general population rather than the subpopulation that experience disabilities (Nam & Yoon, 2022). This can be related to previous RaceRunning studies as although RaceRunning is open to anyone with a disability (Lebau, 2020), RaceRunning specific interventions predominantly focus on the effects on CP, due to majority of participants having this condition (Kristjánsson, 2018; Hjalmarsson et al., 2020). There is however a shift towards inclusivity of participants as more recent studies (Sukal-Moulton et al., 2022; Van Schie et al., 2022) have branched out to other conditions such as arthrogryposis, Dandy-Walker malformation transverse myelitis and other neurological disorders with promising results in similar or contrasting measurement outcomes. As no previous RaceRunning studies were found investigating resting BP, it is important to consider whether the outcomes of the present study were due to the severity of conditions, the types of disabilities participating, or if the methods of collecting BP contributed towards the non-significant outcome. More research into this area should be considered to get a better understanding of the impact RaceRunning has on cardiovascular outcomes.

5.2 Thigh Circumference, Calf Circumference and Isometric Strength

Within the general population, low thigh and calf circumference is associated with higher risks of all-cause and cardiovascular mortality (Abreo et al., 2021). As individuals with moderate-to-severe disabilities have restricted mobility (Jacobson, 2020), this can

increase their associated risk. Researchers confirmed this with reductions in lower limb muscle volume of up to 50% in individuals with CP compared to TD peers being determined (Shortland, 2009; Dahan-Oliel et al., 2012; Hussain et al., 2014), highlighting the importance of this outcome measure within the present study. Thigh and calf circumference showed no significant changes following 12 weeks of RaceRunning training. In a group of individuals with CP, research has found that on the least affected side, there was no change in muscle thickness after 12-weeks of RaceRunning training (Hjalmarsson et al., 2020) which supports our findings. However, they did find improvements in the medial gastrocnemius muscle thickness in the most affected limb but not in the vastus lateralis. The separation of affected and unaffected limb contrasts the present study, with both muscle thickness and strength being separated into right and left limbs. This is due to the present study focussing on the NDD population and not specific conditions (Moreno-De-Luca et al., 2013). Although some conditions such as CP have commodities such as spasticity which have been shown to effect muscle size and muscle weakness (Chen et al., 2018; Lindén et al., 2019), this is not applicable to all NDD populations. Therefore, the study focussed on the overall picture, separating the data into left and right to make the results more readable. Often studies will randomise which leg will be tested, but due to the small participant size, it was deemed that both should be assessed.

Age is a contributing factor to muscle hypertrophy, with suggestions that younger participants may achieve greater improvements in muscle mass during resistance exercise (Peterson et al., 2011). Furthermore, adaptations such as muscle hypertrophy could occur at a much slower rate despite improvements in muscular strength (Wang et al., 2021). It is also possible that RaceRunning was able to offset the deterioration in muscle size, rather than increasing it. Individuals with a calf circumference of less than 31cm have a significantly higher risk of mortality compared to those with greater calf sizes (Abreo et al., 2021). Participants in the present study recorded a calf circumference of 31cm on average on both legs, with limited improvements post 12-week intervention. This highlights that RaceRunning can demonstrate some positive effects even if the results were deemed non-significant.

Strengthening weak muscles has been highlighted by researchers as an important factor in improving activity capacity (Dallmeijer et al., 2017). As individuals with CP tend to present with a reduction in walking ability as they age (Opheim et al., 2009), maintaining their function or even improving it is vital. Knee flexion isometric strength was found to be significantly greater in both the left leg from 45.2 ± 44 Nm to 64.5 ± 48.8 Nm and in the right leg from 41 ± 29.8 Nm to 71.1 ± 51.1 Nm following 12 weeks of RaceRunning. Knee extension isometric strength saw significant improvements in the left leg from 87.8 ± 53.7 Nm to 110.8 ± 63.7 Nm but no significant differences within the right leg. This is supported by previous research, stating that RaceRunning has been shown to stimulate skeletal muscle hypertrophy (Hjalmarsson et al., 2020). A meta-analysis of exercise-based therapy intensity on gross motor function in individuals with CP concluded that gross motor function score was greatly associated with the number of daily training hours and the programme duration (Hsu et al., 2019). Whilst the extent of training may have not been sufficient for some measured outcomes in the present study, it could have been enough for other outcomes such as strength. Neural adaptations to training have been reported within the motor cortex, spinal cord and/or neuromuscular junction (Hedayatpour & Falla, 2015). For example, following resistance training, increases in force production were suggested to be due to the changes in excitation and inhibition from the motor cortex to the spinal cord, increasing motor neurone output (Siddique et al., 2020). The increased maximal motor unit discharge rates, increased incidence of brief interspike intervals and decreased internal interspike variability, subsequently increase force production (Hedayatpour & Falla, 2015; Siddique et al., 2020). In those with CP, peak muscle activity was a stronger predictor of change in muscle strength after 10 weeks of resistance training compared to 22 weeks (Theis et al., 2021). Some TD adults respond to exercise with an increase in strength only but not in muscle size or vice versa (Ahtiainen et al., 2016). Whilst traditional training can improve strength, muscle mass does not increase the potential for strength gain (Buckner et al., 2021). These adaptations could explain the disproportionate increase in isometric strength tests compared to muscle size following the 12-week RaceRunning intervention.

Improvements in isometric strength however did not translate to all areas of assessment. No significant results were found in both the left and right during plantarflexion. Research has shown during plantarflexion, individuals with CP will have coactivity near to 35% compared to 22 and 24% in those without CP (Tedroff et al., 2008). This can cause incomplete muscle activation and an inability to select the correct muscle for a given action. Indeed, individuals who had low muscle activation in the gastrocnemius had a more limited response to resistance training compared with those who had higher voluntary activation (Theis et al., 2021). Furthermore, researchers have determined that using a dynamometer for measuring ankle plantarflexion can be difficult in the NDD population due to some individuals being unable to maintain the plantargrade position (Crompton et al., 2007). This could explain the improvements within knee flexion and extension strength, but no significant improvements observed within ankle plantarflexion strength. It may also be argued that RaceRunning does not offer enough specificity of training for muscular strength adaptations to be observed. A study investigating the effects of an adapted physical education programme in adolescents with intellectual disabilities across a 3-year period, found that there were improvements in muscular endurance but not in BMI or flexibility (Pan et al., 2022). This supports the idea that even after an extensive intervention period not all fitness components can be resolved in a single intervention and require extensive work to achieve specific. Kossakowski et al., (2021) supports and challenges this by stating that due to the specificity and technical requirements of RaceRunning, benefits can only be achieved by individuals with a particular disability type. Whilst the present study did not determine significant differences in muscle thickness, the overall improvements in isometric strength within the knee demonstrates that RaceRunning can be an effective training method for the NDD population in improving muscular adaptations in the long-term.

5.3 6-minute RaceRunning Test

Individuals with chronic diseases or physical disabilities have been reported to have lower cardiorespiratory fitness, highlighting the importance of interventions to help increase their aerobic capacity (Haapala et al., 2017). There was no significant change in the speed and distance covered during the 6-minute RaceRunning Test (6MRT) from

baseline to 12-weeks after the RaceRunning intervention. This is supported by Sperl (2018) but contrasts Hjalmarsson et al., (2020), who showed significant improvements in 6MRT distance after their 12-week intervention. Gillett et al., (2018), showed that maximum isometric plantarflexion strength explained 61% of variance in 6-minute walking test, with Dallmeijer et al., (2017) supporting this by showing hip adductors and knee flexors also contributed towards mobility. Since no change in 6MRT distance was also coupled with no changes in plantarflexion strength in the present study, these findings from previous research indicate that plantarflexion strength may contribute to the non-significant changes in 6MRT.

For cardiorespiratory training, researchers have conducted interventions with reported improved cardiorespiratory outcomes from exercising for around 20 minutes at least two to four times a week at a moderate intensity (around 60-70% of maximum heart rate) (Verschuren et al., 2016). Previous RaceRunning studies have conducted in a similar manner by having sessions twice per week and saw 6MRT performance improvements but monitored intensity of sessions through perceived exertion (Hjalmarsson et al., 2020). This is an important consideration as the present study only conducted sessions once per week, indicating that this may not have been enough for cardiorespiratory adaptations. Similarly, Sperl (2018) conducted their intervention with RaceRunning sessions being held once per week for 8 weeks and determined similar results to the present study regarding 6MRT performance. They also concluded that RaceRunning could provide an opportunity to improve cardiorespiratory endurance through increases in heart rate as a result. As the present study saw decreases in RHR, it indicates that whilst the intensity of training sessions could have contributed towards improvements in 6MRT performance, the reduced frequency of sessions per week could have resulted in the nonsignificant findings. Furthermore, due to the limited experience prior to the commencement of the study, it is possible that these adaptations could have occurred at a later stage. This highlights that the intensity and frequency of RaceRunning sessions as well as the length of the intervention is important to potentially help the NDD population to improve their cardiorespiratory endurance.

Performance in 6MRT will also largely be determined by volitional effort (the use of one's will). Schlichta et al., (2022) found a significant reduction in time to exhaustion

with both mental fatigue (29%) and emotional suppression (20.7%) within physically active males during high intensity endurance exercise. Mental fatigue can be defined as a psychobiological state which is caused by prolonged periods of demanding cognitive activity (Van Cutsem et al., 2017; Schlichta et al., 2022). Studies have shown that mental fatigue and emotion suppression can increase the perception of effort, resulting in a detrimental effect on endurance performance (McCormick et al., 2019). Due to resource constraints, both tests were conducted through field testing, limiting the ability to control variables such as the environment. In marathon runners, a reported head or side wind showed significant decreases in running performance ($p<0.001$) (Knechtle et al., 2019). This is important to consider as whilst wind speed and direction were not recorded, due to the study being conducted outside, it could have played a role in the decreased performances observed in the present study. Those that are new to RaceRunning may not be used to performing at high intensities and may struggle to provide the volitional effort necessary to perform the 6MRT accurately. Kossakowski et al., (2021) and Van der Linden et al., (2022) support this as they reported 4% of participants felt extreme fatigue and sore muscles after training. In a systematic review on the effect of mental fatigue on performance, they concluded that the decline in endurance performance was due to mental fatigue and was associated with increased perceived exertion (Van Cutsem et al., 2017). They also determined that maximal strength, power, anaerobic work and physiological variables that are associated with endurance (e.g heart rate, blood lactate, oxygen uptake, cardiac output, VO2) were not affected by mental fatigue. Mentally fatigued individuals have been shown to have a substantial depletion of cognitive resources, which could negatively impact situational motivation and subjective fatigue (Schlichta et al., 2022). It is possible that whilst physiologically participants saw improvements, psychologically they were not as motivated to perform at a high intensity. This is seen within the present study as whilst 6MRT decreased, isometric strength tests and resting heart rate improved post intervention. This highlights that mental fatigue could have played a role in decreasing 6MRT performance and should be investigated further.

5.4 Kinematic Analysis

Kinematic changes during RaceRunning were recorded at baseline and 12 weeks to identify any changes in running technique. The limited equipment available could have been a contributing factor to the findings of the present study. Most angles measured at the ankle, knee and hip during stance and swing phases did not show any significant changes. However, knee angle was significantly lower at the toe-off to drawback, drawback and drawback to mid-swing phases. Often when analysing movements, multiple cameras are placed across the playing area and are calibrated to the dimensions of the area, which enables a greater calculation of speeds (Shih, 2017). However due to equipment availability, only one camera was used. As there is a such a wide range of disabilities and disorders amongst this population and therefore a variety of impairments, collection of video recordings should have been collected on both sides. This is important to note as whilst majority of kinematic values were deemed nonsignificant, the researcher is unsure as to whether this is a reliable assumption due to only one side being recorded and analysed.

Plantarflexion was recorded during the initial contact phase at both baseline (-2.5 ± 15.47) and 12-weeks (-0.16 ± 10.82) which supports the findings by Shafizadeh et al., (2019) who noted the similarity in technique to forefoot runners. A 12-week longitudinal intervention using minimalistic shoes determined significant changes in plantarflexion from 0.61 (± 3.76) to −1.89 (± 5.27) during stance phases but no significant changes in hip kinematics (Yang et al., 2020). As they utilised individuals that do not have a disability, they would be considered to have an efficient gait, enabling far greater improvements to be observed compared to individuals with NDD as demonstrated in the present study. This is supported by Ryan et al., (2020a) as they determined that isometric plantar flexor strength explained at least 50% of walking capacity measure variance in adults with CP during progressive resistance training. In an ankle specific intervention focussing on improving muscular strength, they determined substantial improvements in gait function in ankle kinematics, speed and endurance (Burdea et al., 2012). Therefore, it is possible that the lack of improvement in plantarflexion strength in the present study contributed to no significant results within ankle kinematics.

Reduced knee angle during swing phases is associated with lower locomotory energy costs, producing a better running economy (Folland et al., 2017). As kinematic values were taken during the 6MRT, the significant reductions in knee flexion during toe-off to drawback (24.55 ± 8.17 to 15.57 ± 10.06), drawback (45.52 ± 21.58 to 26.96 ± 11.34) and drawback to mid-swing (53.52 ± 17.87 to 27.27 ± 11.06) phases could be due to participants running more economically by maintaining a more consistent speed. After a 12-week running programme for beginners, researchers found no significant differences observations that could indicate a more progressive and less injury prone running style (Maas & Vanwanseele 2022). However, as this article utilised ambulant individuals with no reported disabilities, they may not have an inefficient running gait as observed amongst individuals with NDD (Noorkoiv et al., 2019). As the design of the RaceRunning frame helps supports their bodies, it enables them to propel forward and compensate for an impaired limb or joint (Van der Linden et al., 2021). This could allow participants to focus more on running technique, improving knee kinematic values during initial swing phases.

Running-induced fatigue amongst novice runners has reportedly resulted in no significant differences in kinematics within the knee and hip during flexion and extension (Koblbauer et al., 2014). In conjunction with Van der Linden et al., (2022) reporting increases in muscle tightness, this is important as it demonstrates that even in TD individuals, some running aspects are more difficult to change over a prolonged period when interventions solely focus on increasing endurance (Maas & Vanwanseele, 2022). Research has shown that interventions that report fatigue-induced kinematic value changes in running are not always generalisable to outdoor running as they often utilise treadmills (Strohrmann et al., 2012). This could explain the differences in results amongst the knee and hip within the present study compared to previous research with the few significant changes in knee kinematics but no reported significance within the hip. This highlights the need for further investigations on a larger and longer intervention scale, to fully assess kinematic changes within RaceRunning.

5.5 Sample Size

On a more quantitative level, the observed power and effect size gives some insight into the sample size recruited, in addition to the p (alpha) value. Whilst the overall aim for

recruitment was to get as many people involved in the study, only 9 participants were able to complete the 12-week study. A type I error occurs when the hypothesis is falsely accepted and is calculated through the alpha or p-value (Yuan & Maxwell, 2005). In measurements such as RHR, KF, KE and some kinematic values, significant results ($p<0.05$) were recorded. If a non-significant result is produced ($p>0.05$), utilising power and effect size helped determine whether the study was underpowered (Yuan & Maxwell, 2005; Serdar et al., 2021). A power calculation which is usually set at 0.8, is used to assess the probability of accepting a false null hypothesis, known as a type II error (Serdar et al., 2021). As RHR, KF and KE produced significant results with a medium to high effect size, it demonstrates that for these areas, the sample size was deemed appropriate. However, other aspects of testing produced non-significant results, which when delving into the observed power and effect sizes, raises concerns of an underpowered study.

Observed power varied amongst BP, with systolic results being 0.278 and diastolic being 0.70 however both effect sizes were low. Previous studies that have investigated BP have recruited large participant sizes to produce significant results (Zhang et al., 2021), which could explain the non-significant results in the present study. Similarly, thigh and calf circumference studies utilised large participants sample sizes of over 100 participants and saw significant results (Mienche et al., 2019). While this may not be the case for all studies investigating thigh and calf circumference, the low observed power and effect size determined in the present study supports the proposal that of a larger participant sample pool is required in future research. Despite the right leg KE showing non-significant results and an observed power of 0.448, the significant results on the left size ($p = 0.018$), in addition to significant results in KF, reduces the likelihood of a type II error. Plantarflexion saw medium effect sizes (0.43 and 0.53) but non-significant results, which in combination with the observed power of 0.268 in the left an 0.508 in the right, suggests that with a larger participant sample, significant results may have been observed.

The 6MRT also saw non-significant results which showed similarities to Sperl (2018). However, in comparison to Hjalmarsson et al., (2020) they determined significant results but recruited 15 participants compared to six participants in Sperl (2018) and nine in the

present study. This is important as both average speed and overall performance had an observed power of around 20% which could explain the non-significant findings, increasing the likelihood of a type II error. While kinematic analysis did show some significant values it is likely that both a type I and type II error occurred as only five participants took part in this study. In the instances that significant results were reported, the observed power and effect size showed the test was overpowered. This seems unlikely due to the other kinematic values determined the sample size recruited to be underpowered. This means that a type I error likely occurred within the present study. A greater participant size would be useful for future research as exhibited by Straudi et al., (2009) whereby they recruited 34 participants and clustered them into walking performance groups for later analysis. As the present study had limited participants, grouping participants into subgroups was not possible, which could be a contributing factor to nonsignificant results for majority of results. Overall, the present study may not have enough participants for some areas of interest. Future research should strive towards recruiting more participants to help improve the observed power and to reduce the likelihood of type I and type II errors.

5.6 Clinical Implications

Whilst the majority of measures included in the study were found not to change significantly following 12 weeks of RaceRunning, the present study does suggest that RaceRunning can provide some benefits in terms of muscle strength, muscle size and resting heart rate. In combination with previous findings which demonstrate some positive changes as a result of RaceRunning, this highlights the importance of recommending the sport to a population that has restricted opportunities to be physically active. The lack of facilities (Rimmer 2005; Rimmer et al., 2017) and a lack of inclusivity (Tant & Watelain, 2016) are often the main contributors to reduced physical activity which RaceRunning can help alleviate due the nature and accessibility of the sport. This was demonstrated by Sukal-Moulton et al., (2022) as they determined amongst individuals with movement challenges, those that liked to exercise found RaceRunning to be a good outlet to participate in with improvements physically and socially. As the sport is catered towards individuals with disabilities, it reduces the need for adaptation and could be integrated into either a school curriculum or community service which has

been highlighted in previous studies (Rimmer, 2005; Tant & Watelain, 2016; Rimmer et al., 2017).

There is also evidence that RaceRunning can provide an activity which increases heart rate and induces a cardiovascular response that may be able to reduce the risk of developing secondary health conditions if used in the long term. This research highlights that those new to RaceRunning may not initially be familiar or comfortable with exercising at a moderate-to-high intensities and this may have impacted some of the potential results found in this study. Indeed, there were a wide range of responses to some tests, with some individuals showing improvements in thigh circumference of up to 17.1% whilst others showing only minimal or no improvement. Many previous studies have only recruited participants with CP (Bryant & Pickering, 2015; Kristjánsson, 2018; Hjalmarsson et al., 2020; Reedman et al., 2022). This one of the few studies that aimed to recruit individuals of other NDD types. Ataxic CP for example accounts for 5% of CP cases and is often associated with spastic diplegic CP (Jones et al., 2007). Dyskinetic CP accounts for 7% of all CP cases (Krägeloh-Mann, 2007). These subtypes were included in the present study, which can provide useful data on a rare condition, often overlooked in NDD research. Due to the heterogenous nature of NDD and the wide range of disability symptoms present, a large sample size would be needed in order to detect some changes in variables (Reedman et al., 2022). The number of participants within the present study is significantly smaller than the average study for this area. This was a limitation of the present study. Nevertheless, the current study provides some important preliminary data and supports the limited number of studies to date looking at the effects of RaceRunning.

5.7 Future Research

Future research should investigate these physiological measures on a larger scale, with a greater sample size and involve a wide variety of disabilities and disorders. Recruiting a wider variety of disability types would ensure that findings are not influenced by a particular condition. This would make it more applicable to a wider population of NDD individuals. A longer intervention could see further developments in cardiorespiratory fitness but would have to be in a controlled environment to reduce the limiting factors found within the present study. Conducting more studies that were open to the diverse

disability types other than CP would be beneficial for researchers and to demonstrate that the sport is inclusive. It could even extend towards studies investigating RaceRunning within the elderly, with similarities being observed amongst previous studies between this group and disability types such as CP (Shortland, 2009). In addition, assessing the extent of improvements within disability types including the various CP subtypes would enable a better overview of the effects of the intervention. Similarly, performing a large-scale study on demographics within RaceRunning would be beneficial as it can establish the variety of conditions within the sport. It would also provide researchers with an idea of how to best represent the population in terms of recruitment within future studies. It would also highlight to practitioners that RaceRunning is open to a much wider population of individuals who may currently be unaware of the sport. Raising awareness would encourage more RaceRunning groups within the community.

Researchers could focus on investigating the various types of running style further, with an emphasis on those susceptible to contractures. By categorising the running techniques, it would enable healthcare practitioners and coaches to better understand the mechanics behind individuals running styles. This would enable them to focus on improving specific aspects that may not be apparent in other running techniques. Determining the extent of improvements within gait at similar speeds across a long-term intervention would be beneficial to fully understand whether kinematic values change over time. In addition, taking these recordings on both sides to ensure there are no generalisations due to lack of data. Performing gait analysis on a large scale at grass root through to elite, could provide coaches with the information to understand the differences in performance. This could be utilised to develop future training programmes to increase overall performance for athletes at lower levels. In addition, with the findings from previous research in relation to running speed such as spasticity, it would be beneficial to conduct a study in which the varying levels of impairments are analysed to understand the specific mechanisms for this reduction in speed. Measuring both active and passive kinematic values would be useful in terms of assessing the extent of angular differences for both a health and performance perspective. An investigation using a mixed method approach on the effects of RaceRunning on wellbeing and QoL

would provide useful information on both physiological and psychological effects. By incorporating both, it would enable a greater insight on the overall impact RaceRunning has on the NDD population particularly when testing on the same group of individuals. It can also help better understand how each aspect effects and interchanges with one another.

Chapter 6 – Conclusion

Individuals with NDD are more at risk of developing a secondary health problems, particularly in severe cases. Researchers have highlighted that RaceRunning may be able to provide this population with physical benefits to reduce these risks. This study aimed to investigate the effects over a 12-week period. In summary, whilst there were significant improvements within resting heart rate and isometric strength and trends towards other measures due to the observed power and the small sample size, it is difficult to fully understand the extent of improvements. Further analysis of the observed power and effect size revealed the present study to be underpowered. Kinematic values also found significant differences within the knee kinematics during the initial swing phases as a result of RaceRunning training but through further analysis, a type I error may have occurred. In conclusion, RaceRunning does provide some benefits towards improvements in physical health and recommends that healthcare practitioners promote the sport to individuals with moderate-to-severe NDD. The full extent of the physical benefits should be investigated further on a larger scale.

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Appendices

Appendix 1.1 Project Approval Form

UNIVERSITY OF GLOUCESTERSHIRE
at Cheltenham and Gloucester

PROJECT APPROVAL

This form should be completed by every candidate and submitted for approval to the School PGR Lead. Please refer to the Research Student Handbook and the Academic Regulations for Research Degrees Provision for further detailed information.

SECTION 1: STUDENT TO COMPLETE			
Family Name	**Thacker**	First Name	**Elizabeth**
Student number	[redacted]	Mode of Study	Full time
RESEARCH DEGREE PROJECT: Master of Science by Research			
COLLABORATING ESTABLISHMENT (A collaborating establishment is an organisation that enters into a formal written agreement with the University to provide facilities and other resources, e.g. access to a database, library, archive etc. A letter of support from the collaborating establishment confirming any agreed arrangements must accompany this application). N/A			
TITLE OF YOUR RESEARCH PROJECT - The effect of RaceRunning on physical health in individuals with moderate-to-severe neurodevelopmental disabilities.			
PROPOSED PLAN OF WORK The total word count for this section, a) to d), is a maximum of 1,500 words, excluding bibliography. All plans should address the required headings set out below			
a) AIM OF THE RESEARCH (Briefly state the main purpose(s) of the research and comment on its wider significance)			

The aim of the research is to determine the effect of 12 weeks RaceRunning on physical health in individuals with moderate-to-severe neurodevelopmental disabilities.

b) RESEARCH OBJECTIVES

(These must be highly focused and feasible)

1. To examine the effect of 12 weeks of RaceRunning on, thigh and calf circumference, muscular strength, cardiorespiratory fitness and resting heart rate and blood pressure, in individuals with moderate-to-severe neurodevelopmental disabilities.
2. To examine the effect of 12 weeks of RaceRunning on running gait in individuals with moderate-to-severe neurodevelopmental disabilities.

c) IMPORTANCE AND ORIGINALITY OF THE RESEARCH

(This should be related to a brief literature review of the field of study).

Neurodevelopmental disabilities (NDD) is a group of disabilities caused by disruption to the developing brain, such as rare genetic syndromes, cerebral palsy (CP), congenital neural anomalies and neurological motor disorders (Thapar & Rutter, 2015). In the UK approximately 6% of the population have some form of neurological motor disorder that affects participation in everyday activities (Nouraei et al., 2017; Gagnon, 2020; Jacobson, 2020) and makes it challenging for these individuals to access provisions which promote health and wellbeing (Shafizadeh et al., 2019). As a result, those with moderate-to-severe NDD are often at an increased risk of developing cardiorespiratory disorders (Ravesloot et al., 2007; Wu et al., 2010).

Whilst it is well established that exercise provides a wide variety of benefits and can reduce the risk of cardiovascular disease, individuals with disabilities are often presented with several challenges that prevent them from participating in sport or activities that may reduce the risk (Butler et al., 2010; Jaarsma et al., 2015). Around 70-75% of people with disabiltities do not participate in any sport or physical activity (Shafizadeh et al., 2019). Of the sports which are specifically designed for moderate-to-severely disabled individuals (e.g Boccia), they lack the intensity which are associated with a greater reduction in cardiovascular disease prevalence (Carlon et al., 2013; Faria et al., 2014; Łosień et al., 2018; Hjalmarsson et al., 2020).

RaceRunning is a growing disability sport specifically for individuals with moderate-to severe-neurological motor disorders. Whilst research around the effects of RaceRunning for those with CP has begun to emerge, there still remains limited findings particularly in other NDD (Ryan et al., 2020). In the few studies that have investigated the effects of RaceRunning, improved aerobic fitness, stamina and overall wellbeing was noted (Bryant, & Pickering., 2015; Phillips et al., 2017; Hjalmarsson et al., 2020). Pilot studies suggest that individuals with severe cases of CP can achieve moderate-to vigorous-physical activity levels through RaceRunning, with positive effects such as improved aerobic capacity, bone health and muscle thickness, cardiorespiratory endurance and passive range of motion, following 12 weeks of RaceRunning training (Bryant et al., 2015; Hjalmarsson et al., 2020). CP is considered the most prevalent physical disability in childhood, with around 2-2.5 per 1000s births (Hjalmarsson et al., 2020; Ostojic et al., 2020). However, whilst these articles highlight the benefits for RaceRunning for individuals with CP, they are not inclusive of other

disabilities. The proposed study will add to the growing body of research, to investigate the effect of 12 weeks RaceRunning on physical health and quality of life for those with NDD.

d) PROPOSED RESEARCH METHODS

(This should state your methods and your rationale for their use. This section should also discuss the ethical dimensions of the chosen research methods and steps taken to address any issues that arise from them)

Based on current research by Hjalmarsson et al., (2020), as a result of similar testing parameters, 10 participants will be recruited as determined via a sample size calculation based on an effect size of 0.426. This will consist of young people and adults with moderate-to-severe NDD. Recruitment will take place through local RaceRunning clubs in Gloucester, Bath and Cardiff. When designing this study, acknowledgements of resource constraints (Lakens, 2021) were made due to there being only 8 clubs that provide RaceRunning opportunities in England and Wales (Quest, 2020, June 2). Participants will be aged 6-35 years to capture the diversity of those involved in RaceRunning and similar reports were shown by Hjalmarsson et al., (2020) as they utilised an age range of 9-29 years old. Written consent will be gained from all participants over the age of 16 years. For those under 16 years, written assent will be gained from the parent/carer and verbal consent will be gained by the participant themselves. Ethical approval for this study has already been granted. To be eligible to take part, participants will be taking part in one hourly RaceRunning session per week for 12 weeks. Sessions at the clubs used for recruitment are led by an experienced coach who has attended the RaceRunning coaching course. These sessions will generally consist of a warm up, followed by a series drills depending on what the aims of the session are and then a cool down to end the session. The nature of delivery will be challenging to control in terms of available facilities as they can contribute to multiple confounding variables such as weather conditions. This could affect the findings of the study. Furthermore, coaching style at each location may differ as a result of different participant aims (recreational versus competitive) and resource constraints resulting in recruitment from multiple locations. Utilising this group regardless of whether they participate in RaceRunning recreationally or competitively is beneficial for the study however will have to be taken into consideration when analysing the findings. As a result of the COVID-19 pandemic, individuals with disabilities have significantly reduced levels of physical activity due to the long-term consequence of quarantine (Di Stefano et al., 2021). This will enable more individuals to be recruited as they have not been participating in the sport for a significant amount of time.

Assessments will be conducted at baseline and 12 weeks. The study will collect demographic information including age, sex, the nature of the disability. Physical health will involve measuring resting heart rate and blood pressure using a heart rate monitor (Heart Rate Monitors: Models Fs3c, FT1, 610i, 810i, RS800CX, RCX5, FT7, Polar, Electro Oy, Kempele, Finland) and blood pressure cuff and machine (Blood pressure machines: Omron RX-M, HEM-628-E, Omron Corporation, Kyoto, 600-8530, Japan). Thigh and calf circumference will be measured using an anthropometric tape measure

at the most prominent point of the muscle belly. Due to the available facilities, all tests will be conducted outdoors which will pose a challenge to control external variables and will be taken into consideration when discussing the findings of the study. The same clothing will be worn to ensure that the thickness of the material does not change and affect the findings. Whilst this method is beneficial in terms of being non-invasive and practical, there is more potential for human error therefore measurements will be taken multiple times to ensure more reliable results. Knee flexor and extensor strength as well as ankle plantarflexion strength will be recorded using a handheld dynamometer.

Participants will also be asked to perform a 6-minute RaceRunning test (6MRT) proposed by Bolster et al., (2017) as a reliable method of assessing cardiorespiratory fitness. It consists of participants propelling themselves continuously for 6 minutes, at a pace that they are able to maintain for the full duration and will be encouraged throughout. As the test progresses, participants will gradually feel fatigued and intensity will generally increase due to the extent they are continually moving for. Participants will do the test on a running track and therefore their pace can be monitored based on the number of laps they are able to complete throughout. Any additional distance will be measured using a measuring wheel (Screwfix, United Kingdom). Finally, video footage of RaceRunning technique will be collected to determine whether there are changes in gait over the 12 weeks. This will be conducted via triangulating a Canon XM2 Digital Video Camera (Canon Inc., Tokyo, Japan) across a 5-metre distance. The video footage will be recorded during the 6MRT and analysed using Quintics Biomechanics Software v.26 (Quintic, Sutton Coldfield, UK). Analysis will consist of collecting all sagittal plane kinematic values for the hip, knee and ankle at initial contact, midstance, toe-off and swing phases. Kinematic curves will help to determine the values of each location. Understanding the gait whilst participating in RaceRunning will be beneficial as there are no reported articles on this specific area. By analysing their gait, the aim is to determine whether there is a difference over the 12-week period, with the findings potentially being used by coaches for performance and/or healthcare professionals in terms of overall health.

Data for all tests will be analysed using a series of t-tests on SPSS to assess differences in each variable at baseline and at 12 weeks.

BIBLIOGRAPHY (20 references should suffice and the bibliography should be presented in the style approved within your discipline. You may wish to refer to your supervisor if unsure).

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TEMPORAL PLAN (Outline the time frame envisaged for your research tasks).
Guidance notes: please use Gantt template provided or suitable alternative. This should include work undertaken to date (e.g. pilot study; literature review, etc.). Please refer to the Academic Regulations for Research Degree Provision for the maximum period of registration permitted for your programme of study. *SEE FINAL PAGE for CONTINUATION SHEET*

	Date											
Activities	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Background Reading												

Literature Review											
Participant Paperwork (Par-Q, Health Questionnaires, Informed Consent Forms)											
Ethical Approval											
Data Collection											
Data Analysis											
Project Write-up											
Draft Hand In											
Improvements											
Project Submission											

RESEARCH ETHICS

(The research must be ethically sound, and must be conducted in accordance with the University's *Research Ethics: A Handbook of Principles and Procedures*, and with be within the code of conduct for the specific discipline. Specific ethical issues, including confidentiality, must be addressed within the proposed plan of work above):

1. My research will be conducted under the guidelines of (please tick):

☒ The University of Gloucestershire's Handbook of Research Ethics

☐ The University of Gloucestershire's standard protocols in the exercise physiology laboratory

☐ The NHS Research Governance Framework

☐ The British Sociological Association

☐ The British Psychological Society Code of Conduct

☐ The British Educational Research Association

☐ The Market Research Society

☐ The Oral History Association

☐ Other (please state and attach copy) _ _ _ _ _ _ _ _ _ _

2. Does this proposal contain elements that make reference to the University Research Ethics Committee mandatory?

☒ Yes ☐ No

(Please see *Research Ethics: A Handbook of Principles and Procedures* Part A, section 6, and Guidelines for Working with Children and Young People)

2.3 – Informed Consent, 2.3.8, 2.3.10, 2.5, 2.6.1.6, 2.6.1.7

3. Any specific issues concerning the ethics of this research that require particular comment are detailed in section d) Proposed Research Methods on page _ _ [please enter page number].

STUDENT CHECKLIST

Before submitting your Project Approval Form to your Supervisor, please confirm that you have:

☒Completed the form in full.

☒Checked the ethical implications of your project with your supervisor. Students requiring clearance from the University's Research Ethics Committee (UREC) need to take responsibility for submitting the appropriate paperwork to UREC and gaining the Committee's approval before commencing any data collection.

☒Signed and dated this page (by hand or electronically, but not a typed signature).

STATEMENT BY THE APPLICANT

I wish to apply for approval to undertake the above mentioned degree on the basis of the proposals given in this application. I confirm that the particulars given are correct and I understand that, except with specific permission, I must prepare and defend my thesis in English. I have read and understood the University of Gloucestershire's *Research Ethics: A Handbook of Principles and Procedures.* I agree to abide by the regulations, and the *Research Ethics Principles and Procedures* of the University.

Signature:	Date: 02/02/2022
[redacted]	

NOW SEND THE COMPLETED AND SIGNED FORM TO YOUR SUPERVISOR(S)

SECTION 2: SUPERVISORS TO COMPLETE

RECOMMENDATION BY THE SUPERVISORY TEAM

I/We support this application and believe that the candidate has the potential to complete successfully the programme of work proposed. I/We recommend that the applicant's *Project* for the above research degree be submitted for review. I/We also confirm that the student has been advised of the review process and the possible outcomes.

Attach the ***Project Approval - Supervisor Pre-submission checklist*** to this document before submitting to the PGR Lead for review.

Are there any budget implications beyond those discussed at candidate's interview stage?

☒ No

☐ Yes. Please contact budget holder (usually the Head of School) and notify School PGR Lead

FIRST SUPERVISOR

Name (including title): Dr Kiara Lewis

SIGNATURE: [redacted]	Date: 26/11/2021

SECOND SUPERVISOR 2 (if applicable)

Name (including title) Daniel Cowen

SIGNATURE: [redacted]	Date: 26/11/2021

NOW EMAIL THE COMPLETED FORM TO YOUR SCHOOL PGR LEAD OR NOMINATED LOCATION HIGHLIGHTED ON THE PROJECT APPROVAL PRE-SUBMISSION CHECKLIST FOR YOUR SCHOOL

SECTION 3: SCHOOL TO COMPLETE – PGR Lead or nominated member of School staff	
☒ The student checklist has been completed ☐ The student indicates the project should be referred to UREC in the 'Research Ethics' section. A copy of the Project Approval form has been passed to the Officer of UREC. [*Note: Approval for the project at REC should normally be confirmed before the PGR Lead passes the Project Approval form on for review*.] ☒ Student and Supervisor(s) signatures have been added to the form ☒ The Project Approval - Supervisor Pre-submission checklist has been received ☒ The supervisory team is appropriate and legal in relation to the Academic Regulations for Research Degree Provision. If no, outline action to be taken below (e.g. appointment of second supervisor with specific skill range etc.) If any of the boxes are not checked, please return the Project Approval form to the student for completion/correction. ☒ I confirm that this form has passed an administrative check.	
The following have been nominated as reviewer(s) for this proposal. Reviewer 1: Dr Colin Baker Reviewer 2: Prof Mark De Ste Croix	
PGR LEAD NAME: Dr Colin Baker	Date: 26/11/2021

NOW EMAIL THE FORM TO THE REVIEWER(S)

SECTION 4: PGR LEAD TO COMPLETE	
FINAL RECOMMENDATION OF THE REVIEWERS I confirm the final recommendation of the reviewer(s) as ☒ APPROVE ☐ REJECT (where a different award pathway can be offered, please note below) ☐ OFFER ALTERNATIVE AWARD PATHWAY ……	
Signature: 	Date: 28/04/2022

NOW EMAIL THE COMPLETED FORM TO THE STUDENT, SUPERVISOR(S) AND RESEARCH ADMINISTRATION OFFICE

CONTINUATION OF TEMPORAL PLAN												
	Date											
Activities	YYYY				YYYY				YYYY			

Appendix 1.2 Participant Information Letter (Adult)

The effect of RaceRunning on fitness and mobility in young people with cerebral palsy

'RaceRunning' is a sport that allows people who usually have problems walking or propelling a wheelchair, to move on their own using a 'running bike' or RaceRunner. We are trying to find out how RaceRunning affects your child's fitness and your everyday movement.

Before you decide whether you would like to join the study, it is important you know why this research is being done and what your role would be in it. So please read this leaflet carefully. Talk about it with your family, friends, physiotherapist if you want to. You can contact one of us on the email given at the end of this leaflet and ask any questions or concerns you may have.

Why are we doing this research?

People who take part in RaceRunning have told us that RaceRunning makes them feel better and fitter but there is no proper scientific evidence (proof) of this. With this study we want to find out if RaceRunning can improve fitness and mobility (e.g. walking, propelling a wheelchair or transferring in and out of a wheelchair).

Why have I been asked to take part?

You have been asked to take part, because you take part in RaceRunning.

What does the study involve?

If you agree to take part we will ask you to continue taking part in RaceRunning. We will measure a number of things at the start and 6 and 12 weeks later.

What will happen if I take part?

1. **Before any assessments take place**

   We will start by making sure you are still happy to take part and we will ask you to sign a consent form.

   We will ask you some questions about your use of a walking aid or wheelchair, if you take any medication, and if you have had surgery for your legs. We will also ask about your everyday mobility.

2. **Assessment sessions (at your RaceRunning session) (0, 6 and 12 weeks)**

   We will ask you to complete some questionnaires, with questions such as how much physical activity you do, how many times you have visited a doctor or a therapist in the past 3 months and quality of life. You can complete these at home.

   At each of the three testing sessions, we will start by measuring resting heart rate and blood pressure, which will take around 10 minutes. We will also measure muscle strength of the muscles in your legs, using a special machine called a hand-held dynamometer.

   After this, we will ask you to do a RaceRunning specific fitness test on the track. We will ask you to run around the track for 6 minutes and cover as much distance as possible. You will wear the heart rate monitor whilst doing this.

   We will also ask you to run 100 m as fast as you can while using your RaceRunner so that we can analyse your running style using a video camera.

Do I have to take part?

No! It is up to you. If you do wish to take part:

- ➢ You will be asked to sign a form giving consent
- ➢ You will be given a copy of the information sheet to keep
- ➢ Your are free to stop taking part at any time during the research without giving a reason

Is there anything to be worried about?

If you are not used to regular exercise, taking part in RaceRunning may result in some muscle soreness during the first few sessions, but this should pass after a while and is a normal response to exercise. The fitness test will require you to give an 'all out' effort so you will feel out of breath. Of course, you can also stop at any time in the test without having to give a reason.

What are the possible benefits of taking part?

People taking part in RaceRunning have reported to enjoy RaceRunning and some feel taking part has improved their ability to transfer, stand or walk. However, this has not been scientifically proven and not everyone may experience the same positive effects. Our ultimate aim is to provide scientific evidence for possible positive and negative effects of RaceRunning on people's fitness, health and everyday mobility.

Who is organising and funding the research?

This research is conducted by researchers from the University of Gloucestershire and Queen Margaret University. The research is funded by Action Medical Research and the Chartered Society for Physiotherapy Charitable Trust.

What happens when the research project stops?

The information from the study will be collected and analysed and will be reported in a research paper. When you agree to take part in a research study, researchers from QMU and UoG will collect the minimum personally-identifiable information needed for the purposes of the research project. Information that you provide will only be used in the ways needed to conduct and analyse the research study. QMU and UoG will act as the data controller for this study. This means that we are responsible for looking after your information and using it properly. Both universities will keep identifiable information about you for 5 years after the study has finished.

Who has reviewed the study?

Every research study is checked by an ethics committee to make sure it is okay to do. This research has been checked and approved by the Queen Margaret University Divisional Research Ethics Committee and an NHS research ethical committee.

Contact details:

If you have any questions, then you can contact one of the research team:

- **Lizzie Thacker, Postgraduate Researcher**, [redacted], Tel: [redacted]
- **Dr Nicola Theis,** [redacted], Tel: [redacted]

Thank you for reading this. You are welcome to ask any questions about this research

Appendix 1.3 Parent/Guardian Information Letter

UNIVERSITY OF GLOUCESTERSHIRE

supported by action medical research for children

Charity reg. nos 208701 and SC039284

Queen Margaret University EDINBURGH

The effect of RaceRunning on fitness and mobility in young people with cerebral palsy

'RaceRunning' is a sport that allows people who usually have problems walking or propelling a wheelchair, to move on their own using a 'running bike' or RaceRunner. We are trying to find out how RaceRunning affects your child's fitness and your everyday movement.

Before you decide whether you would like your child to join the study, it is important you know why this research is being done and what your child's role would be in it. So please read this leaflet carefully. Talk about it with your family, friends, physiotherapist if you want to. You can contact one of us on the email given at the end of this leaflet and ask any questions or concerns you may have.

Why are we doing this research?

People who take part in RaceRunning have told us that RaceRunning makes them feel better and fitter but there is no proper scientific evidence (proof) of this. With this study we want to find out if RaceRunning can improve fitness and mobility (e.g. walking, propelling a wheelchair or transferring in and out of a wheelchair).

Why has my child been asked to take part?

Your child has been asked to take part, because they have cerebral palsy and take part in RaceRunning.

What does the study involve?

If you agree for your child to take part we will ask them to continue taking part in RaceRunning. We will measure a number of things at the start and 6 and 12 weeks later.

What will happen to my child if we take part?

3. Before any assessments take place

We will start by making sure your child is still happy to take part and we will ask you and your child to sign a consent form.

We will ask you and your child some questions about their use of a walking aid or wheelchair, if they take any medication, and if they have had surgery for their legs. We will also ask about their everyday mobility.

4. Assessment sessions (at your child's RaceRunning session) (0, 6 and 12 weeks)

We will ask you and your child to complete some questionnaires, with questions such as how much physical activity they do, how many times they have visited a doctor or a therapist in the past 3 months and quality of life. You can complete these at home.

At each of the three testing sessions, we will start by measuring resting heart rate and blood pressure, which will take around 10 minutes. We will also measure muscle strength of the muscles in your child's legs, using a special machine called a hand-held dynamometer.

After this, your child will be asked to do a RaceRunning specific fitness test on the track. We will ask them to run around the track for 6 minutes and cover as much distance as possible. They will wear the heart rate monitor whilst doing this.

We will also ask your child to run 100 m as fast as they can while they are using the RaceRunner so that we can analyse their running style using a video camera.

Does my child have to take part?

No! It is up to you and your child. If you do wish your child to take part:

- ➢ They will be asked to sign a form giving consent
- ➢ They will be given a copy of the information sheet to keep

- ➢ Your child is free to stop taking part at any time during the research without giving a reason

Is there anything to be worried about?

If your child is not used to regular exercise in which they use their legs, taking part in RaceRunning may result in some muscle soreness during the first few sessions, but this should pass after a while and is a normal response to exercise. The fitness test will require your child to give their 'all out' effort so they will feel out of breath. For safety reasons, somebody will walk/run alongside your child throughout the test and will stop the test if necessary. Of course, your child can also stop at any time in the test without having to give a reason.

What are the possible benefits to my child, of taking part?

People taking part in RaceRunning have reported to enjoy RaceRunning and some feel taking part has improved their ability to transfer, stand or walk. However, this has not been scientifically proven and not everyone may experience the same positive effects. Our ultimate aim is to provide scientific evidence for possible positive and negative effects of RaceRunning on people's fitness, health and everyday mobility.

Who is organising and funding the research?

This research is conducted by researchers from the University of Gloucestershire and Queen Margaret University. The research is funded by Action Medical Research and the Chartered Society for Physiotherapy Charitable Trust.

What happens when the research project stops?

The information from the study will be collected and analysed and will be reported in a research paper. When you agree for your child to take part in a research study, researchers from QMU and UoG will collect the minimum personally-identifiable information needed for the purposes of the research project. Information about your child will be used in the ways needed to conduct and analyse the research study. QMU and UoG will act as the data controller for this study. This means that we are responsible for looking after your child's information and using it properly. Both universities will keep identifiable information about your child for 5 years after the study has finished.

Who has reviewed the study?

Every research study is checked by an ethics committee to make sure it is okay to do. This research has been checked and approved by the Queen Margaret University Divisional Research Ethics Committee and an NHS research ethical committee.

Contact details:

If you have any questions, then you can contact one of the research team:

- **Lizzie Thacker, Postgraduate Researcher**, [redacted], Tel: [redacted]

- **Dr Nicola Theis,** [redacted], Tel: [redacted]

Thank you for reading this. You are welcome to ask any questions about this research

Appendix 1.4 Informed Consent Form

Informed consent form

Title of Project:	The effect of RaceRunning on fitness and mobility in young people with cerebral palsy
Principal investigator:	Nicola Theis Senior Lecturer in Sport & Exercise Biomechanics Faculty of Applied Sciences, University of Gloucestershire, Oxstalls Campus Oxstalls Lane, Gloucester, GL2 9HW [redacted]

I am happy for myself/my child to take part in this study:

Printed Name: _____ Date: _____

Do you understand that we have asked you/your child to participate in a research study?	Yes	No
Have you read and received a copy of the information letter?	Yes	No
Do you understand the benefits and risks involved in you/your child taking part in this research study?	Yes	No
Do you understand that you are free to contact the research team to ask questions and discuss this study?	Yes	No
Do you understand that you are free to refuse your/your child's participation, or to withdraw from the study at any time, without consequence, and that your/your child's information will be withdrawn at your request?	Yes	No
Do you understand that we will keep your/your child's data confidential?	Yes	No
Do you understand who will have access to your/your child's information?	Yes	No

Signature:

For any questions, contact Dr Nicola Theis
E: ntheis@glos.ac.uk
T: 01242 715288

Appendix 1.5 Raw Data

1.5.1 SPSS Output for Descriptives (Mean and SD)

Descriptives

			Statistic	Std. Error
RHRPRE	Mean		84.33	7.232
	95% Confidence Interval for Mean	Lower Bound	67.66	
		Upper Bound	101.01	
	5% Trimmed Mean		83.87	
	Median		80.00	
	Variance		470.750	
	Std. Deviation		21.697	
	Minimum		56	
	Maximum		121	
	Range		65	
	Interquartile Range		33	
	Skewness		.835	.717
	Kurtosis		-.064	1.400
RHRPOST	Mean		74.33	5.022
	95% Confidence Interval for Mean	Lower Bound	62.75	
		Upper Bound	85.91	
	5% Trimmed Mean		73.31	
	Median		74.00	
	Variance		227.000	
	Std. Deviation		15.067	
	Minimum		57	
	Maximum		110	
	Range		53	
	Interquartile Range		13	
	Skewness		1.782	.717
	Kurtosis		4.437	1.400

Descriptives

		Statistic	Std. Error
	Mean	137.00	7.146

SYSPRE	95% Confidence Interval for Mean	Lower Bound	118.63	
		Upper Bound	155.37	
	5% Trimmed Mean		136.28	
	Median		132.50	
	Variance		306.400	
	Std. Deviation		17.504	
	Minimum		118	
	Maximum		169	
	Range		51	
	Interquartile Range		23	
	Skewness		1.405	.845
	Kurtosis		2.600	1.741
SYSPOST	Mean		144.17	7.918
	95% Confidence Interval for Mean	Lower Bound	123.81	
		Upper Bound	164.52	
	5% Trimmed Mean		143.85	
	Median		141.00	
	Variance		376.167	
	Std. Deviation		19.395	
	Minimum		122	
	Maximum		172	
	Range		50	
	Interquartile Range		37	
	Skewness		.439	.845
	Kurtosis		-1.330	1.741
DIAPRE	Mean		92.50	3.990
	95% Confidence Interval for Mean	Lower Bound	82.24	
		Upper Bound	102.76	
	5% Trimmed Mean		92.06	
	Median		90.00	
	Variance		95.500	
	Std. Deviation		9.772	
	Minimum		84	
	Maximum		109	
	Range		25	

	Interquartile Range		17	
	Skewness		1.049	.845
	Kurtosis		.381	1.741
DIAPOST	Mean		95.00	11.413
	95% Confidence Interval for Mean	Lower Bound	65.66	
		Upper Bound	124.34	
	5% Trimmed Mean		95.50	
	Median		89.00	
	Variance		781.600	
	Std. Deviation		27.957	
	Minimum		53	
	Maximum		128	
	Range		75	
	Interquartile Range		48	
	Skewness		-.170	.845
	Kurtosis		-.386	1.741

Descriptives

			Statistic	Std. Error
SIXMRTPRE	Mean		802.0000	168.37260
	95% Confidence Interval for Mean	Lower Bound	369.1844	
		Upper Bound	1234.8156	
	5% Trimmed Mean		810.2222	
	Median		788.5000	
	Variance		170096.000	
	Std. Deviation		412.42696	
	Minimum		131.00	
	Maximum		1325.00	
	Range		1194.00	
	Interquartile Range		620.25	
	Skewness		-.574	.845
	Kurtosis		.677	1.741

SIXMRTPOST	Mean		722.5000	160.26348
	95% Confidence Interval for Mean	Lower Bound	310.5296	
		Upper Bound	1134.4704	
	5% Trimmed Mean		727.0000	
	Median		669.0000	
	Variance		154106.300	
	Std. Deviation		392.56375	
	Minimum		121.00	
	Maximum		1243.00	
	Range		1122.00	
	Interquartile Range		638.25	
	Skewness		-.215	.845
	Kurtosis		.146	1.741

Descriptives

			Statistic	Std. Error
TCLEFTPRE	Mean		44.8125	3.67974
	95% Confidence Interval for Mean	Lower Bound	36.1113	
		Upper Bound	53.5137	
	5% Trimmed Mean		44.8917	
	Median		44.2500	
	Variance		108.324	
	Std. Deviation		10.40789	
	Minimum		29.00	
	Maximum		59.20	
	Range		30.20	
	Interquartile Range		19.00	
	Skewness		-.025	.752
	Kurtosis		-.906	1.481
	Mean		44.7000	4.01853

TCLEFTPOST	95% Confidence Interval for Mean	Lower Bound	35.1977	
		Upper Bound	54.2023	
	5% Trimmed Mean		44.9444	
	Median		43.1500	
	Variance		129.189	
	Std. Deviation		11.36612	
	Minimum		26.00	
	Maximum		59.00	
	Range		33.00	
	Interquartile Range		18.67	
	Skewness		-.237	.752
	Kurtosis		-.833	1.481
TCRIGHTPRE	Mean		45.5250	3.94619
	95% Confidence Interval for Mean	Lower Bound	36.1937	
		Upper Bound	54.8563	
	5% Trimmed Mean		45.6278	
	Median		45.4500	
	Variance		124.579	
	Std. Deviation		11.16151	
	Minimum		28.00	
	Maximum		61.20	
	Range		33.20	
	Interquartile Range		19.17	
	Skewness		-.143	.752
	Kurtosis		-.839	1.481
TCRIGHTPOST	Mean		44.2500	3.90343
	95% Confidence Interval for Mean	Lower Bound	35.0198	
		Upper Bound	53.4802	
	5% Trimmed Mean		44.4944	
	Median		41.7500	
	Variance		121.894	
	Std. Deviation		11.04057	

	Minimum		26.00	
	Maximum		58.10	
	Range		32.10	
	Interquartile Range		17.30	
	Skewness		-.190	.752
	Kurtosis		-.765	1.481
CCLEFTPRE	Mean		32.8500	2.85319
	95% Confidence Interval for Mean	Lower Bound	26.1033	
		Upper Bound	39.5967	
	5% Trimmed Mean		32.7056	
	Median		30.5500	
	Variance		65.126	
	Std. Deviation		8.07005	
	Minimum		21.80	
	Maximum		46.50	
	Range		24.70	
	Interquartile Range		12.45	
	Skewness		.496	.752
	Kurtosis		-.457	1.481
CCLEFTPOST	Mean		31.6375	2.17830
	95% Confidence Interval for Mean	Lower Bound	26.4866	
		Upper Bound	36.7884	
	5% Trimmed Mean		31.8194	
	Median		31.3500	
	Variance		37.960	
	Std. Deviation		6.16115	
	Minimum		20.50	
	Maximum		39.50	
	Range		19.00	
	Interquartile Range		8.95	
	Skewness		-.548	.752
	Kurtosis		.119	1.481
CCRIGHTPRE	Mean		30.8625	2.25531
	95% Confidence Interval for Mean	Lower Bound	25.5295	
		Upper Bound	36.1955	

	5% Trimmed Mean		30.8194	
	Median		30.5500	
	Variance		40.691	
	Std. Deviation		6.37897	
	Minimum		22.50	
	Maximum		40.00	
	Range		17.50	
	Interquartile Range		11.43	
	Skewness		.069	.752
	Kurtosis		-1.602	1.481
CCRIGHTPOST	Mean		31.7375	2.11508
	95% Confidence Interval for Mean	Lower Bound	26.7361	
		Upper Bound	36.7389	
	5% Trimmed Mean		31.9861	
	Median		31.3000	
	Variance		35.788	
	Std. Deviation		5.98234	
	Minimum		20.50	
	Maximum		38.50	
	Range		18.00	
	Interquartile Range		8.22	
	Skewness		-.747	.752
	Kurtosis		.424	1.481

Descriptives

			Statistic	Std. Error
LEFTKEPRE	Mean		87.8213	17.91032
	95% Confidence Interval for Mean	Lower Bound	46.5200	
		Upper Bound	129.1226	
	5% Trimmed Mean		87.7601	
	Median		71.8092	
	Variance		2887.015	

	Std. Deviation		53.73095	
	Minimum		17.66	
	Maximum		159.09	
	Range		141.43	
	Interquartile Range		102.84	
	Skewness		.247	.717
	Kurtosis		-1.704	1.400
LEFTKEPOST	Mean		110.7803	21.23142
	95% Confidence Interval for Mean	Lower Bound	61.8206	
		Upper Bound	159.7401	
	5% Trimmed Mean		109.7368	
	Median		90.5790	
	Variance		4056.961	
	Std. Deviation		63.69427	
	Minimum		31.07	
	Maximum		209.28	
	Range		178.22	
	Interquartile Range		113.31	
	Skewness		.713	.717
	Kurtosis		-.618	1.400
RIGHTKEPRE	Mean		90.6008	17.71410
	95% Confidence Interval for Mean	Lower Bound	49.7520	
		Upper Bound	131.4496	
	5% Trimmed Mean		89.6259	
	Median		85.0200	
	Variance		2824.105	
	Std. Deviation		53.14231	
	Minimum		10.73	
	Maximum		188.03	

	Range		177.30	
	Interquartile Range		71.91	
	Skewness		.411	.717
	Kurtosis		.089	1.400
RIGHTKEPOST	Mean		106.1660	17.60645
	95% Confidence Interval for Mean	Lower Bound	65.5654	
		Upper Bound	146.7666	
	5% Trimmed Mean		106.2811	
	Median		117.0660	
	Variance		2789.885	
	Std. Deviation		52.81936	
	Minimum		28.12	
	Maximum		182.14	
	Range		154.02	
	Interquartile Range		93.85	
	Skewness		-.075	.717
	Kurtosis		-1.417	1.400
LEFTKFPRE	Mean		45.1878	14.67922
	95% Confidence Interval for Mean	Lower Bound	11.3374	
		Upper Bound	79.0381	
	5% Trimmed Mean		44.2318	
	Median		30.0840	
	Variance		1939.316	
	Std. Deviation		44.03766	
	Minimum		.00	
	Maximum		107.58	
	Range		107.58	
	Interquartile Range		88.86	
	Skewness		.643	.717

	Kurtosis		-1.689	1.400
LEFTKFPOST	Mean		64.4917	16.26665
	95% Confidence Interval for Mean	Lower Bound	26.9807	
		Upper Bound	102.0026	
	5% Trimmed Mean		61.3751	
	Median		44.7990	
	Variance		2381.437	
	Std. Deviation		48.79996	
	Minimum		18.64	
	Maximum		166.44	
	Range		147.80	
	Interquartile Range		69.16	
	Skewness		1.350	.717
	Kurtosis		1.208	1.400
RIGHTKFPRE	Mean		40.9767	9.94040
	95% Confidence Interval for Mean	Lower Bound	18.0541	
		Upper Bound	63.8993	
	5% Trimmed Mean		40.8245	
	Median		35.6430	
	Variance		889.304	
	Std. Deviation		29.82120	
	Minimum		.00	
	Maximum		84.69	
	Range		84.69	
	Interquartile Range		53.10	
	Skewness		.442	.717
	Kurtosis		-1.007	1.400
RIGHTKFPOST	Mean		71.0680	17.04265
	95% Confidence Interval for Mean	Lower Bound	31.7676	
		Upper Bound	110.3684	

	5% Trimmed Mean		69.8448	
	Median		47.4150	
	Variance		2614.067	
	Std. Deviation		51.12794	
	Minimum		5.89	
	Maximum		158.27	
	Range		152.38	
	Interquartile Range		86.98	
	Skewness		.577	.717
	Kurtosis		-.883	1.400
LEFTPLFPRE	Mean		56.2767	14.09066
	95% Confidence Interval for Mean	Lower Bound	23.7836	
		Upper Bound	88.7698	
	5% Trimmed Mean		53.6298	
	Median		37.9320	
	Variance		1786.922	
	Std. Deviation		42.27199	
	Minimum		14.72	
	Maximum		145.48	
	Range		130.77	
	Interquartile Range		56.24	
	Skewness		1.319	.717
	Kurtosis		1.486	1.400
LEFTPLFPOST	Mean		74.1563	13.31382
	95% Confidence Interval for Mean	Lower Bound	43.4546	
		Upper Bound	104.8581	
	5% Trimmed Mean		73.8394	
	Median		58.2060	
	Variance		1595.321	

	Std. Deviation		39.94147	
	Minimum		15.04	
	Maximum		138.98	
	Range		123.93	
	Interquartile Range		61.64	
	Skewness		.244	.717
	Kurtosis		-.878	1.400
RIGHTPLFPRE	Mean		44.7336	10.84784
	95% Confidence Interval for Mean	Lower Bound	19.7184	
		Upper Bound	69.7488	
	5% Trimmed Mean		42.0050	
	Median		41.2020	
	Variance		1059.081	
	Std. Deviation		32.54353	
	Minimum		13.34	
	Maximum		125.24	
	Range		111.90	
	Interquartile Range		20.70	
	Skewness		2.176	.717
	Kurtosis		5.850	1.400
RIGHTPLFPOST	Mean		62.1300	11.01426
	95% Confidence Interval for Mean	Lower Bound	36.7311	
		Upper Bound	87.5289	
	5% Trimmed Mean		61.6940	
	Median		66.3810	
	Variance		1091.825	
	Std. Deviation		33.04278	
	Minimum		17.33	
	Maximum		114.78	
	Range		97.45	

	Interquartile Range		58.21	
	Skewness		-.011	.717
	Kurtosis		-.929	1.400

Descriptives

			Statistic	Std. Error
ICANKLEPRE	Mean		102.4960	6.91932
	95% Confidence Interval for Mean	Lower Bound	83.2849	
		Upper Bound	121.7071	
	5% Trimmed Mean		102.6861	
	Median		105.6400	
	Variance		239.385	
	Std. Deviation		15.47207	
	Minimum		81.87	
	Maximum		119.70	
	Range		37.83	
	Interquartile Range		29.55	
	Skewness		-.400	.913
	Kurtosis		-1.580	2.000
ICANKLEPOST	Mean		100.1600	4.83845
	95% Confidence Interval for Mean	Lower Bound	86.7263	
		Upper Bound	113.5937	
	5% Trimmed Mean		99.9333	
	Median		100.2000	
	Variance		117.053	
	Std. Deviation		10.81910	
	Minimum		87.50	
	Maximum		116.90	

	Range		29.40	
	Interquartile Range		17.80	
	Skewness		.831	.913
	Kurtosis		1.573	2.000
ICKNEEPRE	Mean		155.9420	3.66118
	95% Confidence Interval for Mean	Lower Bound	145.7769	
		Upper Bound	166.1071	
	5% Trimmed Mean		155.7561	
	Median		153.0600	
	Variance		67.021	
	Std. Deviation		8.18664	
	Minimum		148.40	
	Maximum		166.83	
	Range		18.43	
	Interquartile Range		15.70	
	Skewness		.592	.913
	Kurtosis		-2.174	2.000
ICKNEEPOST	Mean		150.2600	4.69080
	95% Confidence Interval for Mean	Lower Bound	137.2363	
		Upper Bound	163.2837	
	5% Trimmed Mean		150.1389	
	Median		145.4000	
	Variance		110.018	
	Std. Deviation		10.48895	
	Minimum		140.90	
	Maximum		161.80	
	Range		20.90	
	Interquartile Range		20.25	
	Skewness		.498	.913
	Kurtosis		-3.199	2.000

ICHIPPRE	Mean		110.8220	6.43089
	95% Confidence Interval for Mean	Lower Bound	92.9670	
		Upper Bound	128.6770	
	5% Trimmed Mean		111.1978	
	Median		109.0400	
	Variance		206.782	
	Std. Deviation		14.37991	
	Minimum		90.08	
	Maximum		124.80	
	Range		34.72	
	Interquartile Range		26.35	
	Skewness		-.556	.913
	Kurtosis		-.552	2.000
ICHIPPOST	Mean		113.9000	6.44787
	95% Confidence Interval for Mean	Lower Bound	95.9978	
		Upper Bound	131.8022	
	5% Trimmed Mean		114.5944	
	Median		118.3000	
	Variance		207.875	
	Std. Deviation		14.41787	
	Minimum		89.10	
	Maximum		126.20	
	Range		37.10	
	Interquartile Range		21.10	
	Skewness		-1.810	.913
	Kurtosis		3.670	2.000

Descriptives

	Statistic	Std. Error

MSTANKLEPRE	Mean		92.6400	6.30801
	95% Confidence Interval for Mean	Lower Bound	75.1261	
		Upper Bound	110.1539	
	5% Trimmed Mean		91.8889	
	Median		86.7000	
	Variance		198.955	
	Std. Deviation		14.10515	
	Minimum		81.70	
	Maximum		117.10	
	Range		35.40	
	Interquartile Range		20.33	
	Skewness		1.908	.913
	Kurtosis		3.849	2.000
MSTANKLEPOST	Mean		93.4000	5.47932
	95% Confidence Interval for Mean	Lower Bound	78.1870	
		Upper Bound	108.6130	
	5% Trimmed Mean		93.1500	
	Median		90.7000	
	Variance		150.115	
	Std. Deviation		12.25214	
	Minimum		79.10	
	Maximum		112.20	
	Range		33.10	
	Interquartile Range		20.65	
	Skewness		.817	.913
	Kurtosis		1.292	2.000
MSTKNEEPRE	Mean		150.7760	7.71895
	95% Confidence Interval for Mean	Lower Bound	129.3448	
		Upper Bound	172.2072	
	5% Trimmed Mean		150.1467	

	Median		144.2800	
	Variance		297.911	
	Std. Deviation		17.26010	
	Minimum		136.18	
	Maximum		176.70	
	Range		40.52	
	Interquartile Range		31.50	
	Skewness		.987	.913
	Kurtosis		-.399	2.000
MSTKNEEPOST	Mean		149.9000	9.87811
	95% Confidence Interval for Mean	Lower Bound	122.4740	
		Upper Bound	177.3260	
	5% Trimmed Mean		149.7000	
	Median		145.6000	
	Variance		487.885	
	Std. Deviation		22.08812	
	Minimum		124.90	
	Maximum		178.50	
	Range		53.60	
	Interquartile Range		42.45	
	Skewness		.317	.913
	Kurtosis		-1.801	2.000
MSTHIPPRE	Mean		125.1960	8.86788
	95% Confidence Interval for Mean	Lower Bound	100.5748	
		Upper Bound	149.8172	
	5% Trimmed Mean		124.8156	
	Median		124.8100	
	Variance		393.196	

	Std. Deviation		19.82917	
	Minimum		102.14	
	Maximum		155.10	
	Range		52.96	
	Interquartile Range		34.41	
	Skewness		.705	.913
	Kurtosis		.880	2.000

Descriptives

			Statistic	Std. Error
TOANKLEPRE	Mean		109.7720	5.45039
	95% Confidence Interval for Mean	Lower Bound	94.6393	
		Upper Bound	124.9047	
	5% Trimmed Mean		109.6133	
	Median		108.7200	
	Variance		148.534	
	Std. Deviation		12.18743	
	Minimum		94.80	
	Maximum		127.60	
	Range		32.80	
	Interquartile Range		21.37	
	Skewness		.500	.913
	Kurtosis		.654	2.000
TOANKLEPOST	Mean		115.6200	4.32879
	95% Confidence Interval for Mean	Lower Bound	103.6014	
		Upper Bound	127.6386	
	5% Trimmed Mean		115.8556	
	Median		118.9000	
	Variance		93.692	

	Std. Deviation		9.67946	
	Minimum		102.30	
	Maximum		124.70	
	Range		22.40	
	Interquartile Range		18.40	
	Skewness		-.657	.913
	Kurtosis		-1.747	2.000
TOKNEEPRE	Mean		132.3080	2.31842
	95% Confidence Interval for Mean	Lower Bound	125.8710	
		Upper Bound	138.7450	
	5% Trimmed Mean		132.0122	
	Median		130.3000	
	Variance		26.875	
	Std. Deviation		5.18414	
	Minimum		128.60	
	Maximum		141.34	
	Range		12.74	
	Interquartile Range		7.52	
	Skewness		1.960	.913
	Kurtosis		3.980	2.000
TOKNEEPOST	Mean		135.3400	7.52633
	95% Confidence Interval for Mean	Lower Bound	114.4436	
		Upper Bound	156.2364	
	5% Trimmed Mean		135.8556	
	Median		143.9000	
	Variance		283.228	
	Std. Deviation		16.82938	
	Minimum		110.70	
	Maximum		150.70	
	Range		40.00	

	Interquartile Range		30.40	
	Skewness		-.916	.913
	Kurtosis		-.938	2.000
TOHIPPRE	Mean		138.6220	7.17959
	95% Confidence Interval for Mean	Lower Bound	118.6883	
		Upper Bound	158.5557	
	5% Trimmed Mean		138.9472	
	Median		141.7200	
	Variance		257.733	
	Std. Deviation		16.05405	
	Minimum		115.69	
	Maximum		155.70	
	Range		40.01	
	Interquartile Range		30.00	
	Skewness		-.626	.913
	Kurtosis		-.774	2.000
TOHIPPOST	Mean		132.1200	8.66443
	95% Confidence Interval for Mean	Lower Bound	108.0637	
		Upper Bound	156.1763	
	5% Trimmed Mean		133.1389	
	Median		136.5000	
	Variance		375.362	
	Std. Deviation		19.37426	
	Minimum		99.30	
	Maximum		146.60	
	Range		47.30	
	Interquartile Range		30.65	
	Skewness		-1.690	.913
	Kurtosis		3.026	2.000

Descriptives

			Statistic	Std. Error
DBANKLEPRE	Mean		121.3160	4.01909
	95% Confidence Interval for Mean	Lower Bound	110.1572	
		Upper Bound	132.4748	
	5% Trimmed Mean		121.0789	
	Median		119.5000	
	Variance		80.765	
	Std. Deviation		8.98696	
	Minimum		113.00	
	Maximum		133.90	
	Range		20.90	
	Interquartile Range		17.13	
	Skewness		.620	.913
	Kurtosis		-1.358	2.000
DBANKLEPOST	Mean		118.4600	6.53105
	95% Confidence Interval for Mean	Lower Bound	100.3269	
		Upper Bound	136.5931	
	5% Trimmed Mean		117.8278	
	Median		111.3000	
	Variance		213.273	
	Std. Deviation		14.60387	
	Minimum		106.50	
	Maximum		141.80	
	Range		35.30	
	Interquartile Range		24.90	
	Skewness		1.331	.913
	Kurtosis		1.020	2.000

DBKNEEPRE	Mean		104.4780	9.65161
	95% Confidence Interval for Mean	Lower Bound	77.6808	
		Upper Bound	131.2752	
	5% Trimmed Mean		105.6189	
	Median		111.9700	
	Variance		465.768	
	Std. Deviation		21.58165	
	Minimum		66.82	
	Maximum		121.60	
	Range		54.78	
	Interquartile Range		29.69	
	Skewness		-1.957	.913
	Kurtosis		4.138	2.000
DBKNEEPOST	Mean		123.0400	5.11083
	95% Confidence Interval for Mean	Lower Bound	108.8501	
		Upper Bound	137.2299	
	5% Trimmed Mean		123.4611	
	Median		124.7000	
	Variance		130.603	
	Std. Deviation		11.42817	
	Minimum		104.70	
	Maximum		133.80	
	Range		29.10	
	Interquartile Range		19.55	
	Skewness		-1.235	.913
	Kurtosis		1.569	2.000
DBHIPPRE	Mean		123.6440	6.50184

	95% Confidence Interval for Mean	Lower Bound	105.5920	
		Upper Bound	141.6960	
	5% Trimmed Mean		124.0011	
	Median		127.1600	
	Variance		211.370	
	Std. Deviation		14.53857	
	Minimum		102.26	
	Maximum		138.60	
	Range		36.34	
	Interquartile Range		26.77	
	Skewness		-.778	.913
	Kurtosis		-.387	2.000
DBHIPPOST	Mean		131.1800	6.07918
	95% Confidence Interval for Mean	Lower Bound	114.3015	
		Upper Bound	148.0585	
	5% Trimmed Mean		131.6778	
	Median		133.2000	
	Variance		184.782	
	Std. Deviation		13.59345	
	Minimum		110.40	
	Maximum		143.00	
	Range		32.60	
	Interquartile Range		24.65	
	Skewness		-.958	.913
	Kurtosis		.277	2.000

Descriptives

	Statistic	Std. Error
Mean	87.1760	6.88638

MSWANKLEPRE	95% Confidence Interval for Mean	Lower Bound	68.0564	
		Upper Bound	106.2956	
	5% Trimmed Mean		87.1844	
	Median		82.3900	
	Variance		237.111	
	Std. Deviation		15.39840	
	Minimum		69.80	
	Maximum		104.40	
	Range		34.60	
	Interquartile Range		29.85	
	Skewness		.241	.913
	Kurtosis		-2.646	2.000
MSWANKLEPOST	Mean		82.7000	1.70968
	95% Confidence Interval for Mean	Lower Bound	77.9532	
		Upper Bound	87.4468	
	5% Trimmed Mean		82.4333	
	Median		80.8000	
	Variance		14.615	
	Std. Deviation		3.82296	
	Minimum		80.70	
	Maximum		89.50	
	Range		8.80	
	Interquartile Range		4.85	
	Skewness		2.175	.913
	Kurtosis		4.765	2.000
MSWKNEEPRE	Mean		100.3480	11.17558
	95% Confidence Interval for Mean	Lower Bound	69.3196	
		Upper Bound	131.3764	
	5% Trimmed Mean		100.5478	
	Median		105.8000	
	Variance		624.468	

	Std. Deviation		24.98936	
	Minimum		66.50	
	Maximum		130.60	
	Range		64.10	
	Interquartile Range		46.29	
	Skewness		-.322	.913
	Kurtosis		-.835	2.000
MSWKNEEPOST	Mean		116.9200	3.10023
	95% Confidence Interval for Mean	Lower Bound	108.3124	
		Upper Bound	125.5276	
	5% Trimmed Mean		116.8056	
	Median		116.1000	
	Variance		48.057	
	Std. Deviation		6.93232	
	Minimum		108.30	
	Maximum		127.60	
	Range		19.30	
	Interquartile Range		10.75	
	Skewness		.716	.913
	Kurtosis		2.035	2.000
MSWHIPPRE	Mean		91.4560	8.27555
	95% Confidence Interval for Mean	Lower Bound	68.4794	
		Upper Bound	114.4326	
	5% Trimmed Mean		91.4789	
	Median		95.8400	
	Variance		342.424	
	Std. Deviation		18.50470	
	Minimum		66.40	
	Maximum		116.10	
	Range		49.70	
	Interquartile Range		32.18	
	Skewness		-.088	.913

	Kurtosis		.227	2.000
MSWHIPPOST	Mean		101.8800	8.21440
	95% Confidence Interval for Mean	Lower Bound	79.0732	
		Upper Bound	124.6868	
	5% Trimmed Mean		101.2556	
	Median		90.6000	
	Variance		337.382	
	Std. Deviation		18.36796	
	Minimum		87.50	
	Maximum		127.50	
	Range		40.00	
	Interquartile Range		33.40	
	Skewness		.836	.913
	Kurtosis		-1.913	2.000

Descriptives

			Statistic	Std. Error
HPANKLEPRE	Mean		101.5300	4.19596
	95% Confidence Interval for Mean	Lower Bound	89.8802	
		Upper Bound	113.1798	
	5% Trimmed Mean		101.1944	
	Median		101.9400	
	Variance		88.030	
	Std. Deviation		9.38245	
	Minimum		92.60	
	Maximum		116.50	
	Range		23.90	
	Interquartile Range		15.65	
	Skewness		1.166	.913
	Kurtosis		1.497	2.000
	Mean		96.3800	5.44329

HPANKLEPOST	95% Confidence Interval for Mean	Lower Bound	81.2670	
		Upper Bound	111.4930	
	5% Trimmed Mean		96.8500	
	Median		100.9000	
	Variance		148.147	
	Std. Deviation		12.17157	
	Minimum		77.70	
	Maximum		106.60	
	Range		28.90	
	Interquartile Range		21.90	
	Skewness		-1.083	.913
	Kurtosis		.080	2.000
HPKNEEPRE	Mean		138.5100	8.80911
	95% Confidence Interval for Mean	Lower Bound	114.0520	
		Upper Bound	162.9680	
	5% Trimmed Mean		139.2294	
	Median		145.0000	
	Variance		388.002	
	Std. Deviation		19.69776	
	Minimum		105.87	
	Maximum		158.20	
	Range		52.33	
	Interquartile Range		30.40	
	Skewness		-1.442	.913
	Kurtosis		2.713	2.000
HPKNEEPOST	Mean		150.0800	5.36017
	95% Confidence Interval for Mean	Lower Bound	135.1978	
		Upper Bound	164.9622	

	5% Trimmed Mean		150.3389	
	Median		152.0000	
	Variance		143.657	
	Std. Deviation		11.98570	
	Minimum		131.30	
	Maximum		164.20	
	Range		32.90	
	Interquartile Range		19.20	
	Skewness		-.904	.913
	Kurtosis		1.960	2.000
HPHIPPRE	Mean		91.4980	7.78628
	95% Confidence Interval for Mean	Lower Bound	69.8798	
		Upper Bound	113.1162	
	5% Trimmed Mean		91.5183	
	Median		98.8600	
	Variance		303.131	
	Std. Deviation		17.41066	
	Minimum		72.43	
	Maximum		110.20	
	Range		37.77	
	Interquartile Range		33.38	
	Skewness		-.355	.913
	Kurtosis		-2.871	2.000
HPHIPPOST	Mean		104.2600	6.16479
	95% Confidence Interval for Mean	Lower Bound	87.1438	
		Upper Bound	121.3762	
	5% Trimmed Mean		103.6278	
	Median		98.3000	
	Variance		190.023	
	Std. Deviation		13.78488	

	Minimum	92.50	
	Maximum	127.40	
	Range	34.90	
	Interquartile Range	21.70	
	Skewness	1.625	.913
	Kurtosis	2.713	2.000

Descriptives

			Statistic	Std. Error
IC2MSTANKLEPRE	Mean		98.7380	6.69708
	95% Confidence Interval for Mean	Lower Bound	80.1439	
		Upper Bound	117.3321	
	5% Trimmed Mean		98.4544	
	Median		98.1800	
	Variance		224.255	
	Std. Deviation		14.97513	
	Minimum		81.66	
	Maximum		120.92	
	Range		39.26	
	Interquartile Range		26.80	
	Skewness		.646	.913
	Kurtosis		.343	2.000
IC2MSTANKLEPOST	Mean		99.8660	4.37463
	95% Confidence Interval for Mean	Lower Bound	87.7201	
		Upper Bound	112.0119	
	5% Trimmed Mean		100.0206	
	Median		103.7300	
	Variance		95.687	
	Std. Deviation		9.78197	
	Minimum		87.50	
	Maximum		109.45	
	Range		21.95	

	Interquartile Range		18.80	
	Skewness		-.513	.913
	Kurtosis		-2.572	2.000
IC2MSTKNEEPRE	Mean		155.6440	4.98009
	95% Confidence Interval for Mean	Lower Bound	141.8171	
		Upper Bound	169.4709	
	5% Trimmed Mean		155.5178	
	Median		152.1500	
	Variance		124.006	
	Std. Deviation		11.13582	
	Minimum		141.89	
	Maximum		171.67	
	Range		29.78	
	Interquartile Range		19.20	
	Skewness		.465	.913
	Kurtosis		.346	2.000
IC2MSTKNEEPOST	Mean		149.5000	5.15053
	95% Confidence Interval for Mean	Lower Bound	135.1998	
		Upper Bound	163.8002	
	5% Trimmed Mean		149.0139	
	Median		148.4500	
	Variance		132.640	
	Std. Deviation		11.51694	
	Minimum		139.18	
	Maximum		168.57	
	Range		29.39	
	Interquartile Range		18.54	
	Skewness		1.467	.913
	Kurtosis		2.452	2.000

IC2MSTHIPPRE	Mean		116.6880	7.44829
	95% Confidence Interval for Mean	Lower Bound	96.0082	
		Upper Bound	137.3678	
	5% Trimmed Mean		116.3972	
	Median		114.7500	
	Variance		277.385	
	Std. Deviation		16.65488	
	Minimum		96.45	
	Maximum		142.16	
	Range		45.71	
	Interquartile Range		27.43	
	Skewness		.723	.913
	Kurtosis		1.590	2.000
IC2MSTHIPPOST	Mean		112.1060	6.28010
	95% Confidence Interval for Mean	Lower Bound	94.6697	
		Upper Bound	129.5423	
	5% Trimmed Mean		112.6456	
	Median		115.5000	
	Variance		197.198	
	Std. Deviation		14.04273	
	Minimum		89.10	
	Maximum		125.40	
	Range		36.30	
	Interquartile Range		23.22	
	Skewness		-1.390	.913
	Kurtosis		2.160	2.000

Descriptives

			Statistic	Std. Error
MST2TOANKLE PRE	Mean		96.5980	5.42781
	95% Confidence Interval for Mean	Lower Bound	81.5280	
		Upper Bound	111.6680	
	5% Trimmed Mean		95.8572	
	Median		91.5400	
	Variance		147.306	
	Std. Deviation		12.13696	
	Minimum		88.54	
	Maximum		117.99	
	Range		29.45	
	Interquartile Range		16.58	
	Skewness		2.077	.913
	Kurtosis		4.420	2.000
MST2TOANKLE POST	Mean		98.4520	3.23086
	95% Confidence Interval for Mean	Lower Bound	89.4817	
		Upper Bound	107.4223	
	5% Trimmed Mean		98.2717	
	Median		97.8200	
	Variance		52.192	
	Std. Deviation		7.22443	
	Minimum		90.28	
	Maximum		109.87	
	Range		19.59	
	Interquartile Range		11.77	
	Skewness		1.003	.913
	Kurtosis		1.899	2.000
MST2TOKNEEP RE	Mean		149.2900	6.30449
	95% Confidence Interval for Mean	Lower Bound	131.7859	
		Upper Bound	166.7941	
	5% Trimmed Mean		149.2106	

	Median		145.4700	
	Variance		198.733	
	Std. Deviation		14.09726	
	Minimum		134.77	
	Maximum		165.24	
	Range		30.47	
	Interquartile Range		27.73	
	Skewness		.307	.913
	Kurtosis		-2.910	2.000
MST2TOKNEEPOST	Mean		146.7540	8.32458
	95% Confidence Interval for Mean	Lower Bound	123.6412	
		Upper Bound	169.8668	
	5% Trimmed Mean		147.3250	
	Median		151.4400	
	Variance		346.494	
	Std. Deviation		18.61434	
	Minimum		118.93	
	Maximum		164.30	
	Range		45.37	
	Interquartile Range		34.22	
	Skewness		-.889	.913
	Kurtosis		-.267	2.000
MST2HIPPRE	Mean		134.2820	8.53183
	95% Confidence Interval for Mean	Lower Bound	110.5938	
		Upper Bound	157.9702	
	5% Trimmed Mean		134.3733	
	Median		137.3400	
	Variance		363.960	

	Std. Deviation		19.07775	
	Minimum		107.25	
	Maximum		159.67	
	Range		52.42	
	Interquartile Range		32.13	
	Skewness		-.211	.913
	Kurtosis		.985	2.000
MST2TOHIPPOST	Mean		126.2820	9.42014
	95% Confidence Interval for Mean	Lower Bound	100.1275	
		Upper Bound	152.4365	
	5% Trimmed Mean		127.4322	
	Median		132.9000	
	Variance		443.695	
	Std. Deviation		21.06407	
	Minimum		90.23	
	Maximum		141.63	
	Range		51.40	
	Interquartile Range		32.64	
	Skewness		-1.793	.913
	Kurtosis		3.334	2.000

Descriptives

			Statistic	Std. Error
TO2DBANKLEPRE	Mean		128.0640	6.17090
	95% Confidence Interval for Mean	Lower Bound	110.9308	
		Upper Bound	145.1972	
	5% Trimmed Mean		128.1178	
	Median		132.1100	
	Variance		190.400	

	Std. Deviation		13.79854	
	Minimum		112.77	
	Maximum		142.39	
	Range		29.62	
	Interquartile Range		27.09	
	Skewness		-.312	.913
	Kurtosis		-2.938	2.000
TO2BDANKLEPOST	Mean		122.5180	4.56462
	95% Confidence Interval for Mean	Lower Bound	109.8446	
		Upper Bound	135.1914	
	5% Trimmed Mean		122.3972	
	Median		121.6500	
	Variance		104.179	
	Std. Deviation		10.20681	
	Minimum		110.55	
	Maximum		136.66	
	Range		26.11	
	Interquartile Range		19.05	
	Skewness		.381	.913
	Kurtosis		-.712	2.000
TO2DBKNEEPRE	Mean		125.4460	3.65168
	95% Confidence Interval for Mean	Lower Bound	115.3073	
		Upper Bound	135.5847	
	5% Trimmed Mean		125.5278	
	Median		129.8100	
	Variance		66.674	
	Std. Deviation		8.16541	
	Minimum		115.48	
	Maximum		133.94	

	Range		18.46	
	Interquartile Range		15.23	
	Skewness		-.469	.913
	Kurtosis		-2.675	2.000
TO2DBKNEEPOST	Mean		134.4300	4.49929
	95% Confidence Interval for Mean	Lower Bound	121.9380	
		Upper Bound	146.9220	
	5% Trimmed Mean		134.9667	
	Median		138.7500	
	Variance		101.218	
	Std. Deviation		10.06071	
	Minimum		117.30	
	Maximum		141.90	
	Range		24.60	
	Interquartile Range		15.67	
	Skewness		-1.763	.913
	Kurtosis		3.090	2.000
TO2DBHIPPRE	Mean		137.4880	4.39645
	95% Confidence Interval for Mean	Lower Bound	125.2815	
		Upper Bound	149.6945	
	5% Trimmed Mean		137.6217	
	Median		137.5700	
	Variance		96.644	
	Std. Deviation		9.83075	
	Minimum		123.88	
	Maximum		148.69	
	Range		24.81	
	Interquartile Range		18.45	
	Skewness		-.375	.913
	Kurtosis		-.865	2.000

TO2DBHIPPOST	Mean		128.9520	9.28234
	95% Confidence Interval for Mean	Lower Bound	103.1801	
		Upper Bound	154.7239	
	5% Trimmed Mean		130.3400	
	Median		138.4900	
	Variance		430.809	
	Std. Deviation		20.75595	
	Minimum		92.04	
	Maximum		140.88	
	Range		48.84	
	Interquartile Range		26.44	
	Skewness		-2.172	.913
	Kurtosis		4.763	2.000

Descriptives

			Statistic	Std. Error
DB2MSWANKLEPRE	Mean		106.2780	3.97691
	95% Confidence Interval for Mean	Lower Bound	95.2363	
		Upper Bound	117.3197	
	5% Trimmed Mean		106.4294	
	Median		105.2400	
	Variance		79.079	
	Std. Deviation		8.89264	
	Minimum		93.75	
	Maximum		116.08	
	Range		22.33	
	Interquartile Range		16.42	
	Skewness		-.415	.913
	Kurtosis		-.688	2.000

DB2MSWANKLEPOST	Mean		107.5560	3.13720
	95% Confidence Interval for Mean	Lower Bound	98.8457	
		Upper Bound	116.2663	
	5% Trimmed Mean		107.3539	
	Median		106.2300	
	Variance		49.210	
	Std. Deviation		7.01499	
	Minimum		99.77	
	Maximum		118.98	
	Range		19.21	
	Interquartile Range		10.41	
	Skewness		1.218	.913
	Kurtosis		2.698	2.000
DB2MSWKNEEPRE	Mean		96.4840	7.99300
	95% Confidence Interval for Mean	Lower Bound	74.2919	
		Upper Bound	118.6761	
	5% Trimmed Mean		97.2483	
	Median		98.7400	
	Variance		319.440	
	Std. Deviation		17.87288	
	Minimum		66.82	
	Maximum		112.39	
	Range		45.57	
	Interquartile Range		28.85	
	Skewness		-1.490	.913
	Kurtosis		2.508	2.000
DB2MSWKNEEPOST	Mean		122.7260	4.94810
	95% Confidence Interval for Mean	Lower Bound	108.9879	
		Upper Bound	136.4641	

	5% Trimmed Mean		123.2422	
	Median		126.3400	
	Variance		122.419	
	Std. Deviation		11.06430	
	Minimum		103.93	
	Maximum		132.23	
	Range		28.30	
	Interquartile Range		17.05	
	Skewness		-1.706	.913
	Kurtosis		3.196	2.000
DB2MSWHIPPRE	Mean		112.0020	3.55872
	95% Confidence Interval for Mean	Lower Bound	102.1214	
		Upper Bound	121.8826	
	5% Trimmed Mean		112.1006	
	Median		112.6000	
	Variance		63.322	
	Std. Deviation		7.95754	
	Minimum		102.26	
	Maximum		119.97	
	Range		17.71	
	Interquartile Range		15.70	
	Skewness		-.209	.913
	Kurtosis		-2.502	2.000
DB2MSWHIPPOST	Mean		123.3480	7.31940
	95% Confidence Interval for Mean	Lower Bound	103.0261	
		Upper Bound	143.6699	
	5% Trimmed Mean		123.4333	
	Median		121.4000	

	Variance		267.868	
	Std. Deviation		16.36667	
	Minimum		100.23	
	Maximum		144.93	
	Range		44.70	
	Interquartile Range		27.89	
	Skewness		-.188	.913
	Kurtosis		.808	2.000

Descriptives

			Statistic	Std. Error
MSW2HPANKLE PRE	Mean		94.3600	6.75918
	95% Confidence Interval for Mean	Lower Bound	75.5935	
		Upper Bound	113.1265	
	5% Trimmed Mean		93.9056	
	Median		87.2000	
	Variance		228.433	
	Std. Deviation		15.11398	
	Minimum		81.63	
	Maximum		115.27	
	Range		33.64	
	Interquartile Range		28.28	
	Skewness		.762	.913
	Kurtosis		-1.892	2.000
MSW2HPANKLE POST	Mean		93.3680	3.63361
	95% Confidence Interval for Mean	Lower Bound	83.2795	
		Upper Bound	103.4565	
	5% Trimmed Mean		93.5850	
	Median		96.9100	
	Variance		66.015	
	Std. Deviation		8.12499	
	Minimum		81.03	
	Maximum		101.80	
	Range		20.77	

	Interquartile Range		14.14	
	Skewness		-.947	.913
	Kurtosis		.257	2.000
MSW2HPKNEEPRE	Mean		116.1800	10.57167
	95% Confidence Interval for Mean	Lower Bound	86.8283	
		Upper Bound	145.5317	
	5% Trimmed Mean		116.4806	
	Median		123.1300	
	Variance		558.801	
	Std. Deviation		23.63898	
	Minimum		85.18	
	Maximum		141.77	
	Range		56.59	
	Interquartile Range		45.18	
	Skewness		-.442	.913
	Kurtosis		-1.919	2.000
MSW2HPKNEEPOST	Mean		131.7160	5.73362
	95% Confidence Interval for Mean	Lower Bound	115.7969	
		Upper Bound	147.6351	
	5% Trimmed Mean		131.9583	
	Median		132.8800	
	Variance		164.372	
	Std. Deviation		12.82077	
	Minimum		112.47	
	Maximum		146.60	
	Range		34.13	
	Interquartile Range		22.50	
	Skewness		-.700	.913
	Kurtosis		.742	2.000

MSW2HPHIPPRE	Mean		91.0260	6.93467
	95% Confidence Interval for Mean	Lower Bound	71.7723	
		Upper Bound	110.2797	
	5% Trimmed Mean		91.1911	
	Median		95.6700	
	Variance		240.448	
	Std. Deviation		15.50639	
	Minimum		69.48	
	Maximum		109.60	
	Range		40.12	
	Interquartile Range		28.11	
	Skewness		-.427	.913
	Kurtosis		-.564	2.000
MSW2HPHIPPOST	Mean		100.5100	10.91123
	95% Confidence Interval for Mean	Lower Bound	70.2156	
		Upper Bound	130.8044	
	5% Trimmed Mean		100.6056	
	Median		91.6000	
	Variance		595.274	
	Std. Deviation		24.39824	
	Minimum		69.35	
	Maximum		129.95	
	Range		60.60	
	Interquartile Range		44.58	
	Skewness		.039	.913
	Kurtosis		-1.460	2.000

Descriptives

		Statistic	Std. Error
HPANKLEPRE	Mean	107.4920	4.43897

	95% Confidence Interval for Mean	Lower Bound	95.1674	
		Upper Bound	119.8166	
	5% Trimmed Mean		107.4711	
	Median		109.8000	
	Variance		98.522	
	Std. Deviation		9.92584	
	Minimum		96.83	
	Maximum		118.53	
	Range		21.70	
	Interquartile Range		19.50	
	Skewness		-.197	.913
	Kurtosis		-2.770	2.000
HPANKLEPOST	Mean		98.9920	5.91945
	95% Confidence Interval for Mean	Lower Bound	82.5570	
		Upper Bound	115.4270	
	5% Trimmed Mean		99.5894	
	Median		106.6000	
	Variance		175.199	
	Std. Deviation		13.23629	
	Minimum		77.70	
	Maximum		109.53	
	Range		31.83	
	Interquartile Range		21.98	
	Skewness		-1.381	.913
	Kurtosis		1.164	2.000
HPKNEEPRE	Mean		146.1120	5.36630
	95% Confidence Interval for Mean	Lower Bound	131.2128	
		Upper Bound	161.0112	
	5% Trimmed Mean		146.8994	

	Median		151.9400	
	Variance		143.986	
	Std. Deviation		11.99941	
	Minimum		125.02	
	Maximum		153.03	
	Range		28.01	
	Interquartile Range		16.69	
	Skewness		-2.057	.913
	Kurtosis		4.274	2.000
HPKNEEPOST	Mean		151.2260	5.60066
	95% Confidence Interval for Mean	Lower Bound	135.6761	
		Upper Bound	166.7759	
	5% Trimmed Mean		151.6344	
	Median		154.2000	
	Variance		156.837	
	Std. Deviation		12.52345	
	Minimum		131.30	
	Maximum		163.80	
	Range		32.50	
	Interquartile Range		21.44	
	Skewness		-1.172	.913
	Kurtosis		1.440	2.000
HPHIPPRE	Mean		94.5580	6.33857
	95% Confidence Interval for Mean	Lower Bound	76.9593	
		Upper Bound	112.1567	
	5% Trimmed Mean		94.2139	
	Median		92.2300	
	Variance		200.887	
	Std. Deviation		14.17347	
	Minimum		81.01	

	Maximum		114.30	
	Range		33.29	
	Interquartile Range		27.07	
	Skewness		.574	.913
	Kurtosis		-1.367	2.000
HPHIPPOST	Mean		104.6980	6.05392
	95% Confidence Interval for Mean	Lower Bound	87.8896	
		Upper Bound	121.5064	
	5% Trimmed Mean		104.0394	
	Median		98.2700	
	Variance		183.250	
	Std. Deviation		13.53697	
	Minimum		93.85	
	Maximum		127.40	
	Range		33.55	
	Interquartile Range		21.46	
	Skewness		1.639	.913
	Kurtosis		2.578	2.000

Descriptives

			Statistic	Std. Error
SpeedPre	Mean		3.2160	.93650
	95% Confidence Interval for Mean	Lower Bound	.6159	
		Upper Bound	5.8161	
	5% Trimmed Mean		3.2261	
	Median		3.2900	
	Variance		4.385	
	Std. Deviation		2.09408	
	Minimum		.37	
	Maximum		5.88	
	Range		5.51	
	Interquartile Range		3.84	
	Skewness		-.171	.913

	Kurtosis		-.282	2.000
SpeedPost	Mean		2.2560	.57885
	95% Confidence Interval for Mean	Lower Bound	.6489	
		Upper Bound	3.8631	
	5% Trimmed Mean		2.2828	
	Median		2.4500	
	Variance		1.675	
	Std. Deviation		1.29435	
	Minimum		.24	
	Maximum		3.79	
	Range		3.55	
	Interquartile Range		2.09	
	Skewness		-.861	.913
	Kurtosis		1.844	2.000

Descriptives

			Statistic	Std. Error
SPSIXMRTPRE	Mean		2.2278	.46770
	95% Confidence Interval for Mean	Lower Bound	1.0255	
		Upper Bound	3.4300	
	5% Trimmed Mean		2.2506	
	Median		2.1903	
	Variance		1.312	
	Std. Deviation		1.14563	
	Minimum		.36	
	Maximum		3.68	
	Range		3.32	
	Interquartile Range		1.72	
	Skewness		-.574	.845
	Kurtosis		.677	1.741
SPSIXMRTPOST	Mean		2.0068	.44528
	95% Confidence Interval for Mean	Lower Bound	.8622	
		Upper Bound	3.1514	
	5% Trimmed Mean		2.0193	

	Median	1.8583	
	Variance	1.190	
	Std. Deviation	1.09071	
	Minimum	.34	
	Maximum	3.45	
	Range	3.12	
	Interquartile Range	1.77	
	Skewness	-.216	.845
	Kurtosis	.147	1.741

1.5.2 SPSS Output for Normality Test

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
RHRPRE	.247	9	.120	.895	9	.224
RHRPOST	.293	9	.025	.821	9	.036

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
SYSPRE	.257	6	.200*	.884	6	.290

SYSPOST	.163	6	.200*	.951	6	.749
DIAPRE	.213	6	.200*	.883	6	.283
DIAPOST	.238	6	.200*	.901	6	.381

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
SIXMRTPRE	.212	6	.200*	.964	6	.848
SIXMRTPOST	.203	6	.200*	.956	6	.792

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
TCLEFTPRE	.125	8	.200*	.975	8	.932
TCLEFTPOST	.193	8	.200*	.943	8	.640
TCRIGHTPRE	.123	8	.200*	.982	8	.970
TCRIGHTPOST	.205	8	.200*	.917	8	.403
CCLEFTPRE	.235	8	.200*	.955	8	.766
CCLEFTPOST	.169	8	.200*	.947	8	.676
CCRIGHTPRE	.174	8	.200*	.937	8	.584
CCRIGHTPOST	.199	8	.200*	.909	8	.344

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
LEFTKEPRE	.182	9	.200*	.906	9	.288
LEFTKEPOST	.185	9	.200*	.898	9	.243
RIGHTKEPRE	.169	9	.200*	.960	9	.797
RIGHTKEPOST	.161	9	.200*	.951	9	.702
LEFTKFPRE	.235	9	.164	.815	9	.030
LEFTKFPOST	.321	9	.008	.836	9	.052
RIGHTKFPRE	.169	9	.200*	.924	9	.429
RIGHTKFPOST	.234	9	.169	.925	9	.433
LEFTPLFPRE	.223	9	.200*	.872	9	.130
LEFTPLFPOST	.211	9	.200*	.959	9	.792
RIGHTPLFPRE	.328	9	.006	.730	9	.003
RIGHTPLFPOST	.123	9	.200*	.959	9	.784

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
ICANKLEPRE	.181	5	.200*	.957	5	.789
ICANKLEPOST	.262	5	.200*	.945	5	.703
ICKNEEPRE	.238	5	.200*	.883	5	.321
ICKNEEPOST	.278	5	.200*	.788	5	.064
ICHIPPRE	.222	5	.200*	.909	5	.461

ICHIPPOST	.341	5	.057	.806	5	.091

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
MSTANKLEPRE	.333	5	.073	.773	5	.048
MSTANKLEPOST	.197	5	.200*	.958	5	.791
MSTKNEEPRE	.247	5	.200*	.879	5	.303
MSTKNEEPOST	.177	5	.200*	.955	5	.775
MSTHIPPRE	.206	5	.200*	.969	5	.866
MSTELBOPOST	.255	5	.200*	.871	5	.271

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
TOANKLEPRE	.169	5	.200*	.986	5	.962
TOANKLEPOST	.233	5	.200*	.900	5	.409
TOKNEEPRE	.339	5	.062	.757	5	.035
TOKNEEPOST	.294	5	.180	.882	5	.317
TOHIPPRE	.177	5	.200*	.958	5	.791
TOHIPPOST	.300	5	.162	.807	5	.093

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
DBANKLEPRE	.210	5	.200*	.907	5	.448

DBANKLEPOST	.288	5	.200*	.852	5	.201
DBKNEEPRE	.378	5	.019	.756	5	.033
DBKNEEPOST	.229	5	.200*	.906	5	.443
DBHIPPRE	.196	5	.200*	.948	5	.720
DBHIPPOST	.208	5	.200*	.893	5	.375

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
MSWANKLEPRE	.235	5	.200*	.890	5	.357
MSWANKLEPOST	.403	5	.008	.629	5	.002
MSWKNEEPRE	.186	5	.200*	.980	5	.935
MSWKNEEPOST	.272	5	.200*	.928	5	.585
MSWHIPPRE	.194	5	.200*	.976	5	.915
MSWHIPPOST	.330	5	.078	.810	5	.097

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
HPANKLEPRE	.280	5	.200*	.887	5	.340
HPANKLEPOST	.245	5	.200*	.878	5	.298
HPKNEEPRE	.280	5	.200*	.874	5	.282
HPKNEEPOST	.254	5	.200*	.936	5	.639
HPHIPPRE	.264	5	.200*	.850	5	.194
HPHIPPOST	.267	5	.200*	.839	5	.161

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
IC2MSTANKLEPRE	.172	5	.200*	.974	5	.898
IC2MSTANKLEPOST	.254	5	.200*	.881	5	.315
IC2MSTKNEEPRE	.223	5	.200*	.964	5	.838
IC2MSTKNEEPOST	.300	5	.161	.863	5	.237
IC2MSTHIPPRE	.230	5	.200*	.957	5	.789
IC2MSTHIPPOST	.246	5	.200*	.895	5	.383

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
MST2TOANKLEPRE	.375	5	.021	.711	5	.012
MST2TOANKLEPOST	.263	5	.200*	.935	5	.633
MST2TOKNEEPRE	.234	5	.200*	.869	5	.262
MST2TOKNEEPOST	.199	5	.200*	.921	5	.536
MST2HIPPRE	.192	5	.200*	.976	5	.914
MST2TOHIPPOST	.302	5	.154	.793	5	.071

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
TO2DBANKLEPRE	.242	5	.200*	.861	5	.233

TO2BDANKLEPOST	.143	5	.200*	.984	5	.954
TO2DBKNEEPRE	.303	5	.149	.862	5	.237
TO2DBKNEEPOST	.272	5	.200*	.798	5	.078
TO2DBHIPPRE	.168	5	.200*	.975	5	.904
TO2DBHIPPOST	.408	5	.007	.649	5	.003

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
DB2MSWANKLEPRE	.189	5	.200*	.954	5	.769
DB2MSWANKLEPOST	.320	5	.103	.879	5	.305
DB2MSWKNEEPRE	.293	5	.186	.863	5	.241
DB2MSWKNEEPOST	.298	5	.169	.834	5	.150
DB2MSWHIPPRE	.225	5	.200*	.898	5	.396
DB2MSWHIPPOST	.208	5	.200*	.979	5	.928

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
MSW2HPANKLEPRE	.282	5	.200*	.851	5	.199
MSW2HPANKLEPOST	.269	5	.200*	.923	5	.552
MSW2HPKNEEPRE	.216	5	.200*	.937	5	.644
MSW2HPKNEEPOST	.182	5	.200*	.974	5	.901
MSW2HPHIPPRE	.218	5	.200*	.970	5	.878

MSW2HPHIPPOST	.243	5	.200*	.934	5	.626

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
HPANKLEPRE	.243	5	.200*	.878	5	.299
HPANKLEPOST	.317	5	.111	.828	5	.134
HPKNEEPRE	.349	5	.046	.688	5	.007
HPKNEEPOST	.205	5	.200*	.926	5	.570
HPHIPPRE	.208	5	.200*	.918	5	.516
HPHIPPOST	.283	5	.200*	.823	5	.123

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
SpeedPre	.114	5	.200*	.998	5	.999
SpeedPost	.246	5	.200*	.943	5	.688

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
SPSIXMRTPRE	.212	6	.200*	.964	6	.848
SPSIXMRTPOST	.203	6	.200*	.956	6	.792

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

1.5.3 SPSS Output Differences Tests

Test Statistics[a]

	RHRPOST - RHRPRE
Z	-2.079[b]
Asymp. Sig. (2-tailed)	.038

a. Wilcoxon Signed Ranks Test
b. Based on positive ranks.

Paired Samples Test

		Paired Differences							Significance	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	SYSPRE - SYSPOST	-7.167	13.243	5.406	-21.064	6.731	-1.326	5	.121	.242
Pair 2	DIAPRE - DIAPOST	-2.500	30.032	12.260	-34.016	29.016	-.204	5	.423	.846

Paired Samples Test

		Paired Differences							Significance	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	SIXMRTPRE - SIXMRTPOST	79.500	116.543	47.579	-42.805	201.805	1.671	5	.078	.156

Paired Samples Test

		Paired Differences					t	df	Significance	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			One-Sided p	Two-Sided p
Pair 1	TCLEFTPRE - TCLEFTPOST	-.12222	3.64650	1.21550	-2.92517	2.68072	-.101	8	.461	.922
Pair 2	TCRIGHTPRE - TCRIGHTPOST	1.02222	3.47699	1.15900	-1.65043	3.69487	.882	8	.202	.404
Pair 3	CCLEFTPRE - CCLEFTPOST	1.21250	3.63610	1.28556	-1.82736	4.25236	.943	7	.188	.377
Pair 4	CCRIGHTPRE - CCRIGHTPOST	-.87500	2.26258	.79994	-2.76657	1.01657	-1.094	7	.155	.310

Paired Samples Test

		Paired Differences					t	df	Significance	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			One-Sided p	Two-Sided p
Pair 1	LEFTKEPRE - LEFTKEPOST	-22.95903	23.21551	7.73850	-40.80405	-5.11402	-2.967	8	.009	.018

Pair 2	RIGHTKEPRE - RIGHTKEPOST	-15.56520	22.46262	7.48754	-32.83149	1.70109	-2.079	8	.036	.071

Test Statistics[a]

	LEFTKFPOST - LEFTKFPRE
Z	-2.310[b]
Asymp. Sig. (2-tailed)	.021

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Paired Samples Test

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	RIGHTKFPRE - RIGHTKFPOST	-30.09127	24.11956	8.03985	-48.63120	-11.55133	-3.743	8	.003	.006

Paired Samples Test

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p

Pair 1	LEFTPLFPRE - LEFTPLFPOST	-17.87963	35.32491	11.77497	-45.03276	9.27349	-1.518	8	.084	.167

Test Statistics[a]

	RIGHTPLFPOST - RIGHTPLFPRE
Z	-1.779[b]
Asymp. Sig. (2-tailed)	.075

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Paired Samples Test

		Paired Differences					t	df	Significance One-Sided p	Significance Two-Sided p
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper				
Pair 1	ANKICPRE - ANKICPOST	2.33600	22.64376	10.12666	-25.77994	30.45194	.231	4	.414	.829
Pair 2	ANKTOPRE - ANKTOPOST	-5.84800	16.11090	7.20501	-25.85233	14.15633	-.812	4	.231	.463
Pair 3	ANKDBPRE - ANKDBPOST	2.85600	20.23034	9.04729	-22.26329	27.97529	.316	4	.384	.768
Pair 4	ANKHPPRE - ANKHPPOST	5.15000	7.36025	3.29160	-3.98896	14.28896	1.565	4	.096	.193

Test Statistics[a]

	ANKMSTPOST - ANKMSTPRE	ANKMSWPOST - ANKMSWPRE
Z	-.135[b]	-.674[b]
Asymp. Sig. (2-tailed)	.893	.500

a. Wilcoxon Signed Ranks Test
b. Based on positive ranks.

Paired Samples Test

		Paired Differences					t	df	Significance One-Sided p	Significance Two-Sided p
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper				
Pair 1	ANKIC2MSTPRE - ANKIC2MSTPOST	-1.12800	14.94867	6.68525	-19.68923	17.43323	-.169	4	.437	.874
Pair 2	ANKTO2DBPRE - ANKTO2DBPOST	5.54600	12.89095	5.76501	-10.46023	21.55223	.962	4	.195	.391
Pair 3	ANKTO2MSWPRE - ANKTO2MSWPOST	-1.27800	4.64220	2.07605	-7.04205	4.48605	-.616	4	.286	.571
Pair 4	ANKMSW2HPPRE - ANKMSW2HPPOST	.99200	12.81382	5.73052	-14.91846	16.90246	.173	4	.435	.871

Pair 5	ANKHPPLUSPRE - ANKHPPLUSPOST	8.50000	11.28229	5.04559	-5.50881	22.50881	1.685	4	.084	.167

Test Statistics[a]

	ANKMST2TOPOST - ANKMST2TOPRE
Z	-.674[b]
Asymp. Sig. (2-tailed)	.500

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Paired Samples Test

		Paired Differences							Significance	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	KNICPRE - KNICPOST	5.6820	12.3796	5.5363	-9.6892	21.0532	1.026	4	.181	.363
Pair 2	KNMSTPRE - KNMSTPOST	.87600	6.60349	2.95317	-7.32332	9.07532	.297	4	.391	.782
Pair 3	KNMSWPRE - KNMSWPOST	-16.57200	30.19746	13.50471	-54.06710	20.92310	-1.227	4	.144	.287
Pair 4	KNHPPRE - KNHPPOST	-11.57000	24.40610	10.91474	-41.87418	18.73418	-1.060	4	.174	.349

Pair 5	KNIC2MSTPRE - KNIC2MSTPOST	6.14400	7.06825	3.16102	-2.63239	14.92039	1.944	4	.062	.124
Pair 6	KNMST2TOPRE - KNMST2TOPOST	2.53600	8.04435	3.59754	-7.45238	12.52438	.705	4	.260	.520
Pair 7	KNTO2DBPRE - KNTO2DBPOST	-8.98400	6.77405	3.02945	-17.39509	-.57291	-2.966	4	.021	.041
Pair 8	KNTO2MSWPRE - KNTO2MSWPOST	-26.24200	7.72333	3.45398	-35.83178	-16.65222	-7.598	4	<.001	.002
Pair 9	KNMSW2HPPRE - KNMSW2HPPOST	-15.53600	28.95762	12.95024	-51.49163	20.41963	-1.200	4	.148	.296

Test Statistics[a]

	KNTOPOST - KNTOPRE	KNDBPOST - KNDBPRE	KNHPPLUSPOST - KNHPPLUSPRE
Z	-.405[b]	-2.023[b]	-.405[b]
Asymp. Sig. (2-tailed)	.686	.043	.686

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Paired Samples Test

	Paired Differences							Significance	
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	t	df	One-Sided p	Two-Sided p

					Lower	Upper				
Pair 1	HIPICPRE - HIPICPOST	-3.07800	9.03574	4.04099	-14.2973	8.14133	-.762	4	.244	.489
Pair 2	HIPMSTPRE - HIPMSTPOST	6.95600	11.90232	5.32288	-7.82268	21.73468	1.307	4	.131	.261
Pair 3	HIPTOPRE - HIPTOPOST	6.50200	10.73600	4.80128	-6.82850	19.83250	1.354	4	.124	.247
Pair 4	HIPDBPRE - HIPDBPOST	-7.53600	12.25707	5.48153	-22.75516	7.68316	-1.375	4	.121	.241
Pair 5	HIPMSWPRE - HIPMSWPOST	-10.42400	13.01857	5.82208	-26.58869	5.74069	-1.790	4	.074	.148
Pair 6	HIPHPPRE - HIPHPPOST	-12.76200	11.98484	5.35978	-27.64314	2.11914	-2.381	4	.038	.076
Pair 7	HIPIC2MSTPRE - HIPIC2MSTPOST	4.58200	10.71956	4.79394	-8.72810	17.89210	.956	4	.197	.393
Pair 8	HIPMST2TOPRE - HIPMST2TOPOST	8.00000	13.29401	5.94526	-8.50670	24.50670	1.346	4	.125	.250
Pair 9	HIPTO2MSWPRE - HIPTO2MSWPOST	-11.34600	9.89942	4.42716	-23.63775	.94575	-2.563	4	.031	.062
Pair 10	HIPMSW2HPPRE - HIPMSW2HPPOST	-9.48400	11.69808	5.23154	-24.00909	5.04109	-1.813	4	.072	.144
Pair 11	HIPHPPLUSPRE - HIPHPPLUSPOST	-10.14000	8.97495	4.01372	-21.28387	1.00387	-2.526	4	.032	.065

Test Statistics[a]

	HIPDB2MSWPOST - HIPDB2MSWPRE
Z	-1.753[b]
Asymp. Sig. (2-tailed)	.080

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Paired Samples Test

		Paired Differences					t	df	Significance One-Sided p	Significance Two-Sided p
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper				
Pair 1	AVSPEEDPRE - AVSPEEDPOST	.22097	.32363	.13212	-.11866	.56060	1.672	5	.078	.155

Paired Samples Test

		Paired Differences					t	df	Significance One-Sided p	Significance Two-Sided p
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper				

Pair 1	SIXMRTSPPRE - SIXMRTSPPOST	.80477	1.15233	.47044	-.40453	2.01406	1.711	5	.074	.148