THE EFFECTS A REHABILITATION DOG HAS ON WALKNG BALANCE AND FEAR OF FALLING IN INDIVIDUALS WITH AN INCOMPLETE SPINAL CORD INJURY

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ABSTRACT

Background: Individuals with an incomplete spinal cord injury (iSCI) may experience gait instability and falls. Falls can result in injuries, a fear of falling, and reduced balance confidence which can lead to restriction of activities of daily living. Rehabilitation dogs are specially trained and certified to assist individuals with mobility impairments and have been shown to benefit walking for individuals with neurological conditions. The effects of a rehabilitation dog on walking, fear of falling, and balance confidence in individuals with an iSCI has yet to be assessed.

Methods: In this quasi-experimental research study, five individuals with an iSCI (3 females: 43-54 years; 2 males: 42-69 years) and five age- and sex- matched neurotypical individuals (control group: 3 females: 42-55 years; 2 males: 42-68 years) were recruited to participate. Participants completed normal and tandem walking trials, with and without the rehabilitation dog, while their eyes were open and closed. Outcome variables included stride velocity, relative double support time (%DS), step length, step width, mediolateral (ML) and anterior-posterior (AP) margin of stability (MOS) average (Av). Variability was assessed for all the outcome variables using standard deviation (SD). The Mini Balance Evaluation Systems Test (MiniBESTest), Activity Specific Balance Confidence Scale (ABC Scale), Falls Efficacy Scale – International questionnaire (FES-I), and additional questions added to the ABC and FES-I questionnaire were used to examine balance, balance confidence, and fear of falling, respectively. Visual analog scales (VAS) were included to measure participants' perceptions of walking with the rehabilitation dog.

Results: Without the rehabilitation dog, participants with iSCI walked slower and with shorter steps, a smaller AP MOS Av, and a higher %DS, %DS SD, and wider steps than controls. It appeared individuals with an iSCI showed some improvements with the rehabilitation dog while the control group showed worsening when the dog was added. For iSCI participants, the rehabilitation dog reduced the impact of the eyes closed condition while walking compared to without the rehabilitation dog by decreasing their %DS (mean and SD) to a value similar to controls.. Tandem walking with the rehabilitation dog resulted in similar AP MOS Av between groups, but overall, the rehabilitation dog had minimal impact on tandem walking. The group with iSCI had a lower balance control (iSCI 17.2±9.34, control 26.8±0.80), balance confidence (iSCI 67.6±15.3, control 92.4±2.78), and increased fear of falling (iSCI 28.6±7.16, control 20.6±1.51) compared to the control group as expected. Responses to the additional questions for the ABC and FES-I suggest walking with the rehabilitation dog improved balance confidence and decreased fear of falling for individuals with an iSCI. VAS results showed both groups felt subjective improvements walking with the rehabilitation dog.

Conclusion: Walking with the rehabilitation dog appeared to improve measures of gait and confidence in the participants with iSCI including objective (kinematic) and patient-reported outcomes. Further research is required with a larger number of participants to explore how a more experienced rehabilitation dog walk with an iSCI population and other neurological conditions.

Preface and Author Contributions

I, Dylan Koshman, was the primary author of this thesis. Drs. Alison Oates and Gary Linassi were the co-supervisors of this thesis. Drs. Darren Nickel and Sarah Donkers were members of the research advisory committee. I thank Valerie Caron for assistance with the rehabilitation dog during the data collections for this project. All custom MATLAB scripts were written by Dr. Joel Lanovaz.

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LIST OF DEFINITIONS

Centre of mass: The location of total body mass and weight of the average centre of mass for each body segment (1)

Base of support: The area beneath an individual formed by the feet or all supporting contact surfaces on which an individual is walking or standing (2)

Balance: The even distribution of weight where the centre of mass is within the base of support (2)

Balance/Postural control: A term used to describe the act of achieving, restoring, or maintaining balance during any static or dynamic activity (2)

Stability: The body's ability to resist becoming unbalanced when moving from an unbalanced to a balanced state (3)

Margin of stability: The distance between the position of the velocity-dependent centre of mass and the edge of the base of support used to measure dynamic stability (4)

LIST OF ABBREVIATIONS

10 MWT	10-metre Walk test
ABC Scale	Activity-Specific Balance Confidence Scale
AP	Anterior-Posterior
AIS	American Spinal Injury Association Impairment Scale
Av	Average
BESTest	Balance Evaluation Systems Test
BOS	Base of Support
COM	Centre of Mass
COP	Centre of Pressure
CNS	Central Nervous System
%DS	Relative Double Support
FES-I	Falls Efficacy Scale International
iSCI	Incomplete Spinal Cord Injury
MiniBESTest	Mini Balance Evaluation Systems Test
ML	Medial-Lateral
MOS	Margin of Stability
PD	Parkinson's Disease
SCI	Spinal Cord Injury
TUG	Timed Up and Go
VAS	Visual Analog Scale
xCOM	Extrapolated Centre of Mass

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Chapter 1 - Introduction

A spinal cord injury (SCI) results in weakness and paralysis that affects gait stability which puts people at risk for things like falls. The increased risk of falling can result in fall related injuries, more than a neurotypical population (5, 6). The increased frequency of falling with a SCI can lead to the development of a fear of falling (7). It also can lead to individuals restricting activities of daily living in an attempt to prevent falling (8). Ambulatory devices can help individuals with an incomplete spinal cord injury (iSCI) move within their environments and to improve balance, decreasing the chance of falling. Ambulatory devices such as canes, walkers, and crutches have been shown to improve balance, but improper usage can increase the chance of injury causing individuals to abandon their devices (9-11). As we learn more about the balance challenges in individuals with a SCI, new gait assistive devices should be explored that could potentially minimize these negative effects.

1.1 Spinal Cord Injury and Classification

A SCI causes disruption to sensory, motor, and/or autonomic neural pathways. Partial or complete loss of function below the level of injury is dependent on the severity and location of the lesion. Injury to the spinal cord can occur through a traumatic or non-traumatic event. A traumatic SCI can be caused by a sudden impact on the spine from motor vehicle accidents, violence, sports, or falls and is often associated with fracture or dislocation of the vertebrae. In most spinal cord injuries, the spinal cord is not completely severed but often bruised or torn. It also can be damaged by displaced bone fragments and disc material and is often associated with ligamentous disruption (12). Trauma to the spinal cord causing damage is the result of four primary mechanisms of injury: 1) impact with persistent compression (i.e., bone fragments compress the spinal cord), 2) impact with transient compression (hyperextension), 3) distraction (adjacent vertebrae pulled apart causing stretching and tearing), 4) laceration (severe dislocations) (12, 13). Non-traumatic SCI can be caused by congenital or developmental malformation (i.e. Spina bifida and cerebral palsy), degenerative CNS disorders (ex. Friedreich's ataxia), infections, neuroinflammation (i.e. multiple sclerosis), toxic causes, vertebral subluxations, stenosis, and tumours (14, 15).

A SCI is often described in terms of completeness (complete vs incomplete), mechanism of injury (traumatic vs non-traumatic), severity (location, motor and/or sensory impairment graded using AIS), limbs affected (paraplegia vs tetraplegia) and their neurological level of injury. The location and the severity of an injury to the spinal cord can be graded using the American Spinal Injury Association Impairment Scale (AIS). The AIS classifies SCI with a rating of A, B, C, D, or E. Table 1 summarizes each AIS grade, the conditions individuals present with, and the type of injury (ex. sensory incomplete). AIS testing includes examination of myotomes, dermatomes sensory abilities, and anorectal function (16). The dermatomal-based sensory examination consists of 28 specific dermatomes tested using a light touch and pinprick (16). Each dermatome is rated as 0 (absent sensation), 1 (impaired sensation) or 2 (normal sensation). The inability to differentiate pinprick from light touch is graded as 0 (16, 17). The motor exam consists of assessing 10 muscular groups bilaterally with 5 in the upper extremities and 5 lower extremities. Motor strength is evaluated bilaterally on a 100-point scale (50 left and

50 right side of body) and is scored using the Medical Research Council (MRC) grading scale from 0 to 5. A score of 0 represents complete paralysis and 5 is normal strength through full range (16). The anorectal examination evaluates the completeness of the injury by evaluating the presence of spinal shock acutely. Spinal shock is the change in physiological function following a SCI that presents with loss of spinal cord function below the level of injury, flaccid paralysis, loss of bowel and bladder control, and loss of reflex activity (18). The external sphincter is examined for voluntary motor contraction, and sensation determined by examining anal cutaneous and deep anal pressure sensation (16).

After spinal shock has resolved, the AIS examination further evaluates the sacral segments to evaluate the presence of a complete or incomplete injury. A complete spinal cord injury is defined as the absence of all motor and sensory function below the level of injury including the sacral segments. An iSCI still has some motor and sensory function below the level of injury. The neurological level of injury is the most caudal segment of the spinal cord with normal sensory and antigravity motor function on both sides of the body (19) and is a reference point for classification and assessment of the injury. Paraplegia is the result of an injury to the spinal cord in the thoracic, lumbar, or sacral segments. This results in loss of function of the lower extremities with sparing of the upper extremities (12, 20). Individuals with incomplete paraplegia have a greater opportunity to regain locomotor ability within a year (76%) compared to those with complete paraplegia (12, 21). Complete paraplegia describes a situation where the spinal cord has been damaged enough that all motor control and sensation below the level of injury are lost. Individuals with complete paraplegia experience limited recovery of lower limb function if their level of injury is above T9 (12, 22), while an injury below T9 has a 38% chance to regain lower limb function (12, 22). Tetraplegia is caused by damage to the cervical segments of the spinal cord resulting in partial or total loss of function in all four limbs (12, 20). Individuals who present with incomplete tetraplegia often have multi-level involvement and plateau in their recovery around 9–12 months (12, 23). Individuals with complete tetraplegia are usually the most severely impaired but 66-90% gain function one level below the level of injury (12).

Table 1.1: AIS Classification Scale (24)

Grade	Type of Injury	Conditions
A	Complete	No sensory/motor function preserved in sacral segments (S4-5).
B	Sensory incomplete	Sensory but not motor function is preserved below neurological level and sacral segments S4-5. There is also no motor function more than 3 levels below motor level on either side of body.
C	Motor Incomplete	Motor function present at the most caudal segments for voluntary anal contraction or based on the sensory criteria, patient meets sensory incomplete status. This can be sensory function preservation at most caudal sacral segments S4-5 by light touch, pin pricks, or deep anal pressure. Patients have some motor function more than three levels below ipsilateral motor level. Also, less than half of key muscle function below neurological level of injury having a muscle grade ≥ 3.
D	Motor Incomplete	Motor incomplete status and half or more of key muscles, motor function preserved below neurological level and have a muscle grade ≥3.
E	Normal	Sensory/motor function graded normal and given an AIS grade of E if they had previous deficits. Someone without a SCI isn't graded on the AIS scale.

Based on the anatomy of the spinal cord, certain (but not all) injuries can result in patterned clinical presentations including Central cord syndrome, Brown-Sequard syndrome, anterior cord syndrome, cauda equina syndrome, and conus medullaris syndrome (25). Central cord syndrome is the most common clinical syndrome (roughly 15-25% of cases) (26). It is most common in individuals who have sustained a hyperextension injury of the cervical spine and can be associated with or without a fracture or possibly a dislocation. It presents with greater weakness in the upper limbs than lower limbs (25). Brown-Sequard syndrome can result from penetrating trauma such as a knife wound and can result in ipsilateral loss of proprioception, sense of vibration, motor control, and contralateral loss of pain and temperature below the lesion (25). Anterior cord syndrome is rare and is caused by a decrease or absence of blood to the anterior 2/3 of the spinal cord affecting mostly the corticospinal and spinothalamic tracts. This results in the loss of motor function, pain, and temperature sensation (25). Cauda equina syndrome is the injury to lumbosacral plexus and nerve roots. It will cause a flaccid paralysis of the lower limb muscles and areflexia of the bowel and bladder. There is also the potential of partial or complete loss of sensation and sacral reflexes to be absent (25). Lastly, the conus medullaris syndrome represents injury to the L1 and L2 and may present with a mixed picture of upper motor neuron and lower motor neuron signs and symptoms (25).

Roughly 80% of individuals that have sustained an iSCI regain the ability to ambulate after participating in a rehabilitation program (27). The ability to walk again is one of the main goals for patients following a SCI and understanding classification, diagnosis, and techniques to improve independence through ambulation is important. AIS classification can be used to help predict the potential to achieve functional walking (28). The likelihood of functional walking is greatly achieved in AIS C and D (28). After rehabilitation and recovery, individuals graded as AIS C are most likely able to regain the ability to walk, but typically walk with assistance (ex. brace or assistive device) (28, 29). Age plays a factor as well. Roughly 71-91% of individuals with an iSCI grade of AIS C under the age of 50 years regain ambulation but only 25-42% over the age of 50 regain ambulation 1 year post injury (28, 30, 31). All individuals with an iSCI classified as AIS D under the age of 50 were able to recovery ambulation while 80-100% of individuals over the age of 50 were able to regain ambulatory function one-year post-injury (28, 29). With individuals with injuries classified as AIS C and D being able to regain some level of ambulatory function, both classifications were included in this study.

1.2 Fear of Falling

Experiencing a SCI can pose one of the greatest emotional and physical challenges an individual may face and cause a negative outcome on a person's physical ability and independence (32). A subset of Social Cognitive Theory explores the concept of self-efficacy (33). Self efficacy is an individual's perception of their own ability to organize and execute a task (8, 34). For individuals with a SCI, there is a trend for an inverse relationship between the severity of the neurological impairment and self efficacy in achieving self-goals, overcoming adversity, and their belief in their own ability (32, 35, 36). Self efficacy may influence an individual's willingness or intention to perform activities of daily living due to concerns they won't be able to maintain balance (balance self-efficacy) or fall (falls self-efficacy) (8). One negative aspect of low self-efficacy shown in older adults was that those that have a lower falls and balance self-efficacy tend to avoid activities that put them at risk of falling (8). The avoidance of activities can lead to physical deconditioning, decrease in postural control, falling, and deterioration in function resulting in an increased risk of secondary complications causing a negative effect on quality of life (8). Rehabilitation programs focusing on education, understanding what caused a fall to occur, and establishing preventive strategies to help minimize falls have been seen to improve independence within an iSCI population (37, 38).

A fear of falling can develop after a fall that can lead to activity limitations and loss of independence even after one has recovered from their previous fall-related injury (39). The fear of falling is a behavioural concept that raises concerns about an individual beginning to self-restrict from participating in activities and; therefore, negatively impacts their life leading to frailty and decreased independence (39). The Falls Efficacy Scale International (FES-I) assesses an individual's fear of falling while performing different activities (39) such as walking around the house, going to a mall, and taking a bath or shower. This self-report measure is a 16-item questionnaire that ranges in scores from 16 to 64 with a lower score indicating a higher falls self-efficacy in performing the task without a fear of falling (40) (i.e., 1 = "not at all concerned" to 4= "very concerned") (40). The FES-I is a widely accepted tool and has good reliability and validity (41). The results/scores of the FES-I can assess the concern about falling and help detect concerns related to social activities, home-based activities, and outdoor balance-related tasks that may need to be adjusted.

1.3 Epidemiology and Falls with a SCI

In Canada, the prevalence of SCI reported in 2019 was over 86,000 (42) and it is projected that 121,000 Canadians will be living with a SCI by 2030 (5, 43). The lowest incidence of traumatic SCI is in children ages 0-14 years with adults aged 65 years and older representing the highest incidence (5, 44). Of the new yearly cases, roughly 1,237 are caused by a traumatic injury (5). Males are roughly three times more likely to suffer a SCI compared to females (5, 45). Sustaining an injury resulting in tetraplegia is more common than paraplegia for all ages (46).

Within the lifetime of an individual who has experienced a traumatic SCI, it is estimated to cost roughly $2 million from direct (ex. hospitalization time and rehabilitation) and indirect costs (ex. morbidity and premature mortality) (46). Following an injury, individuals who suffer a SCI spend on average 24 days in an acute hospital for paraplegia and 34 days for tetraplegia (46). At a specialized SCI rehabilitation centre, individuals have an average stay of 72 days for paraplegia and 83 days for tetraplegia (46). Secondary medical conditions cause challenges for individuals with a SCI, and they can negatively impact long-term health, productivity/employment, mobility, and independence (45, 47). Urinary tract infections are the most common followed by pressure ulcers, pneumonia, neuropathic pain, fractures from falls, and deep vein thrombosis (45, 46). Five years after sustaining an injury, just under half of the individuals that had jobs before their injury were unemployed and about one third suffered a decline in income (46). Individuals with a SCI also require more health care services compared to people without a SCI. People with a SCI were 2.7 times more likely to meet with a physician, require 30 more hours of home-care assistance, were hospitalized 2.6 times more often, and spent 3.3 more days in the hospital for secondary complications (45, 48). A SCI is considered a "low incidence injury" but can be very costly. A cost saving approach to help minimize secondary complications, maximize participation in activities of daily living, and increasing quality of life should be further explored. Individuals with a chronic SCI can also benefit from rehabilitation programs that help minimize the decline in functional ability and maintain a better quality of life.

Gait and stability are also affected by a spinal cord injury; both motor and sensory impairments can contribute to an increase in falls due to a decrease in balance control. On average, 75% of individuals with an iSCI experience at least one fall per year (6). Those with an iSCI are more susceptible to falls compared to people with other neurological conditions such as peripheral neuropathy (50%), Parkinson's disease (38-62%), and individuals 65yrs and older (25-35%), and frail individuals who are 80 years and older (40-50%) (6). Falling can cause major injuries such as head trauma, soft tissue injuries, fractures, and dislocations (50). Injuries that have been caused by a fall can require medical attention in 2-20% of these cases (51). The rate of fractures for iSCI is 18% higher than those considered to be neurotypical (5-6%) (6). Individuals with a SCI are influenced by both extrinsic factors (hazards in the environment) contributing to a fall, along with intrinsic factors (reduced strength, fatigue, not paying attention) (6, 49). Predictors of falls for individuals with a SCI include their level of ability, exercise level, physical health, quality of life, and fear of falling (51). The environments individuals walk in, whether indoor or outdoor, can produce an equal occurrence of falls (51). Outdoor falls are more likely to occur when the surfaces are uneven or slippery while walking (49). The combination of factors such as neurological and musculoskeletal problems that occur following a SCI can cause falls (52). Other factors that could contribute to falling are lack of attention or being distracted, and a sudden destabilizing or unexpected perturbation (49, 52). Knowing the increased chance of falling following a SCI, individuals can develop a fear of falling from factors such as individuals' level of activity, extrinsic/intrinsic factors, and the history of falling (7).

1.4 Clinical Assessments of Balance Control and Balance Confidence

Understanding balance control for individuals with an iSCI is aided by choosing the proper clinical assessment tools. Balance assessment tools are used to help guide clinicians in understanding what level of balance control their patient has. Each balance assessment tool has different goals and evaluation strategies to explore the level of balance control of a person. When choosing a balance assessment tool, it is important to choose one that is comprehensive enough to assess those at an increased risk of falling (53). Psychometrically sound (valid, reliable, and responsive) balance assessment should be a primary consideration for choosing which test to administer followed by clinical utility (ex. cost effective, easy to administer) (53). There are several balance assessments that are validated for use in individuals with a SCI and can help identify balance control, confidence, and level of mobility.

Commonly used balance evaluations include the Berg Balance Scale (BBS), Balance Evaluation Systems Test (BESTest), and Mini Balance Evaluation Systems Test (MiniBESTest) (54). Balance confidence when undertaking activities of daily living is examined by the Activities Specific Balance Confidence Scale (ABC Scale) (55). Common functional mobility tasks include the 10-metre Walk Test (10 MWT) to assess speed, 6-minute Walk Test to assess endurance (6MWT) and Timed Up and Go (TUG; assess functional mobility). Functional walking after a SCI can be assessed using the Spinal Cord Injury Functional Ambulation Profile (SCI-FAP) and the Walking Index for Spinal Cord Injury II (WISCI II) assesses walking ability based on need for assistance (56, 57). In this study, the MiniBESTest, ABC Scale, and FES-I questionnaires were used.

The BESTest is a comprehensive balance assessment that captures all components of balance. The MiniBESTest was created as a shorter version of the BESTest. The MiniBESTest is an assessment to evaluate dynamic balance control of an individual and help clinicians identify any postural control deficiencies that could be causing balance impairments. The MiniBESTest was shown to be a valid and reliable tool for those with a SCI (54). The MiniBESTest assesses four out of six components of balance including: anticipatory adjustments, postural responses, sensory orientation, and balance during gait (54). There are a total of 14 tasks that participants complete resulting in a maximum score of 28 with a higher score indicating better balance control (54). The MiniBESTest takes roughly 15 minutes to complete compared to 45 minutes for the BESTest (54). The results can assist clinicians in establishing specific interventions to improve dynamic balance and postural control deficiencies (58).

The ABC scale was used in this study to measure perceived balance confidence while completing specific activities of daily living. It consists of 16 items and participants rate their confidence in completing tasks without losing their balance (e.g., reaching for something at eye level, walking outside on icy sidewalks, walking up or down a ramp) and ranges from 0% (no confidence) to 100% (complete confidence) (59). The ABC scale was also shown to be a valid and reliable measure of balance confidence for those with an iSCI (60). Those with an iSCI have scored lower (67.5±20.3%) when compared to an able-bodied population (94.5±7.3%) that were age and sex matched (54). The results can be used to get a better understanding of an individual's confidence in performing activities and current activity limitations.

1.5 Dynamic Balance

Maintaining balance control is a complex motor skill that is important for the safe execution of movement (62). Balance is the even distribution of weight where the centre of mass (COM) position is within the base of support (BOS) (2). The BOS is the area underneath an individual formed by the feet or all supporting contact surfaces (2). In a static position, an individual will maintain balance if the vertical projection of the COM remains within the BOS (1). If the COM leaves the BOS, then a loss of balance and potentially a fall will occur (1, 2).

Balance control is an individual's ability to maintain or restore postural equilibrium during any static or dynamic activity (2). This comes from the ability to control COM movement during any activity. Postural control is important for 1) Maintaining posture while sitting or standing; 2) Voluntary movement between postures; and, 3) Reacting to an external perturbation (ex. trip, slip) (1, 2)-- All of which incorporate the maintaining, achieving, or restoring of the COM within the BOS. Different strategies are used to maintain postural control that include a reactive (compensatory) and/or predictive (anticipatory) action (2). Predictive postural control involves taking a voluntary movement (ex. step) or increasing muscle activation to anticipate a potential disturbance when moving. A reactive postural control is the movement or muscle response to an unknown or unpredicted disturbance (1).

Stability is the body's ability to resist becoming unbalanced by moving from an unbalanced to a balanced state (3). Increasing stability is associated with the ability to resist greater external forces applied to the individual before becoming unbalanced. Individuals have the capability to modify their posture to resist perturbations if their balance control system is intact. Modifying their posture to a more upright, higher position with a relatively smaller BOS could decrease stability. Alternatively, a lower and relatively larger BOS could increase stability (2).

While walking, the BOS is constantly changing due to the movement of the feet, ambulatory devices, etc. The size of the BOS can be altered by the number of objects on the ground (ex. holding onto an assistive device with two feet on the ground as opposed to standing on one leg). The BOS can also be altered by changing step width (mediolateral direction) and step length (anteroposterior direction) (63). Changing the step size (width and length) can be a response to and/or anticipation of perturbations that are experienced while walking. For forward progression to occur, the COM is moved forward, causing the COM to fall outside of the BOS. The next step forward creates a new BOS to "catch" the COM within the newly formed BOS (1).

A margin of stability (MOS) can be used to calculate the distance between the COM position and the edges of the BOS (4). A dynamic MOS calculation includes both the position and velocity of the COM (often referred to as an extrapolated or xCOM) to account for the dynamic nature of COM movement (4). The anterior-posterior (AP) and mediolateral (ML) directions of the MOS are controlled by foot placement (step length and step width respectively) and are commonly adjusted to control for balance challenges during walking (64).

Greater stability can be achieved by walking at a slower speed, spending more time in double support, walking with a flatter foot, and/or contracting supportive muscles to increase stability in the lower leg joints (65). Individuals with a SCI have been shown to have a significant increase to their variability of step width, step length, ML and AP foot placements relative to the COM, and MOS due to their injury when compared to healthy individuals (66). Gait variability is the fluctuations in walking performance portraying the ability of an individual to consistently reproduce the same gait pattern or have inconsistent alterations with each step (67). The increased stability in individuals with an iSCI could be attributed to slower walking speed which also causes shortening and widening of steps (68).

Maintaining balance control is important to execute safe movements without risking a fall (62). Individuals with a SCI have disruptions to sensorimotor and/or reflexive pathways, due to damage to the spinal cord. Disruptions can cause motor and sensory impairments, leading to challenges to balance control and an increase in falls (6). Challenges with sensory and motor systems that control the xCOM within the changing BOS to maintain balance require different compensatory strategies. Step width, length, and/or stride velocity alterations are all compensatory strategies that have been reported in individuals with an iSCI (63, 69) and can alter the MOS and increase stability (70).

1.6 Sensorimotor Control of Walking

Sensorimotor control of walking is based on sensory input from the visual, somatosensory, and vestibular systems to create a motor output (71) and support balance control. Vision provides information about the environment that can be used to adjust and plan proactive changes for locomotor patterns (72). When an individual encounters an unknown surface, they can visually identify potential hazards such as a sloped surface, staircase, icy or wet surfaces and use predictive balance control strategies to prevent balance loss (73). For example, individuals may shorten step length to provide more stability while walking on icy surfaces (72). Vision is also important for safe and effective locomotion by allowing the person to navigate through the environment, avoiding obstacles, and allowing a proper orientation to the destination (72, 74). When there is an end point in sight, visual input can guide movements to reach that end point (72). The use of vision therefore assists in locomotion and safe maneuvering through the environment.

When vision becomes impaired or the eyes are closed, individuals face further challenges with walking balance. When one system becomes less reliable or absent, the sensory information that is more reliable is weighted more heavily by the brain through sensory reweighting (75). A loss of visual feedback from the environment while walking can increase the chance of falling (76). Walking with eyes closed causes an increase in step width variability, which could suggest that lateral stability control is reliant on visual input (77, 78). A slower walking speed is present during eyes closed walking which is considered an adaptation to provide more time to monitor and control movement when vision is absent (72). Walking with eyes closed also causes people to walk with a shorter stride and increased time spent in double support (76).

Haptic input is the sensory inputs from cutaneous and proprioceptive systems while touching a surface or object in the environment (79) and, when added through light touch, can help improve balance control (80). Improvements in balance control come from the information received about the body’s position in the environment in relation to the source of haptic input (81). Haptic input can be received from different types of devices such as railings, canes, walkers (81). Shear and/or compression forces are sensed by the mechanoreceptors in the finger while touching an object while proprioceptive sensors determine the change in the positioning of the arm relative to the torso (80). While standing with eyes closed, if an individual is lightly touching a stable surface (i.e., adding haptic input), there is an associated reduction in body sway (82). When the haptic input is removed, there is a larger postural sway pattern based on an increase in trunk and centre of pressure (COP; point of the vertical ground reaction) sway patterns (1, 80, 83).

The properties of the object used to add haptic input while walking are important to consider as some devices are fixed into a position (ex. railing) and others require the individual to actively move (i.e., cane) (84). Added haptic input may help provide spatial awareness when the eyes are closed as previous research found an improvement in step and stability parameters when the eyes were closed, and haptic input was added (84). Importantly, added haptic input can enhance balance control without mechanical support by augmenting awareness of body movement and orientation (85).

The ability to utilize haptic input for those with an iSCI may vary depending on their level of injury and their level of sensation and motor function. The effects of haptic input can improve standing balance by compensating for sensory deficits in the lower limbs. For individuals with an iSCI, added haptic input has been shown to improve standing balance control by reducing the amount of postural sway with a larger effect in individuals with more upper extremity cutaneous sensation and deficits in lower extremities (81). Using a haptic device also showed a decrease in stride variability and MOS for those with an iSCI, suggesting there was an increase in balance control due to less variability (86). Conversely, the range of improvement depends on the level of injury and the extent of upper limb somatosensory impairments. Individuals with greater sensory loss in the lower limbs could benefit from the sensory information they receive from haptic devices based on upper limb function (80). Understanding the use of added haptic input and the influence on walking for individuals with an iSCI may expand knowledge related to how assistive devices support walking balance. The use of a rehabilitation dog may provide haptic input through contact with the harness that may benefit individuals with sensory impairments (i.e., individuals with iSCI).

1.7 Assistive Devices

Assistive devices provide a mechanical advantage that assists with locomotion and maintaining balance control by increasing size of the BOS (87). Following a SCI, some individuals can ambulate after rehabilitation, but the quality of ambulation may be affected by their injury due to sensorimotor dysfunction, decreased lower body strength, and/or challenges with muscle activation and timing (87). Assistive devices, such as canes and walkers, can be prescribed to help individuals regain, maintain, and improve their locomotion and complete activities of daily living. Users typically have decreased ability to support their own body weight and the necessary strength to move their legs forward to take a step (10). Individuals with a SCI that require assistance from other people for ambulation without the use of an assistive device reported greater pain interference and depressive symptoms (9, 88). Assistive devices are used to redistribute weight over the device, correct muscular imbalances, reduce fatigue, or to relieve pain (10). Clinicians analyze the individual's injury and prescribe an assistive device depending on the functional requirements of the person and their physical abilities (10). The goal is to get the individual ambulating again and minimize pain while doing so. Many individuals with an iSCI use assistive devices while walking due to the lack of stabilizing, supporting, or forward propulsive forces to promote locomotion (10).

Even though an assistive device can improve locomotion and balance control, it can also lead to improper use, which can be hazardous and result in poor compliance with the device. The rejection of assistive devices can be related to the difficulty in using the device, practitioners not providing follow-up after rehabilitation, and physical and psychological characteristics of the user (89, 90). Abandonment of devices may not only negatively affect their rehabilitation process, but it also can affect inclusion in social activities. The rejection of assistive devices could cause dependence on others for mobility, causing stress and placing a burden on caregivers and family members (11). Roughly 30-50% of people abandon their devices after they receive them, often due to concerns related to the challenges of using the device and a perception of risk (9). Even if individuals decide to use their device, there are negative effects individuals can still experience. While walking with a device, users have the constant need to reposition an assistive device (ex. a walker), and this may cause difficulties with walking due to the challenge of unloading the legs and moving the device forward (10). A lack of strength to move a device over obstacles and different surfaces could result in a loss of balance, causing a fall. While using an assistive device, there is an increased demand on the shoulder joint and soft tissues that can cause joint degeneration, strains, and overuse injuries in individuals with an iSCI (9). Shoulder pain is common in individuals with iSCI from overuse injuries while using a wheelchair or walker (9). The greater reliance on walking with an assistive device could result in more pain and fatigue due to efforts to compensate for the strength and sensory deficits the individual experiences from their injury (9). The negative effects of using an assistive device for ambulation and potential for further injury due to falls, raises the question about alternative methods for assisted ambulation.

1.8 Rehabilitation Dog as an assistive device

The use of a rehabilitation dog to assist with walking balance is a novel approach that is explored as the focus of this thesis. There are different reasons for owning a dog including as a pet, therapy dog, or service/rehabilitation dog. Owning a dog as a pet is more for oneself and family enjoyment, whereas a service dog has been externally trained by a trainer and assists with day-to-day tasks. A rehabilitation dog has been specifically trained to work with many types of people within a clinical setting. A rehabilitation dog is a type of service dog. A therapy dog is used for providing therapeutic and educational purposes from improving physiological measures, academic abilities, and emotional well-being (92). Owning a dog as a pet has been shown to increase physical activity, specifically increasing time spent walking per week (93). Within the elderly population (65 years and older) there was a 12% increase in physical activity shown in individuals who have a dog compared to those who don't (93). Walking a dog in the elderly population is also shown to increase walking frequency, an increased likelihood to achieve 150 minutes of walking per week, and an overall increase in walking speed compared to without a dog (93, 94). Walking with a dog has an impact on a dog owner's mental state and is associated with a decrease in depression compared to non-dog owners (93, 95). A dog has been shown to motivate children to do various tasks and foster socialization and personal interactions (96, 97). Animal-assisted interventions (AAI) refer to the use of animals to benefit humans, and these can include animal-assisted therapy, education, and activities. AAI have been explored for different pathologies, mental disorders, and even cancer (98).

A rehabilitation dog can be used for gait retraining, balance re-education, posture correction, and navigating around obstacles (96). The use of a rehabilitation dog was explored in a stroke population by Rondeau et al (96). While walking with the rehabilitation dog, the participants with a stroke saw improvements in walking speed and gait pattern (i.e., decreasing the amount of minor and major deviations while walking), suggesting the use of a rehabilitation dog could be a beneficial tool (96).

The use of a dog as a mobility aid was also explored within a group of people with Parkinson's disease (PD). Those with PD saw a different effect on their walking compared to the stroke study above including an increased time spent in double support, a narrower BOS, a slower walking speed, and decreased step and stride lengths while walking with the dog (99). Individuals with PD commonly present with deterioration in motor function, a change in gait pattern with a slower velocity and decreased stride length (99). Research has revealed that adding the dog for walking assistance made these traits even worse (99). The authors noted that the basal ganglia, which plays a role in regulating movement so that tasks such as walking become automatic, allows an individual to focus on other tasks while walking instead of putting all their attention into their movement. PD causes damage to the basal ganglia, which results in challenges with regulating movement. Both a motor component of holding onto the dog leash, reacting to the dog's movement, and leading the dog where you want to go by adjusting pressure points on the harness to lead the dog in a specific direction, with the addition of a cognitive component of being aware of where person and dog needs to go safely in the environment would be considered the dual task. People with PD performing dual tasks have a decrease in gait parameters (99). Interestingly, the step length for the foot on the same side as the dog for participants with PD had the greatest decline which could suggest that the dog hindered step progression for the closest foot (99).

The examples of the effect of a rehabilitation dog in two different neurological conditions shows the different challenges each condition presents and how other conditions may differ. The type of dog used could have had an effect as well. For the stroke population, a specifically trained rehabilitation dog was used and obtained from Mira (96), while the PD population used a service dog that was obtained by word of mouth (99). The different types of training these dogs received could have an impact on their ability to assist with walking. Also, the stroke study participants had multiple sessions of gait retraining, while the PD study looked at gait difference over a single visit with and without a dog.

There are also similarities between these studies. Both studies explored the effects a dog had on walking as a potential tool to help each neurological condition with various gait parameters and locomotion within an environment. Both studies addressed the walking challenges people who have had a stroke or who have PD face either with or without an assistive device and both studies explored the use of a dog with divergent results.

Objectives

Due to the reported variability in the effects of walking with a rehabilitation dog (96, 99) and that it has not been previously explored in those with iSCI, further research is required to explore the effectiveness of a rehabilitation dog in this population. Exploring how walking balance is affected in individuals with iSCI while walking with a rehabilitation dog could provide insight on a new clinical tool to help restore normal gait. Currently there is no literature that explores how the use of a rehabilitation dog affects walking balance in those with a SCI. The use of a rehabilitation dog with the iSCI population needs to be explored to help expand our current knowledge surrounding this newly implemented option for gait and balance aid.

The objectives for this thesis were to:

(1) Examine the walking balance of individuals with a chronic iSCI compared to a control group while using a rehabilitation dog for the first time.
(2) Identify reported changes to fear of falling and balance confidence for those with a chronic iSCI and a control group while using a rehabilitation dog.

It was hypothesized that:

(1) The measures of walking balance would show greater improvements in walking parameters while walking with the rehabilitation dog for those with a chronic iSCI compared to a control group; and,
(2) There would be a reported greater decrease in the fear of falling for those with a chronic iSCI compared to a control group while walking with a rehabilitation dog; and,
(3) There would be a reported increase in balance confidence for those with a chronic iSCI compared to a control group while walking with a rehabilitation dog.

Chapter 2 - Methods

2.1 Participants

Five individuals with chronic (≥ 1 year) incomplete spinal cord injury (iSCI) were recruited through a convenience sampling method to participate in this study. A group of five neurotypical individuals were matched by sex and age (+/- 2 years) to serve as a control group. The original proposed sample size was 20 iSCI and 20 control participants but COVID-19 caused challenges with research as outlined more thoroughly in section 4.4. Briefly, COVID-19 caused all research to halt for a period of time at the University of Saskatchewan. The Runway Lab at Merlis Belsher Place was also closed as the facility was turned into a field hospital. With the challenges faced during COVID-19, it was decided that having a sample size of 10 (5 people with iSCI and 5 controls) would provide data as an exploratory study on the research topic. The control group was recruited through word of mouth. Participants with iSCI were recruited through the Saskatchewan Health Authority SCI clinic at Saskatoon City Hospital and from previous research participants who agreed to participate in future research. Inclusion criteria included: (1) ability to walk >20m with or without a walking aid; (2) iSCI for minimum of one year; (3) AIS grade C or D for individuals with a chronic iSCI; (4) no fear or allergy of dogs; (5) over 18 years of age; (6) not experiencing any COVID-19 symptoms, requiring isolation due close contact with someone with COVID-19, and/or tested positive for COVID-19 at the time of testing; (7) having no other condition that could affect their walking ability (e.g., acute injury, other medical conditions such as Parkinson's disease, multiple sclerosis, vestibular conditions affecting balance, joint pain, illness, etc.). This study was approved by the University of Saskatchewan's research ethics board (Bio 1091). Participants provided written informed consent before data collection (ethics certificate and consent form can be found in Appendix A).

2.2 Experimental Protocol

A quasi-experimental design was used explore the iSCI participants and control group outcomes with and without the rehabilitation dog. A single participant data collection was completed in one day over a two-and-a-half-hour session in the Runway Lab at Merlis Belsher Place in Saskatoon. The data collections were from July 2021 to September 2021. Participants wore comfortable clothing and shoes that did not impede walking ability. At the start of the data collection, participants were asked to self-identify their month and year of birth, sex assigned at birth (male, female, prefer not to say), and gender (agender, cisgender, gender diverse, non-binary, genderfluid, transgender, prefer not to say). Participant sex was used to find iSCI and control participants to match with one another. Participants with an iSCI were then asked injury-specific questions including date of injury, level of injury, whether it was a traumatic or non-traumatic injury, and their AIS classification if known. If participants didn't know their AIS classification, they would still be included within this study if they were able to walk with or without an assistive device. The ability to walk with or without assistance from a device would classify them as AIS C or D (28-31).

Clinical tests for balance, balance confidence, and fear of falling were evaluated with the MiniBESTest, ABC Scale, and FES-I Questionnaire, respectively.

The ABC scale was used to measure perceived balance confidence while completing specific activities of daily living. Additional questions were added to the ABC scale to assess participants' perception of balance confidence while walking with and without the rehabilitation dog. Questions that all participants were asked include: "How confident are you that you will not lose your balance or become unsteady when you are…." followed by 11 customized, protocol-based questions, including "…. walking without the use of a walking aid", "…. walking in tandem eyes closed with a rehabilitation dog", and "…. walking normally with a rehabilitation dog". These additional questions were asked after walking trials were completed (Appendix B).

The FES-I questionnaire was used to measure concern about falling while performing different activities of daily living (40). Additional questions were also added to the FES-I questionnaire to examine the participants' concern about falling while performing the walking trials in this study. (Appendix C).

The rehabilitation dog used in this study was trained and certified by the Mira Foundation Inc., located in Quebec Canada, who train rehabilitation dogs for people with visual impairments, physical disabilities, and/or neuromuscular diseases (91). The rehabilitation dog that was used is a Labrador Retriever/Bernese Mountain cross (a 'Labranese') named Loki. At the time of research, he was 3 years of age. (Figure 2.1). Loki was trained to assist individuals with reduced mobility by providing balance support via a harness and has the ability to match the speed of the individual. Loki is also able to recognize when the individual begins to lose their balance and then is able to brace himself against the individual to help prevent a fall. Loki was trained at the Mira organization in Quebec (91).

Figure 2.1: The rehabilitation dog, Loki, freshly groomed. Image from: Mutt Hut on Instagram.

For trials with the rehabilitation dog, the participant would stand next to the rehabilitation dog, on their dominant hand side, where a custom-built dog harness was positioned at a height where their elbow was slightly bent when holding the handle of the harness. The positioning of the dog harness was the same process that is used to measure a gait aid. A physiotherapist trained in handling the rehabilitation dog was present during each data collection to assist the participants, setting up the harness, and commanding the dog.

The Xsens MVN system (Xsens, Enschede, Netherlands) was used to capture 3D movement with inertial sensors consisting of linear accelerometers, gyroscopes, magnetometers, and a barometer. Even though the Xsens system has not been validated in the SCI population, it has been validated within a healthy adult population (100) and PD population (101). Anthropometric measurements were obtained for each participant and inputted into the Xsens software as shown in Table 2.1. The inertial sensors record both linear and angular motion through the use of gyroscopes and accelerometers. Participants' body measurements are utilized to understand the participants' proper global and local position. When a participant's anthropometric measurements are taken, the Xsens system is then able to estimate the vertical displacement of different body segments relative to the ground based on height measurements.

Table 2.1 – Anthropometric Measurements for Xsens MVN System and Units of Measurement

Height (cm)
Weight (kg)
Foot Length (cm)
Shoulder Height (cm)
Shoulder Width (cm)
Arm Span (cm)
Hip Height (cm)
Hip Width (cm)
Knee Height (cm)
Ankle Height (cm)

Once anthropometric measurements were acquired, each participant donned a Lycra™ t-shirt, head band, fingerless gloves, footpads, and Velcro™ straps. A total of 17 inertial sensors were placed on each participant at locations shown in Table 2.2 and Figure 2.2.

Table 2.2 XSens MVN Sensor Placement and Location

Body Segment	**Sensor Placement**
Head	Sensor on back of the head
Shoulders	Sensor placed on each scapula (shoulder blades)
Sternum	Sensor position in the middle of the chest
Upper arm	Sensor placed on middle lateral side of upper arm
Lower arm	Sensor placed on the lateral backside side of the wrist
Hand	Sensor placed within the glove (backside of hand)
Pelvis	Sensor placed middle of sacrum
Upper leg	Sensor place on the middle-lateral side of the upper leg
Lower leg	Sensor placed on the medial side of the tibia (shin bone)
Foot	Sensor placed on the top of the foot

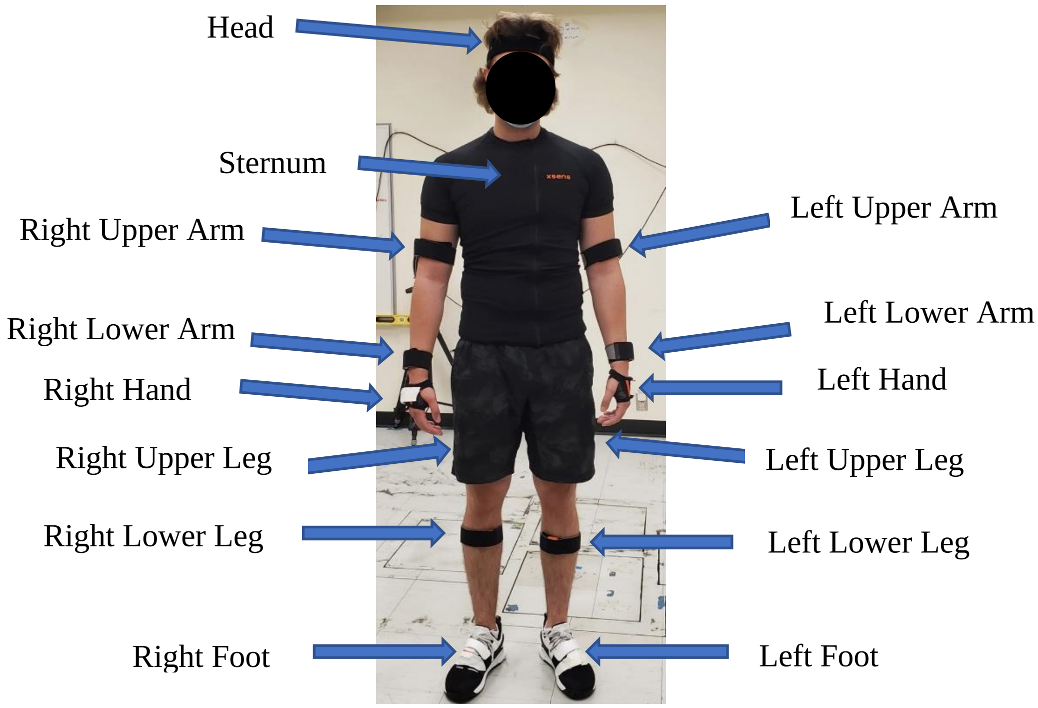

Figure 2.2: Front view of Xsens MVN system and sensor placement of all frontal view sensors. 1 pelvic, 2 shoulder, and 1 head sensor are placed posteriorly.

Once the sensors were in place on the participant, the Xsens wireless system was calibrated to align the sensors with different segments of the participant and minimize the uncertainty of measurements by providing a more precise and consistent measurement. Once the calibration was processed by the Xsens system and the quality was at a "good" or "acceptable" level, data collection proceeded. If the calibration read "poor" or "fail", the calibration was repeated until it was acceptable.

Participants were instructed to walk a distance of 10 m at a self-selected pace in two different walking styles: normal and tandem (heel-to-toe). During each walking style, participants walked with and without the rehabilitation dog, eyes open and eyes closed. Including eyes closed walking conditions also helps to further examine the effect of sensory integration abilities of the participant including use of any sensory input received from contact with the dog's harness. Table 2.3 shows the different conditions that were used:

Table 2.3 Walking Trial Conditions for iSCI and Control Group

With Rehabilitation Dog	Without Rehabilitation Dog
Tandem walking/eyes open	Normal walking/eyes closed
Tandem walking/eyes closed	Normal walking/eyes open
Normal walking/eyes open	Tandem walking/eyes closed
Normal walking/eyes closed	Tandem walking/eyes open

Walking trials were varied for participants to start either with or without the rehabilitation dog to control for the confounding variable of fatigue. Before walking with the rehabilitation dog, participants were given a chance to familiarize themselves with the dog by doing two practice walking trials. Participants were asked to complete, if possible, three walking trials per condition based on their comfort level, with a minimum of one trial completed in a randomized order with and without the rehabilitation dog for a total of 24 trials. Participants were given the option to rest throughout the data collection as needed. Figure 2.3 shows a participant walking with the rehabilitation dog.

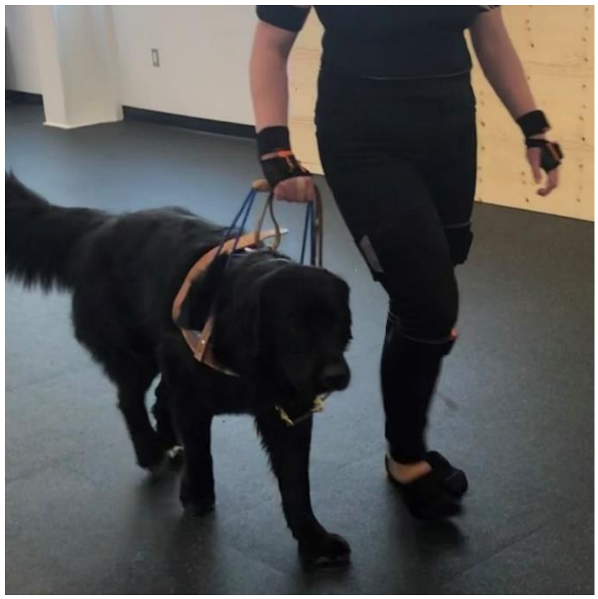

Figure 2.3: Participant fitted with the Xsens system holding onto the harness attached to the rehabilitation dog.

After walking trials were completed, participants then answered the additional, rehabilitation dog-specific questions for the ABC scale and FES-I. Finally, a visual analog scale (VAS) was used to measure participant perceptions of walking with the rehabilitation dog (Appendix D). The questions included: 1. How easy did you find using the rehabilitation dog while walking (0= extremely easy – 10=extremely difficult); 2. Do you think using a rehabilitation dog improved your balance during walking? (0= Did not improve at all – 10= definitely improved); 3. Do you think using the rehabilitation dog impaired your balance during walking? (0= Did not impair at all – 10= definitely impaired); 4. How likely are you to use a rehabilitation dog while walking if there was a rehabilitation dog available? (0= Extremely unlikely – 10= extremely likely). Question 5 asked Do you have anything else to add about your opinion of using the rehabilitation dog?" to add any comments they may have had during their time walking with the rehabilitation dog.

2.3 Data processing and Analysis

The kinematic data collected using the Xsens system were exported and further analysed using a custom routine (MATLAB R2019b for PC, Mathworks, Natick, MA). The kinematic data were filtered with a 10Hz low-pass filter and then average gait velocity, double support time, step length, step width, and a dynamic margin of stability (MOS) in both the anterior-posterior (AP) and mediolateral (ML) direction within each stride (ML MOS Av and AP MOS Av) were calculated. The average was found for each outcome measure across all trials completed (1-3/participant) to get better estimates for each participant. Gait velocity (cm/s) was calculated as the time it takes a participant to walk a specified distance. Double support (DS) time was calculated as the relative time spent in double support during a full gait cycle which was expressed as a percentage (%DS). Step length was calculated as the distance between the estimated points of contact of both feet in the AP direction. Step width was calculated as the distance between the two estimated outermost borders of consecutive foot strikes in the ML direction. For the MOS Av, the xCOM position was compared to the trailing leg heel for the AP MOS while the trailing leg at the 5th metatarsal is for ML MOS. A positive MOS value indicates the xCOM remained within the BOS and that the participant was more stable and less likely to fall. A negative MOS indicates the xCOM extended beyond the BOS boundaries suggesting the participant was more likely to fall (4). The standard deviation (SD) was used to calculate the variability of all outcome measures.

2.4 Statistical Analysis

Advanced inferential statistical analysis would not be normally conducted with such a small sample, However, in this case, it was felt that its inclusion would provide a more fulsome learning experience and therefore was included in this thesis.

For each variable, if a value for one step or stride for a condition fell outside of ± 3 SD of that condition, it was removed from the data. Q-Q plots were visually inspected to see how data were arranged on an expected normal distribution line, boxplots were examined to see if any outliers or extreme outliers were present, and the Shapiro-Wilk test was used to evaluate normality. Initial tests for normality showed that, even with outliers removed, data were still not normally distributed. Outliers were then put back in and a two-step data transformation approach was used to normalize the data for all outcome variables (102). The data were fractionally ranked for all outcome variables in all conditions. Data were then transformed using an inverse distribution function which used the fractionally ranked condition plus the mean and standard deviation. This method was used for all conditions of each outcome variable for both groups. With the transformed data, Shapiro-Wilk test was again used to check for normalization with all transformed data showing normal distribution. All kinematic results will be described using transformed data.

A 2 (group: iSCI vs. control) x 2 (dog: with vs. without rehabilitation dog) x 2 (vision: eyes open vs. eyes closed) repeated measures ANOVA was used for normal and tandem walking separately for each kinematic variable's mean and SD. Significant interactions and main effects were further examined by multivariate (within-group comparison) and univariate (between-group comparison) tests, and pairwise comparisons (Least Significant Difference (LSD)) respectively. Partial eta squared values (η^2) were used to evaluate the effect size of the outcome variables with the following ranges considered; 0.01 = small effect size; 0.06 = medium effect size; and 0.14 = large effect size (103).

A Mann-Whitney U test was used for the MiniBESTest, ABC Scale, additional questions added to ABC Scale, and the VAS Scale results to compare group means. A Chi-square test was used for the categorical variables of the FES-I questionnaire and additional questions added to FES-I questionnaire to examine differences between the two groups. Participants' comments from the VAS scale were extracted and interpreted to gain a perspective on how they felt about the experience with the rehabilitation dog in contrast with the quantitative/objective data.

Statistical analysis was run at both $\alpha \leq 0.01$ and $\alpha \leq 0.05$ to first explore and examine the data set to analyze type 1 or 2 errors. To decrease the potential for Type 1 error occurring and to account for a small sample size, a more conservative approach was taken with $\alpha \leq 0.01$. After analysis, there were no statistically significant values which could have meant there was the occurrence of a Type 2 error (false negative). The potential for a Type 2 error occurring would have meant the failure to reject the null hypothesis. To balance the chance of a Type 1 or 2 error occurring, it was decided to remove the conservative approach and use an alpha value of 0.05 to indicate statistical significance (104). Statistical analysis was performed using IBM SPSS (IBM SPSS Statistics, Version 28).

Chapter 3 - Results

3.1 Demographic Data

In the summer and fall of 2021, five individuals with an iSCI and five age- and sex-matched neurotypical individuals participated (see Table 3.1). Most of the participants completed three trials of each walking condition except two participants with an iSCI: One participant with an iSCI did not complete any trials of the tandem walking without the rehabilitation dog condition due to self-perceived concerns about loss of balance. The other participant completed all walking trials without the rehabilitation dog while using their assistive device (a walker). This participant was only able to complete one trial each of normal and tandem walking eyes open and eyes closed with the rehabilitation dog for each condition over self-perceived concerns about balance while walking with the rehabilitation dog instead of using their own assistive walking device.

A summary of participant demographics can be found in Table 3.1 Injury causes were traumatic for four participants with an iSCI (80%) while one was considered non-traumatic (20%). The time since diagnosis of SCI averaged 21.2 years (±21.98). All participants self-identified as cisgender.

Table 3.1 Participant Demographics

Participant Demographic	iSCI Mean ± SD (Range)	Control Mean ± SD (Range)
Height (m)	1.69 ± 0.09 (1.57 – 1.83)	1.78 ± 0.12 (1.64 – 1.95)
Weight (kg)	79.18 ± 15.92 (59.10 – 101.00)	85.84 ± 22.87 (55.50 – 104.50)
Sex (male: female)	2:3	2:3
Age (years)	52.00 ± 10.90 (42 – 69)	51.80 ± 10.78 (42-68)
Time Since Injury (years)	21.20 ± 21.98 (3 – 55)	N/A
Traumatic: Non-traumatic	4:1	N/A

3.2 Normal Walking Kinematic Data

Table 3.2 presents means and standard deviations for the outcome variables and Table 3.3 presents the results for the interaction effects and main effects for normal walking. All outcome variables are represented by means and their variability (SD).

Table 3.2 Kinematic data for normal walking conditions means and standard deviations.

Outcome variable	Group	No Dog Eyes Open	With Dog Eyes Open	No Dog Eyes Closed	With Dog Eyes Closed
Stride Velocity (cm/s)	iSCI	85.08 ± 15.91	90.56 ± 11.27	66.81 ± 14.25	68.66 ± 17.71
	Control	128.83 ± 11.12	112.15 ± 14.47	109.25 ± 9.83	101.87 ± 10.73
Stride Velocity SD (cm/s)	iSCI	3.07 ± 1.31	4.71 ± 3.46	4.07 ± 2.19	4.56 ± 4.20
	Control	3.95 ± 2.65	4.58 ± 2.52	3.40 ± 2.37	4.52 ± 3.12
Double Support Time (%)	iSCI	31.42 ± 4.87	30.60 ± 4.39	33.32 ± 8.40	29.48 ± 9.10
	Control	23.86 ± 4.46	26.47 ± 5.84	26.24 ± 4.50	28.17 ± 5.03
Double Support Time SD (%)	iSCI	2.46 ± 1.38	1.69 ± 0.89	2.71 ± 0.82	3.03 ± 2.69
	Control	1.05 ± 0.50	1.79 ± 0.86	1.51 ± 0.76	2.48 ± 1.31
Step Width (cm)	iSCI	27.45 ± 11.49	21.67 ± 5.01	28.66 ± 8.06	23.89 ± 7.14
	Control	23.11 ± 3.31	22.33 ± 2.62	25.66 ± 3.30	24.64 ± 3.52
Step Width SD (cm)	iSCI	3.35 ± 1.05	2.91 ± 1.11	5.30 ± 2.80	4.00 ± 1.84
	Control	2.97 ± 1.29	2.99 ± 1.13	3.62 ± 1.46	3.78 ± 1.53
Step Length (cm)	iSCI	52.06 ± 4.11	54.58 ± 5.06	43.55 ± 5.08	48.68 ± 10.48
	Control	70.88 ± 3.02	65.92 ± 8.49	64.50 ± 4.71	61.64 ± 5.76
Step Length SD (cm)	iSCI	3.26 ± 1.12	5.02 ± 3.21	4.03 ± 1.54	5.74 ± 3.41
	Control	4.16 ± 3.32	3.97 ± 2.75	3.60 ± 2.80	4.41 ± 3.19
ML MOS Av (cm)	iSCI	10.29 ± 4.07	11.21 ± 6.05	11.76 ± 5.73	9.99 ± 3.59
	Control	11.00 ± 2.70	9.97 ± 3.78	11.47 ± 2.62	10.83 ± 2.25
ML MOS Av SD (cm)	iSCI	1.02 ± 0.45	1.04 ± 0.36	1.96 ± 1.10	1.58 ± 1.36
	Control	1.07 ± 0.75	1.10 ± 0.71	1.18 ± 0.93	1.30 ± 0.94
AP MOS Av (cm)	iSCI	46.11 ± 9.51	42.28 ± 7.34	39.02 ± 9.45	35.38 ± 8.80
	Control	61.04 ± 5.40	55.58 ± 6.64	53.62 ± 4.23	50.35 ± 16.15
AP MOS Av SD (cm)	iSCI	1.45 ± 1.11	2.08 ± 2.03	2.54 ± 0.85	2.40 ± 1.46
	Control	1.48 ± 1.06	2.07 ± 1.21	1.45 ± 1.02	2.13 ± 2.01

Table 3.3 Interaction and main effects for normal walking

Dependent Variable	Vision by Group Interaction effect	Dog by Group Interaction effect	Vision by dog Interaction effect	Vision by Dog by Group interaction effect	Main effect of group	Main effect of vision	Main effect of dog
Stride Velocity	F= 1.525 p = 0.231 η^2 = 0.071	F = 6.830 p = **0.017*** η^2 = 0.255	F = 0.633 p = 0.436 η^2 = 0.031	F = 3.283 p = 0.085 η^2 = 0.021	F = 55.896 **p < 0.001*** η^2 = 0.666	F = 76.397 **p < 0.001*** η^2 = 0.669	F = 1.944 p = 0.178 η^2 = 0.089
Stride Velocity SD	F=0.395 p =0.536 η^2 = 0.018	F= 0.022 p = 0.883 η^2 = 0.001	F = 0.022 p= 0.589 η^2 = 0.011	F = 0.079 p = 0.781 η^2 = 0.004	F = 0.000 p = 0.989 η^2 = 0.000	F=0.011 p = 0.918 η^2 = 0.000	F = 2.284 p = 0.145 η^2 = 0.094
Double Support Time	F = 1.606 p = 0.220 η^2 = 0.074	F = 10.388 **p = 0.004*** η^2 = 0.342	F = 4.561 **p = 0.045*** η^2 = 0.186	F = 1.831 p = 0.191 η^2 = 0.084	F = 4.586 **p = 0.045*** η^2 = 0.187	f = 3.468 p = 0.077 η^2 = 0.148	F = 0.002 P = 0.965 η^2 = 0.000
Double Support Time SD	F = 0.097 p = 0.758 η^2 = 0.005	F = 5.428 **p = 0.030*** η^2 = 0.213	F = 3.014 p = 0.098 η^2 = 0.131	F = 1.288 p = 0.270 η^2 = 0.061	F = 7.400 **p = 0.013*** η^2 = 0.270	F = 3.884 p = 0.063 η^2 = 0.163	F = 1.831 P = 0.191 η^2 = 0.084
Step Width	F = 0.217 p =0.647 η^2 = 0.013	F = 5.067 **p = 0.038*** η^2 = 0.230	F = 0.067 p = 0.799 η^2 = 0.004	F = 0.177 p = 0.680 η^2 = 0.010	F = 0.417 p = 0.527 η^2 = 0.024	F= 7.239 **p = 0.015*** η^2 = 0.299	F = 10.088 **p = 0.006*** η^2 = 0.372
Step Width SD	F = 1.432 p =0.245 η^2 = 0.064	F = 1.955 p = 0.177 η^2 = 0.085	F = 0.387 p = 0.541 η^2 = 0.018	F = 0.736 p = 0.401 η^2 = 0.034	F = 2.354 p = 0.140 η^2 = 0.101	F = 10.942 **p = 0.003*** η^2 = 0.343	F = 1.289 p = 0.269 η^2 =0.058
Step Length	F = 0.544 p = 0.469 η^2 = 0.026	F = 10.640 **p = 0.004*** η^2 = 0.347	F = 1.169 P = 0.292 η^2 = 0.055	F = 0.014 p = 0.907 η^2 = 0.001	F = 79.821 **p < 0.001*** η^2 = 0.800	F = 24.353 **p < 0.001*** η^2 = 0.549	F = 0.001 p = 0.971 η^2 = 0.000
Step Length SD	F = 1.259 p = 0.276 η^2 = 0.062	F = 2.355 p =0.141 η^2 = 0.110	F = 0.230 p = 0.637 η^2 = 0.012	F = 0.273 p = 0.607 η^2 = 0.014	F = 0.236 p = 0.633 η^2 = 0.012	F = 0.898 p = 0.355 η^2 = 0.045	F = 4.854 **p = 0.040*** η^2 = 0.204
ML MOS Av	F = 0.288 p = 0.597 η^2 = 0.014	F = 0.119 p = 0.734 η^2 = 0.006	F = 1.310 p= 0.265 η^2 = 0.059	F = 2.369 p = 0.139 η^2 = 0.101	F = 0.000 p = 0.997 η^2 = 0.000	F = 0.630 p = 0.436 η^2 = 0.029	F = 1.089 p = 0.309 η^2 = 0.049
ML MOS Av SD	F = 2.274 p= 0.146 η^2 = 0.098	F = 0.069 p = 0.429 η^2 = 0.030	F = 0.207 p = 0.654 η^2 = 0.010	F = 0.504 p = 0.485 η^2 = 0.023	F = 1.375 p = 0.254 η^2 = 0.061	F = 5.380 **p = 0.031*** η^2 = 0.204	F = 0.122 p = 0.730 η^2 = 0.006
AP MOS Av	F = 0.046 p = 0.833 η^2 = 0.002	F = 0.030 p = 0.865 η^2 = 0.001	F = 0.152 p = 0.700 η^2 = 0.007	F = 0.104 p = 0.750 η^2 = 0.005	F = 29.702 **p < 0.001*** η^2 = 0.586	F = 17.438 **p < 0.001*** η^2 = 0.454	F = 4.794 **p = 0.040*** η^2 = 0.186
AP MOS Av SD	F = 1.554 p = 0.227 η^2 = 0.072	F = 4.063 p = 0.054 η^2 = 0.127	F = 0.301 p = 0.589 η^2 = 0.015	F = 0.476 p = 0.498 η^2 = 0.023	F = 1.202 p = 0.286 η^2 = 0.057	F = 1.679 p = 0.210 η^2 =0.077	F = 1.640 p = 0.220 η^2 = 0.074

Note: Significance was set at < 0.05. * = interaction and main effects showing significance

Stride velocity presented with a significant group-by-dog interaction ($F(1,20) = 6.830$, $p = 0.017$, $\eta^2 = 0.255$) as seen in Figure 3.1. There was a significant difference between groups without ($F(1,20) = 82.709$, $p < 0.001$, $\eta^2 = 0.805$) (iSCI 75.95cm/s ± 3.78, control 119.04 cm ± 2.56) and with the rehabilitation dog ($F(1,20) = 26.725$, $p < 0.001$, $\eta^2 = 0.572$) (iSCI 79.61cm/s ± 4.23, control 107.01cm/s ± 3.20). There was no significant differences for individuals with an iSCI walking with and without the rehabilitation dog (No Dog 75.95cm/s ± 3.78, With Dog 79.61cm/s ± 4.23) ($F(1,20) = 0.584$, $p = 0.454$, $\eta^2 = 0.028$); however, the control group walked significantly faster without the rehabilitation dog than with the rehabilitation dog ($F(1,20) = 11.043$, $p = 0.003$, $\eta^2 = 0.356$) (No Dog 119.04cm/s ± 2.86, With Dog 107.01cm/s ± 3.20). A main effect of vision ($F(1,20) = 70.563$, $p < 0.001$, $\eta^2 = 0.779$) showed eyes open (eyes open 104.16 cm/s ± 2.27) had a significantly faster stride velocity than eyes closed (eyes closed 88.65 cm/s ± 2.27) . Stride velocity SD did not present with any significant interaction or main effects.

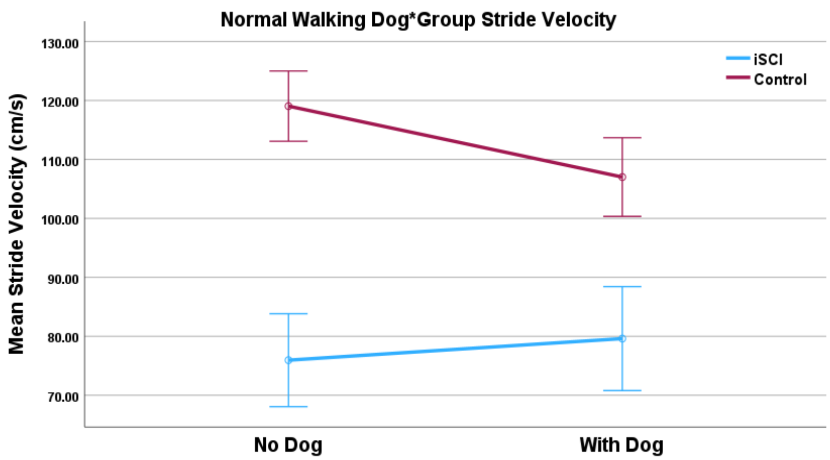

Figure 3.1. Mean stride velocity (cm/s) for both iSCI and control group in without and with rehabilitation dog trials. Errors bars represent 95% confidence interval.

Double support time presented with a significant dog by group interaction ($F(1,20)=10.388$, $p=0.004$, $\eta^2 = 0.342$) shown in Figure 3.2. There was a significant difference between groups while walking without the rehabilitation dog (iSCI 32.37% ± 1.88, control 25.05% ± 1.42) ($F(1,20)=9.660$, $p=0.006$, $\eta^2 = 0.326$). There was no significant difference between groups (iSCI 30.04% ± 2.03, control 27.32% ± 1.53) ($F(1,20)=1.145$, $p=0.297$, $\eta^2 = 0.054$) when walking with the rehabilitation dog. The iSCI group saw no significant difference in double support time between walking without and with the rehabilitation dog (No dog 32.37% ± 1.88, With dog 30.04% ± 2.03) ($F(1,20)=4.194$, $p=0.054$, $\eta^2 = 0.173$). The control group spent significantly less time in double support without the rehabilitation dog compared to with the rehabilitation dog (No dog 25.05% ± 1.42, With dog 27.32% ± 1.53) ($F(1,20)=6.946$, $p=0.016$, $\eta^2 = 0.258$).

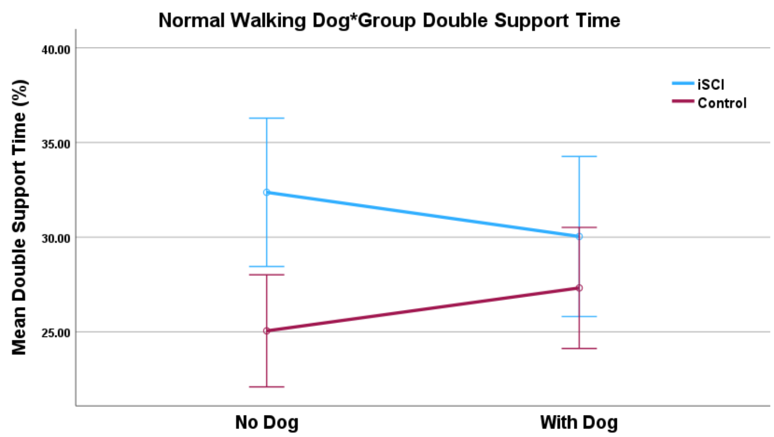

Figure 3.2. Mean double support time (%) for both iSCI and control group in without and with rehabilitation dog trials. Errors bars represent 95% confidence interval

Double support time also presented with a significant dog by vision interaction (F(1,20) = 4.561, p = 0.045, $\eta^2 = 0.186$) as seen in Figure 3.3. There was no significant difference in double support time without and with the rehabilitation dog eyes open (No dog 27.64% ± 1.02, With Dog 29.78% ± 1.39) (F(1,20)=1.467, p=0.240, $\eta^2 = 0.068$) or eyes closed (No dog 28.53% ± 1.19, With dog 28.82% ± 1.49) (F(1,20)=1.078, p=0.311, $\eta^2 = 0.051$). There was significantly less relative double support time with eyes open compared to eyes closed while walking without the rehabilitation dog (Eyes open 27.64% ± 1.02, Eyes closed 29.78% ± 1.39) (F(1,20)=12.213, p=0.002, $\eta^2 = 0.379$). There was no significant difference eyes open and eyes closed walking with the rehabilitation dog (Eyes open 28.55% ± 1.19, Eyes closed 28.82% ± 1.49) (F(1,20)=0.098, p=0.757, $\eta^2 = 0.005$).

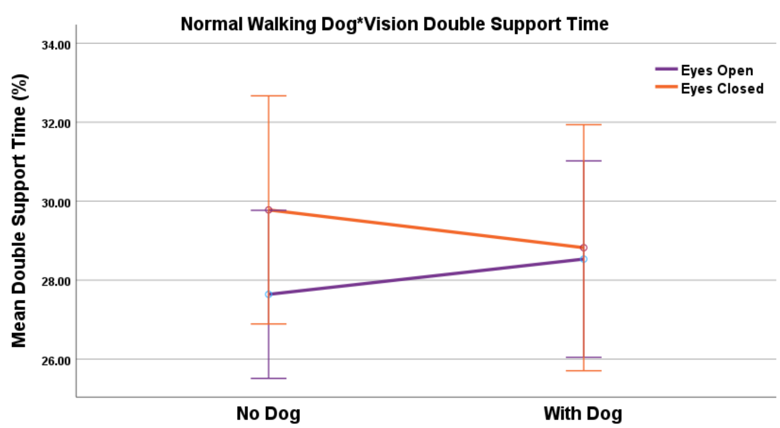

Figure 3.3. Mean double support time (%) for both no dog and with dog trials for eyes open and eyes closed. Errors bars represent 95% confidence interval.

Double support time SD presented with a significant group by dog interaction (F(1,20) = 5.428, p = 0.030, $\eta^2 = 0.213$) shown in Figure 3.4. There was significantly more variability in the iSCI group compared to the control group walking without the rehabilitation dog (iSCI 2.59% ± 0.19, control 1.28% ± 0.16) (F(1,20)=27.539, $p < 0.001$, $\eta^2 = 0.579$) and no significant difference walking with the rehabilitation dog (iSCI 2.36% ± 0.35, control 2.14% ± 0.29) (F(1,20)=0.250, p=0.623, $\eta^2 = 0.012$). The iSCI group presented with no significant difference without or with the rehabilitation dog (No dog 2.59% ± 0.19, With dog 2.36% ± 0.35) (F(1,20)=0.403, p=0.533, $\eta^2 = 0.020$). The control group presented with a significantly lower variability in double support time without the rehabilitation dog compared to with the rehabilitation dog (No dog 1.28% ± 0.16, With dog 2.14% ± 0.29) (F(1,20)=8.289, p=0.009, $\eta^2 = 0.293$).

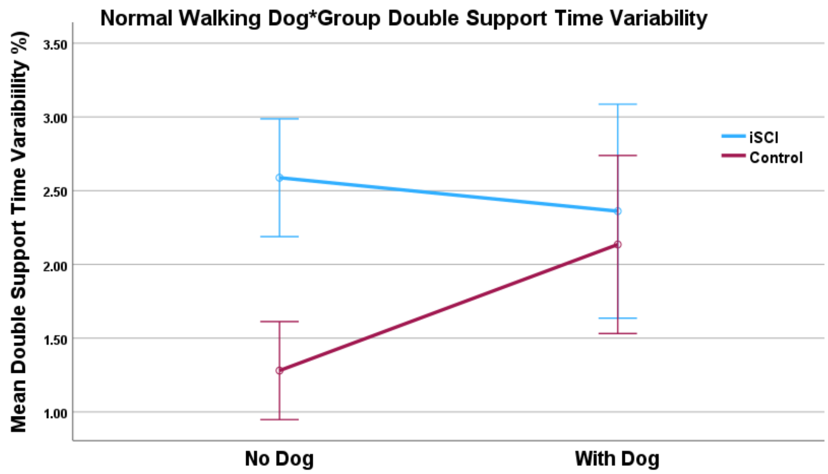

Figure 3.4. Mean variability double support time (%) for both iSCI and controls in without and with the rehabilitation dog. Errors bars represent 95% confidence interval

Step width presented with a significant group by dog interaction (F(1,17) = 5.067, p 0.038, $\eta^2 = 0.230$) as seen in Figure 3.5. There was no significant group difference in step width without (iSCI 28.06cm ± 2.28, controls 24.38cm ± 1.94) (F(1,17)=1.505, p=0.237, $\eta^2 = 0.081$) or with the rehabilitation dog (iSCI 22.78cm ± 1.42, control 23.48cm ± 1.21) (F(1,17)=0.143, p=0.710, $\eta^2 = 0.008$). The iSCI group took significantly wider steps without the rehabilitation dog compared to with the dog (No dog 28.06cm ± 2.28, With dog 22.78cm ± 1.42) (F(1,17)=12.719, p=0.002, $\eta^2 = 0.428$). There was no significant difference in step width for the control group walking without or with the rehabilitation dog (No dog 24.38cm ± 1.94, With dog 23.48cm ± 1.21) (F(1,17)=0.508, p=0.486, $\eta^2 = 0.029$). A significant main effect of vision was also present for step width (F(1,17) = 7.239, p = 0.015, $\eta^2 = 0.299$). Pairwise comparisons showed that eyes closed conditions (25.71cm ± 1.21) had a significantly wider step width than eyes open conditions (23.64cm ± 1.21). Step width SD also presented with a significant main effect of vision (F(1,21)=10.942, p=0.003, $\eta^2 = 0.343$). Pairwise comparisons showed there was a significantly more variable step width with eyes closed (4.172cm ± 0.28) compared to eyes open (3.06cm ± 0.212).

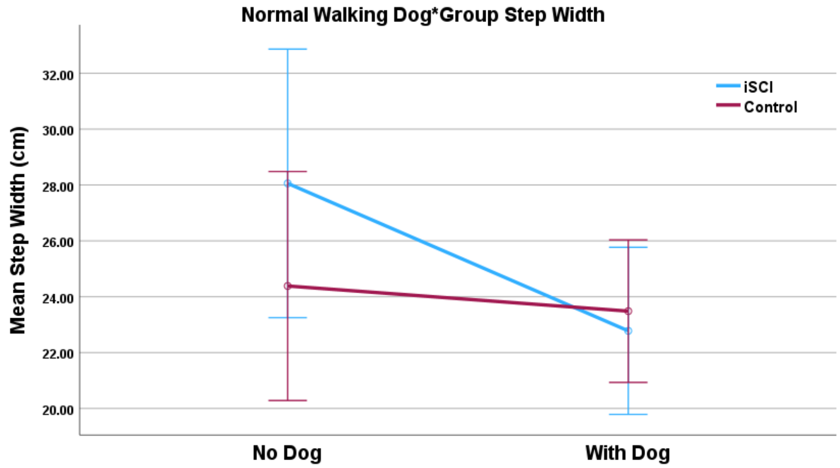

Figure 3.5. Mean step width (cm) for both iSCI and control group in without and with rehabilitation dog trials. Errors bars represent 95% confidence interval.

Step length presented with a significant group by dog interaction ($F(1,20) = 10.640$, $p = 0.004$, $\eta^2 = 0.347$) shown in Figure 3.6. The iSCI group had a significantly shorter step than the control group while walking without (iSCI 47.81cm ± 1.26, control 67.69cm ± 0.95) ($F(1,20) = 158.009$, $p < 0.001$, $\eta^2 = 0.888$) and with the rehabilitation dog (iSCI 51.63cm ± 2.07, control 63.78cm ± 1.57) ($F(1,20) = 21.928$, $p < 0.001$, $\eta^2 = 0.523$). The iSCI group had no significant difference in step length without and with the rehabilitation dog (No dog 47.81cm ± 1.26, With dog 51.63cm ± 2.07) ($F(1,20) = 4.086$, $p = 0.057$, $\eta^2 = 0.170$). The control group had a significantly longer step length without compared to with the rehabilitation dog (No dog 67.69cm ± 0.954, With dog 63.78cm ± 1.57) ($F(1,20) = 7.481$, $p = 0.013$, $\eta^2 = 0.272$). Step length also presented with a significant main effect of vision ($F(1,20) = 24.353$, $p < 0.001$, $\eta^2 = 0.549$). Pairwise comparisons showed steps were significantly longer with eyes open (60.86cm ± 1.01) compared to eyes closed (54.59cm ± 1.18). Step Length SD presented with a significant main effect of dog ($F(1,19)=4.854$, $p=0.040$, $\eta^2 = 0.204$). Pairwise comparisons showed walking with the rehabilitation dog had more variability in step length (4.79cm ± 0.57) compared to without the rehabilitation dog (3.76cm ± 0.51).

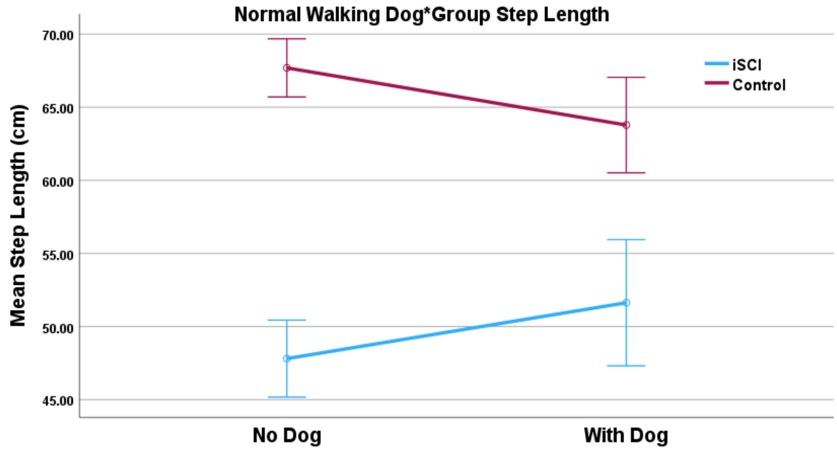

Figure 3.6. Mean step length (cm) for both iSCI and control group in without and with rehabilitation dog trials. Errors bars represent 95% confidence interval.

There were no significant interactions or main effects for ML MOS Av; however, ML MOS Av SD presented with a significant main effect of vision ($F(1,21) = 5.380$, $p = 0.031$, $\eta^2 = 0.204$). Pairwise comparisons showed eyes closed (1.50cm ± 0.16) had significantly more variability than eyes open (1.05cm ± 0.11).

AP MOS Av presented with main effects for dog, vision, and group. There was a significantly larger AP MOS Av without the dog (49.94cm ± 1.27) than with the dog (45.90cm ± 1.90) ($F(1,21) = 4.794$, $p = 0.040$, $\eta^2 = 0.186$). There was a significantly larger AP MOS Av while eyes open (51.25cm ± 1.28) compared to eyes closed (44.59cm ± 1.77) ($F(1,21) = 17.438$, $p < 0.001$, $\eta^2 = 0.454$). There was a significantly larger AP MOS Av in controls (55.15cm ± 1.66) than iSCI (40.69cm ± 2.07) ($F(1,21) = 29.702$, $p < 0.001$, $\eta^2 = 0.586$). AP MOS Av SD presented with no significant interaction and main effects.

3.3 Tandem Walking Kinematic Data

Table 3.4 represents tandem means and SD and Table 3.5 shows walking interactions and main effects.

Table 3.4 Kinematic data for tandem walking means and standard deviation

Outcome variable	Group	No Dog Eyes Open	With Dog Eyes Open	No Dog Eyes Closed	With Dog Eyes Closed
Stride Velocity (cm/s)	iSCI	27.87 ± 7.60	31.20 ± 6.55	21.99 ± 7.34	26.47 ± 4.71
	Control	43.71 ± 12.85	44.99 ± 16.83	44.89 ± 14.09	44.79 ± 15.81
Stride Velocity SD (cm/s)	iSCI	2.61 ± 1.40	4.96 ± 3.16	7.13 ± 4.99	6.92 ± 5.26
	Control	4.18 ± 2.31	5.92 ± 4.71	6.54 ± 3.29	8.42 ± 6.09
Double Support Time (%)	iSCI	34.12 ± 0.12	33.26 ± 2.05	33.92 ± 4.45	36.00 ± 0.71
	Control	28.60 ± 5.05	27.47 ± 5.91	29.29 ± 3.99	28.57 ± 6.07
Double Support Time SD (%)	iSCI	4.88 ± 1.96	6.12 ± 3.05	10.93 ± 6.73	6.89 ± 3.90
	Control	4.15 ± 1.80	4.33 ± 2.47	4.93 ± 2.17	5.67 ± 4.04
Step Width (cm)	iSCI	14.57 ± 2.61	12.55 ± 3.71	15.47 ± 7.13	15.73 ± 4.31
	Control	14.24 ± 5.22	15.04 ± 3.58	16.56 ± 4.10	15.29 ± 4.13
Step Width SD (cm)	iSCI	5.42 ± 6.01	2.60 ± 1.09	6.68 ± 4.94	5.63 ± 4.12
	Control	1.69 ± 0.52	1.97 ± 0.96	4.76 ± 1.96	3.91 ± 2.97
Step Length (cm)	iSCI	31.53 ± 2.58	34.39 ± 6.26	30.58 ± 3.89	32.35 ± 4.07
	Control	33.50 ± 5.61	32.75 ± 5.15	33.42 ± 4.99	33.96 ± 6.29
Step Length SD (cm)	iSCI	6.15 ± 5.02	7.33 ± 4.92	9.48 ± 8.91	6.48 ± 2.69
	Control	4.47 ± 1.72	3.99 ± 1.95	5.86 ± 3.34	4.34 ± 2.22
ML MOS Av (cm)	iSCI	7.02 ± 1.40	6.48 ± 2.25	7.09 ± 4.57	7.54 ± 2.34
	Control	6.23 ± 3.31	6.87 ± 1.63	6.99 ± 2.76	5.37 ± 4.11
ML MOS Av SD (cm)	iSCI	1.90 ± 1.65	2.52 ± 3.89	1.51 ± 0.83	1.40 ± 0.26
	Control	0.61 ± 0.16	0.86 ± 0.24	2.20 ± 1.53	4.71 ± 3.47
AP MOS Av (cm)	iSCI	24.05 ± 4.08	25.98 ± 3.51	22.55 ± 4.33	26.85 ± 7.29
	Control	30.19 ± 4.67	29.89 ± 3.89	31.00 ± 4.06	30.70 ± 4.11
AP MOS Av SD (cm)	iSCI	2.42 ± 2.21	4.86 ± 4.10	2.94 ± 1.06	2.37 ± 1.20
	Control	1.59 ± 0.69	2.13 ± 1.36	2.44 ± 0.93	2.19 ± 0.69

Table 3.5 Tandem walking interaction and main effects

Dependent Variable	Vision by Group Interaction effect	Dog by Group Interaction effect	Vision by dog Interaction effect	Vision by Dog by Group interaction effect	Main effect of group	Main effect of vision	Main effect of dog
Stride Velocity	F = 3.665 p = 0.074 η^2 = 0.186	F = 0.927 P = 0.350 η^2 = 0.055	f = 0.000 p = 0.990 η^2 = 0.000	F = 0.053 P = 0.820 η^2 = 0.003	F = 12.887 **p = 0.002*** F = 0.446	F = 2.450 p = 0.137 η^2 = 0.133	F = 1.619 P = 0.221 η^2 = 0.092
Stride Velocity SD	F = 0.286 P = 0.600 η^2 = 0.019	F = 0.076 p = 0.786 η^2 = 0.005	F = 0.532 p = 0.477 η^2 = 0.034	F = 0.658 p = 0.430 η^2 = 0.042	F = 0.480 p = 0.499 η^2 = 0.031	F = 14.192 **p = 0.002*** η^2 = 0.486	F = 1.153 p = 0.300 η^2 = 0.071
Double Support Time	F = 0.024 p = 0.881 η^2 = 0.002	F = 0.310 p = 0.588 η^2 = 0.025	F = 0.632 p = 0.442 η^2 = 0.050	F = 0.364 p = 0.557 η^2 = 0.029	F = 5.770 **p = 0.033*** η^2 = 0.325	F = 0.791 p = 0.391 η^2 = 0.062	F = 0.013 P = 0.991 η^2 = 0.001
Double Supple Time SD	F = 3.978 p = 0.066 η^2 = 0.221	F = 0.745 p = 0.403 η^2 = 0.051	F = 2.266 p = 0.154 η^2 = 0.139	F = 3.503 p = 0.082 η^2 = 0.200	F = 6.382 **p = 0.024*** η^2 = 0.313	F = 14.424 **p = 0.002*** η^2 = 0.507	F = 0.191 p = 0.669 η^2 = 0.013
Step Width	F = 0.246 p = 0.627 η^2 = 0.016	F = 0.141 p = 0.713 η^2 = 0.009	F = 0.004 p = 0.952 η^2 = 0.000	F = 1.536 p = 0.234 η^2 = 0.093	F = 0.164 p = 0.691 η^2 = 0.011	F = 4.787 **p = 0.045*** η^2 = 0.242	F = 0.413 p = 0.530 η^2 = 0.027
Step Width SD	F = 0.147 p = 0.707 η^2 = 0.010	F = 1.553 p = 0.233 η^2 = 0.100	F = 0.030 p = 0.864 η^2 = 0.002	F = 0.642 p = 0.436 η^2 = 0.044	F = 3.988 p = 0.066 η^2 = 0.222	F = 25.170 **p < 0.001*** η^2 = 0.643	F = 2.807 p = 0.116 η^2 = 0.167
Step Length	F = 4.108 p = 0.060 η^2 = 0.204	F = 4.683 **p = 0.046*** η^2 = 0.226	F = 0.002 p = 0.965 η^2 = 0.000	F = 0.277 p = 0.606 η^2 = 0.017	F = 0.331 p = 0.573 η^2 = 0.020	F = 0.835 p = 0.374 η^2 = 0.050	F = 3.908 p = 0.066 η^2 = 0.196
Step Length SD	F = 0.034 p= 0.857 η^2 = 0.002	F = 0.002 p = 0.964 η^2 = 0.000	F = 2.550 p = 0.131 η^2 = 0.145	F = 0.920 p = 0.353 η^2 = 0.058	F = 6.571 **p = 0.022*** η^2 = 0.305	F = 1.079 p = 0.315 η^2 = 0.067	F = 0.828 p = 0.377 η^2 = 0.052
ML MOS Av	F = 0.500 p = 0.490 η^2 = 0.030	F = 0.121 p = 0.732 η^2 = 0.008	F = 0.288 p = 0.599 η^2 = 0.018	F = 1.915 p = 0.185 η^2 = 0.107	F = 0.477 p = 0.500 η^2 = 0.029	F = 0.022 p = 0.885 η^2 = 0.001	F = 0.174 P = 0.682 η^2 = 0.011
ML MOS Av SD	F = 6.241 **p = 0.034*** η^2 = 0.409	F = 1.244 p = 0.294 η^2 = 0.121	F = 0.494 p = 0.500 η^2 = 0.052	F = 1.887 p = 0.203 η^2 = 0.173	F = 0.137 p = 0.720 η^2 = 0.014	F = 1.991 p = 0.192 η^2 = 0.181	F = 2.622 p = 0.140 η^2 = 0.226
AP MOS Av	F = 0.894 p = 0.359 η^2 = 0.056	F = 6.826 **p = 0.020*** η^2 = 0.313	F = 0.283 p = 0.603 η^2 = 0.019	F = 0.287 p = 0.600 η^2 = 0.019	F = 9.834 **p = 0.007*** η^2 = 0.396	F = 0.171 p = 0.685 η^2 = 0.011	F = 4.636 **p = 0.048*** η^2 = 0.236
AP MOS Av SD	F = 3.737 p = 0.077 η^2 = 0.237	F = 0.622 p = 0.445 η^2 = 0.049	F = 6.700 **p =0.030*** η^2 = 0.336	F = 2.088 p = 0.174 η^2 = 0.148	F = 3.976 p = 0.069 η^2 = 0.249	F = 0.497 p = 0.494 η^2 = 0.040	F = 1.168 p = 0.301 η^2 = 0.089

Note: Significance was set at < 0.05. * = interaction and main effects showing significance

Stride velocity presented with a significant main effect of group ($F(1,16) = 12.887$, $p = 0.002$, $\eta^2 = 0.446$) where the control group (44.57cm/s ± 3.07) had significantly faster stride velocity than the iSCI group (26.88cm/s ± 3.85). Stride velocity SD had a significant main effect of vision ($F(1,15) = 14.192$, $p = 0.002$, $\eta^2 = 0.486$) where eyes closed (7.25cm/s ± 0.88) was significantly more variable than eyes open (4.42cm/s ± 0.53).

Double support time presented a significant main effect of group ($F(1,12) = 5.77$, $p = 0.033$, $\eta^2 = 0.325$) showing the control group spent significantly less time in double support (28.48% ± 1.13) than the iSCI group (34.32% ± 2.16). Double support time SD presented with significant main effects of vision ($F(1,14) = 14.424$, $p = 0.002$, $\eta^2 = 0.507$) and group ($F(1,14) = 6.382$, $p = 0.024$, $\eta^2 = 0.313$). Eyes closed (7.11% ± 0.65) had significantly more variability than eyes open (4.87% ± 0.47) for double support time. The iSCI group (7.21% ± 0.76) had significantly more variable double support time than the control group (4.77% ± 0.59).

Step width presented a significant main effect for vision ($F(1,15) = 4.787$, $p = 0.045$, $\eta^2 = 0.242$) where steps were significantly wider when walking in tandem with eyes closed (15.76cm ± 1.04) compared to eyes open (14.10cm ± 0.85). Step width SD presented with a main effect of vision ($F(1,14) = 25.710$, $p = 0.000$, $\eta^2 = 0.643$) with more variability walking with eyes closed (5.25cm ± 0.62) compared to eyes open (2.92cm ± 0.47).

Step length presented with a significant group by dog interaction ($F(1,16) = 4.683$, $p = 0.046$, $\eta^2 = 0.226$) as seen in Figure 3.7. There was no significant difference in step length between groups without (iSCI 31.05cm ± 1.49, control 33.46cm ± 1.19) ($F(1,16) = 1.590$, $p = 0.031$, $\eta^2 = 0.204$) or with the rehabilitation dog (iSCI 33.37cm ± 1.85, control 33.36cm ± 1.48) ($F(1,16) = 0.000$, $p = 0.995$, $\eta^2 = 0.000$). There was a significant difference between without and with the rehabilitation step length for the iSCI group (No dog 31.05cm ± 1.49, With dog 33.37cm ± 1.85) ($F(1,16) = 7.015$, $p = 0.018$, $\eta^2 = 0.305$). There was no significant difference between without and with the rehabilitation step length for the control group (No dog 33.46cm ± 1.19, With dog 33.36cm ± 1.48) ($F(1,16) = 0.023$, $p = 0.883$, $\eta^2 = 0.001$). Step length SD presented with a significant main effect of group ($F(1,15) = 6.571$, $p = 0.022$, $\eta^2 = 0.305$). Pairwise comparisons showed the iSCI group (7.36cm ± 0.85) had a significantly more variable step length than the control group (4.67cm ± 0.62).

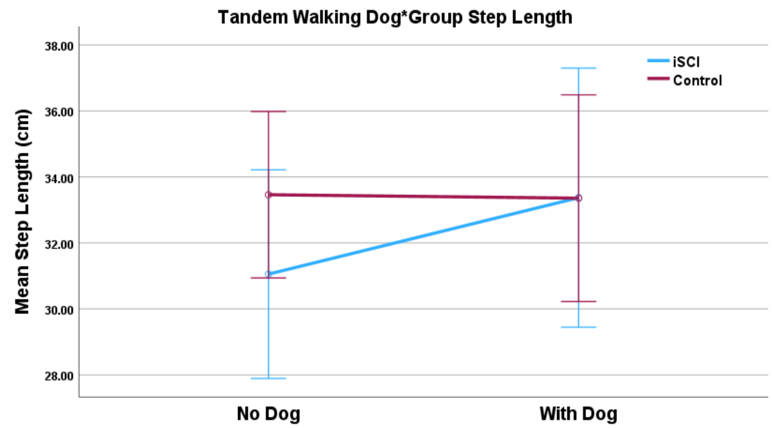

Figure 3.7. Mean step length (cm) for both iSCI and control group in without and with rehabilitation dog trials. Errors bars represent 95% confidence interval.

ML MOS Av did not present with any significant interaction or main effects. ML MOS Av SD presented with a significant vision by group interaction ($F(1,9) = 6.241$, $p = 0.034$, $\eta^2 = 0.409$) shown in Figure 3.8. There was no significant difference between groups with eyes open (iSCI 2.21 cm ± 0.723, controls 0.73cm ± 0.79) ($F(1,9)=1.900$, $p=0.201$, $\eta^2 = 0.174$) and eyes closed (iSCI 1.45 cm ± 0.61, controls 3.47cm ± 0.67) ($F(1,9)=4.861$, $p=0.055$, $\eta^2 = 0.351$). There was no significant difference in eyes open and eyes closed variability for individuals with an iSCI (eyes open 2.21 cm ± 0.723, eyes closed 1.45cm ± 0.61) ($F(1,9)=0.650$, $p=0.441$, $\eta^2 = 0.067$).The control group was significantly more variable when their eyes were closed compared to open (eyes open 0.73 cm ± 0.79, eyes closed 3.46cm ± 0.67) ($F(1,9)=7.004$, $p=0.027$, $\eta^2 = 0.438$).

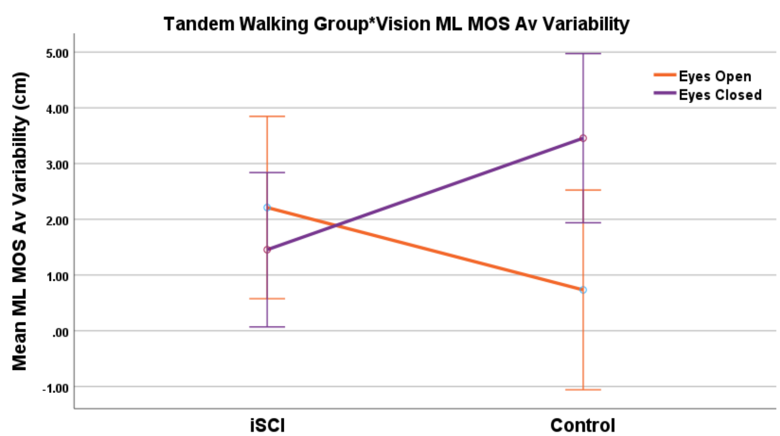

Figure 3.8. Mean variability ML MOS Av (cm) for both iSCI and control group in eyes open and eyes closed trials. Errors bars represent 95% confidence interval.

AP MOS AV presented with a significant group by dog interaction (F(1,15) = 6.826, p = 0.020, η^2 = 0.313) as seen in Figure 3.9. There was a significantly larger AP MOS Av in the control group compared to the iSCI group without the rehabilitation dog (iSCI 23.30cm ± 1.49, controls 30.60cm ± 1.10) (F(1,15) = 15.453, p = 0.001, η^2 = 0.507), but not with the rehabilitation dog (iSCI 26.42cm ± 1.56, controls 30.30cm ± 1.15) (F(1,15) = 4.006, p = 0.064, η^2 = 0.211). The iSCI group had a significantly larger AP MOS AV with the rehabilitation dog than without (No dog 23.30cm ± 1.49, With dog 26.42cm ± 1.56) (F(1,15) = 8.775, p = 0.010, η^2 = 0.369). Controls had no significant difference between without the rehabilitation dog and with the rehabilitation dog (No dog 30.60cm ± 1.10, With dog 30.30cm ± 1.15) (F(1,15) = 0.150, p = 0.704, η^2 = 0.010)

AP MOS Av SD presented with a significant dog by vision interaction (F(1,12) = 6.070,p = 0.030, η^2 = 0.336) shown in Figure 3.10; however follow-up univariate analyses did not reveal any further significant differences

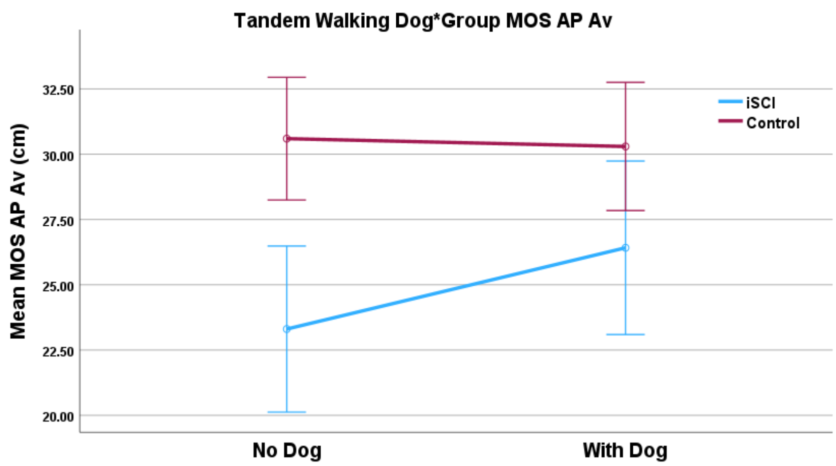

Figure 3.9. Mean variability AP MOS Av (cm) for both iSCI and control group in without the rehabilitation dog and with rehabilitation dog trials. Errors bars represent 95% confidence interval.

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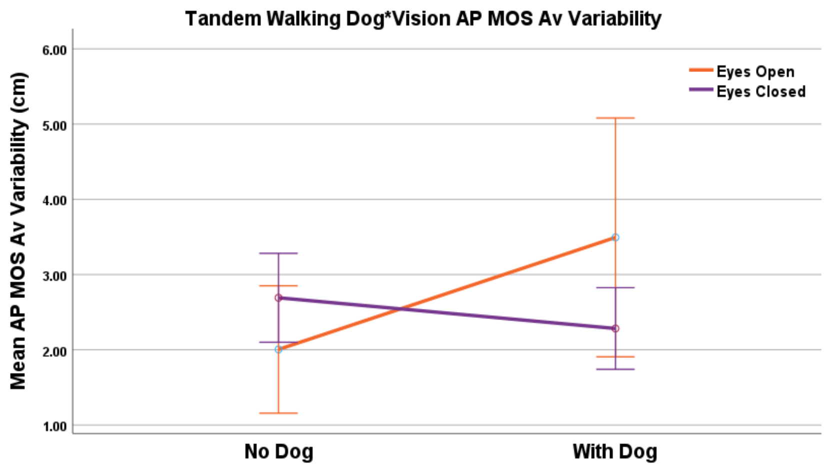

Figure 3.10. Mean variability AP MOS Av SD (cm) for both without the rehabilitation dog and with rehabilitation dog in eyes open and eyes closed trials. Error bars represent 95% confidence interval.

3.3 Questionnaire Data

Means, standard deviations, medians and ranges are presented in table 3.6 for the ABC Scale (original and additional questions), MiniBESTest, and FES-I (original and additional questions).

Table 3.6: Clinical Assessment Scores for both iSCI and Control Group

Clinical Assessments	iSCI			Control		
	Mean ± SD	Median	Range	Mean ± SD	Median	Range
ABC Scale	67.6±15.3	62.5	50.31-88.13	92.4±2.78	93.1	90.0-96.25
Additional questions for ABC Scale	54.6±15.3	47.5	40.0-77.0	75.3±10.7	77.5	58.33-85.0
MiniBESTest	17.2±9.34	20.0	1.00-25.00	26.8±0.80	28.0	24.00-28.00
FES-I Questionnaire	28.6±7.16	29.0	20.00-37.00	20.6±1.51	20.0	19.00-23.00
Additional questions for FES-I Questionnaire	29.2±5.81	32.0	20.0-34.00	22.0±4.00	21.0	19.00-29.00

There was no significant difference between groups (X^2 (2, N = 10) = 4.667, p = 0.097) for the scores of the original FES-I questionnaire or the additional questions (X^2 (2, N = 10) = 2.200, p = 0.333). There was a significant difference (U = 1.000, p = 0.015) between MiniBESTest scores for the iSCI group and the control group, with the control group scoring higher than the iSCI group. The original ABC Scale results were significantly different (U = 0.000, p = 0.008) between groups with the control having a higher score than the iSCI group. The additional questions for the ABC Scale showed no significant difference between groups (U= 3.000, p = 0.056).

Table 3.7 represents the answers to the VAS questions including the average rating (± 1 SD) and all additional comments made by participants. The VAS results saw that both groups felt walking with the rehabilitation dog to be easy (question 1), that walking with the dog improved (question 2) and did not impair (question 3) their balance during walking, and that they were more likely than not to walk with a rehabilitation dog if one was available. There were no group differences for any of the VAS questions (question 1 U=11.000, p=0.753; question 2 U= 11.500, p=0.834; question 3 U=9.500; p=0.530; question 4 U=11.000, p= 0.754). Comments about walking with the rehabilitation dog for participants in both groups were related to concerns for the dog and stepping on the dog while walking. The average (+/- 1 SD) rating was included to show any differences between iSCI and controls.

Table 3.7: VAS questions and comments

Question	Group	Average (+/- 1 SD): range rating	Comments
1. Compared to walking without the rehabilitation dog, how easy did you find using the rehabilitation dog while walking? (0= extremely easy, 10 = extremely difficult)	iSCI	1.62 ± 1.49	• “Felt confident, reassure/support of the dog was always there so had confidence I wouldn’t completely fall if lost balance” • “I felt very secure with Loki”
	Control	1.78 ± 1.99	• “Took a few "walks" to get accustomed to walking with the dog, but overall easy enough”
2. Do you think using the rehabilitation dog improved your balance during walking? (0= did not improve at all, 10 = definitely improved)	iSCI	8.30 ± 1.77	• “Totally 100% confident” • “I think more time for Loki and I to get to understand each other’s walking habits would improve my balance even more” • “Particularly during tandem walks and with eyes closed” • “Felt like I wanted to go for a walk where as without walking is a big chore”
	Control	8.34 ± 1.22	• “Gave me some confidence” • “Improved confidence not sure about actual impact/improvement”

<table>
<tr><td rowspan="2">3. Do you think using the rehabilitation dog impaired your balance during walking? (0= did not impair at all, 10= definitely impaired)</td><td>iSCI</td><td>1.8 ± 1.45</td><td>“Afraid to hurt Loki”
“I found our pacing was a little out of sync, but it was easy to correct when my eyes were open”
“A few times when eyes closed, he wanted to cross over but felt him, so it was okay”</td></tr>
<tr><td>Control</td><td>1.26 ± 0.091</td><td>“The only impairment would have been fear of stepping on the dog”
“No”
“Sometimes felt I was pushing or pulling, was expecting more of a guide dog feeling. I.e.) Loki would lead me”</td></tr>
<tr><td rowspan="2">4. How likely are you to use a rehabilitation dog while walking if there was a one available? (0= extremely unlikely, 10= extremely likely)</td><td>iSCI</td><td>6.52 ± 3.77</td><td>“He made me feel very secure when walking normally”
“I would feel more confident, especially on uneven, slippery, rough surfaces, and in malls or around crowds. I think the rehabilitation dog would be extremely helpful on days [when] I am more fatigued and allow for more independence.”
“I find my ability to move and perform daily tasks does not need a mobility dog to function for ADL. However, if I had impaired vision or worse balance I definitely would.”
“Wish I would have one now - would give me a lot more security to do more walking which I do not do now”
“I am very used to walking without aid”</td></tr>
<tr><td>Control</td><td>6.58 ± 1.74</td><td>“Icy conditions, would probably increase confidence”
“Yes, if need be, I would”
“I would recommend someone try a rehab dog if they need support. I am neutral as a control subject”</td></tr>
</table>

5. Do you have anything else to add about your opinion of using the rehabilitation dog?	iSCI		• "Gives a full sense of security and there is constant feedback for maintaining balance" • "I think he was very helpful"
	Control		• "Great experience and opportunity to support those in need. Thank you"

Chapter 4 - Discussion

The objectives of this thesis were to: (1) examine the walking balance of individuals with a chronic SCI compared to a healthy adult control group while using a rehabilitation dog for the first time; and (2) Identify changes to fear of falling for those with a chronic SCI and a healthy adult control group while using a rehabilitation dog. The results suggest that there were improvements in walking balance and a decrease in the fear of falling with the rehabilitation dog for iSCI participants.

The analysis of the transformed kinematic data, VAS, and the additional questions asked for ABC scale and FES-I, explored the differences between walking with and without a rehabilitation dog. It was hypothesized that participants with an iSCI would show greater walking improvements with the rehabilitation dog compared to the control group and this was partially supported. It appeared iSCI participants had a more confident gait by increasing stride velocity, decreasing %DS, decreasing step width, and increasing step length when walking with the rehabilitation dog compared to without the rehabilitation dog.

For this study, the VAS, and additional questions for the ABC scale and FES-I questionnaires showed a similar result (even though insignificant) in the that there were positive perceptions that were not entirely supported by the objective, transformed kinematic data. More specifically, the additional questions added to the FES-I questionnaire showed trend, even though statistically insignificant, where iSCI participants reported a greater decrease in their fear of falling while walking with the rehabilitation dog compared to the control group thereby supporting the second hypothesis.

4.1 Walking with and Without a Rehabilitation Dog

4.1.1 Normal walking

The kinematic data suggest there was no difference in stride velocity between groups, but the control group walked slower with the rehabilitation dog. The decreased velocity with the dog might be due to the rehabilitation dog not always walking at the same speed as the participant and sometimes stopping during trials. Individuals with an iSCI need a walking speed of at least 0.6m/s to safely ambulate in the community and cross the street (105). Participants in this study were able to maintain a stride velocity between 0.8m/s and 1.1m/s, which is a faster walking speed than previously reported for people with an iSCI walking with a cane (0.7m/s), crutch (0.6m/s), or walker (0.3m/s) (10, 87). The stride velocity results seen here suggests there could be a positive impact of walking with the rehabilitation dog for individuals with an iSCI.

Without the dog, the group with iSCI had a higher %DS value than the control group, which could indicate a more cautious gait cycle (85). Walking with a rehabilitation dog appeared to help the iSCI group and, like stride velocity, hinder the control group. The group with iSCI decreased their %DS when walking with the rehabilitation dog which was opposite to the control group leading to similar values between the two groups when walking with the dog. For both groups, walking with the dog eliminated an increase in %DS when eyes were closed suggesting the dog may have provided an extension of the base of support and/or a higher level of balance control via added haptic input to enhance walking.

Step width was similar between groups when walking with and without the rehabilitation dog; however, the group with iSCI appeared to have a reduced step width when walking with the dog compared to walking without the dog. The narrower steps could suggest a more confident balance control when walking with the dog. One purpose of a walking aid is to expand the BOS which would allow the steps to become narrower without reducing the overall width of the BOS. The iSCI step width values (with the rehabilitation dog 24.33cm and without the dog 25.51cm) compared to previous research with other walking devices, (31.00cm with a walker, 56.00cm with a crutch, and 55.00cm with a cane (10)), suggest that the individuals with iSCI might have been more stable during the gait cycle with the rehabilitation dog than if they were to walk with other devices based on values seen from previous research. Further research should explore the differences between walking with a rehabilitation dog and other devices directly. The notion of improved confidence was supported by the VAS results where individuals with an iSCI said they "felt confident, reassure/support of the dog was always there so had confidence I wouldn't completely fall if I lost balance" and "felt very secure with Loki".

While participants with iSCI had significantly shorter steps than the control group with and without the rehabilitation dog, changes in step length with the dog were different between groups: the group with iSCI increased step length when walking with the dog whereas the control group decreased step length. An increase in step length might represent a more stable gait pattern and a decreased fall risk (64, 106). From previous research with haptic devices, step length for individuals with an iSCI decreased when lightly touching a railing to add haptic input (86). The differences in changes to step length between walking with a rehabilitation dog and walking while lightly touching a railing could suggest an interaction between the human and rehabilitation dog is more complex and different from the use of a railing. The alterations in step width and length while walking with a rehabilitation dog suggest increased balance control and a less cautious gait pattern for those with an iSCI supporting the rehabilitation dog as a viable clinical rehabilitation tool.

The surprising outcome for ML MOS Av is that, even though there was a decrease in step width and increase in stride velocity with the dog, ML MOS Av appeared to not change. On the other hand, AP MOS Av was shown to be significantly decreased when walking with the dog even though step length increased (iSCI only). As outlined in the introduction, a larger MOS suggests increased stability (4, 64). The decreased AP MOS with the dog suggests an increased risk for balance loss; however, the rehabilitation dog could have extended the BOS beyond the boundaries of the feet meaning the COM could have remained at an appropriate distance to the boundary of the adjusted BOS without being measured by the motion capture system.

With support from the additional questions added to the ABC Scale and FES-I, participants had the lowest concern of falling when walking with the rehabilitation dog followed by walking with a walking aid. The highest concern for falling came while walking without a rehabilitation dog or walking aid. Interestingly, controls expressed more concern about falling while walking with a walking aid compared to walking without a walking aid. This could be due to inexperience with walking with a walking aid and uncertainty about how it would affect them (107).

The type of neurological condition may also influence how participants perform while walking with a dog. Parkinson's disease is quite different than iSCI since PD causes damage to the basal ganglia. The basal ganglia are important for regulating movements such as walking and progressive deterioration caused by PD can lead to motor function decline and a worsening gait pattern. In a previous study, the addition of a walking dog negatively impacted the gait pattern for those with PD (99). Conversely, we found those with an iSCI showed no change or improvements when walking with the rehabilitation dog. iSCI could have produced different results than the PD participants since PD participants have challenges regulating movement. People with PD may experience a decrease in their gait parameters while performing a dual task, which consist of a motor component (ex. reacting to the dog's movement) and a cognitive component (ex. awareness where person and dog need to go) (99). Research done by O'Neal and colleagues (99) also had a larger sample size of 19 participants with PD compared to 5 with an iSCI in this study which is important when comparing results. The sample size is important to consider since a larger sample size can result in a smaller the margin of error.

A previous study by Rondeau and colleagues (96) examined the impact of a rehabilitation dog for four individuals who sustained a stroke. Results indicated that participants with a stroke walked faster with a dog and showed gait pattern improvements (96). Similarities can be drawn between both post-stroke within Rondeau and colleagues and iSCI participants. Following a stroke, 80% of individuals regain some locomotion function but many experience significant gait deficits (96). Both stroke and iSCI are neural injuries that are not progressive and require rehabilitation to regain function (ex. walking). Therefore, the use of walking aids is a known approach that can be used to help individuals post-stroke ambulate (96), similarly to the iSCI population.

4.1.2 Normal Walking Variability

Variability represents the fluctuations in walking performance (67). A small amount of variability shows that the motor control system can replicate a consistent walking pattern while a large amount of variability may suggest impaired balance control that could cause an increased fall risk. Within this study, variability of %DS became similar between groups when walking with the dog (i.e., variability for the group with iSCI decreased while it increased for the control group) suggesting the dog may have supported an improvement in the control of relative timing of the gait cycle for individuals with iSCI.

Step length variability: however, increased for both groups walking with the dog which could be related to the behaviour of the dog. The rehabilitation dog sometimes walked in front of and/or at different speeds than the participant which would require adjustments to avoid contact with the dog and balance maintenance.

4.1.3 Tandem walking

Unlike normal walking, there were not many significant changes when walking in tandem walking with the dog. The data suggest the group with iSCI had a small increase in their step length (2.9cm) with the dog; however, it was not significant in the multivariate analyses. Tandem walking is interpreted differently compared to normal walking. Since tandem walking is a heel-to-to movement, an increased step length suggests a decreased performance of the task This could be due to the rehabilitation dog's struggles while walking in tandem. There were times when the rehabilitation dog would walk at a faster pace than the participants causing them to take longer steps to catch up with the dog.

Without the dog, the lower AP MOS Av in the group with iSCI compared to the control group suggests that, during tandem walking, participants with iSCI had a lower balance control. Typically, a higher MOS in individuals with a neurological condition is evident when compensatory strategies (e.g., altering step width, length, stride velocity) are used (108) as seen in this study while walking with the rehabilitation dog. Even though the AP MOS Av values were not statistically significant, AP MOS Av did increase for the iSCI group when with the rehabilitation dog compared to without and came closer to the control group values. The iSCI participants' ability to increase their MOS while walking with the rehabilitation dog showed similar results to Peebles and colleagues (108) that also saw when participants increased their MOS, it improved their walking balance. Therefore, the MOS is useful in evaluating dynamic stability during gait.

The VAS included a question asking, "Do you think using the rehabilitation dog improved your balance during walking?". The group with iSCI felt there was a benefit of walking with the rehabilitation dog especially when their walking balance was challenged by tandem walking tasks, and during eyes closed. The benefits of walking in tandem with the rehabilitation dog was seen in more similar %DS and %DS-SD values between groups, a narrower step for the iSCI group, and reduced the impact of eyes closed on %DS. Considering the limited impact on objective kinematic data paired with subjective perceptions of improvements when tandem walking with a rehabilitation, the use of a rehabilitation dog for challenging walking tasks and for individuals with balance impairments could be further explored.

The apparent reduced impact of the rehabilitation dog for tandem walking could have been due to the challenges that participants had walking with the rehabilitation dog. Some iSCI participants didn't complete all the tandem walking trials because they did not feel comfortable walking in tandem. This could have contributed to a less significant outcome for this method of walking because of fewer data points.

4.1.4 Visual Analog Scale and Additional Questions for ABC Scale and FES-I Scale

As previously mentioned, there appeared to be alignment between the kinematic data and the participants' perceptions of walking with and without the rehabilitation dog. Questions 1 and 2 of the VAS asked how easy participants found walking with the dog compared to without, and whether they felt there was an improvement in walking balance. Participants with iSCI reported walking with the rehabilitation dog was easy and perceived improvements in their walking balance. Even though the participants felt walking with the rehabilitation dog was beneficial, the objective data showed a reduced stride velocity, increased %DS-SD, and a shorter step within the control group. Both groups experienced more variable step lengths and smaller AP MOS Av with the rehabilitation dog.

There was a question asking if participants felt that using the rehabilitation dog impaired their balance during walking. Participants felt the dog was out of pace while walking but could be corrected when their eyes were open, and that Loki wanted to crossover in front of them. These perceptions speak to the challenges of this research and the potentially difficulties of working with a rehabilitation dog.

Lastly, participants were asked "how likely are you to use a rehabilitation dog while walking if there was one available?". The support for using a rehabilitation dog was uniformly positive. An interesting quote was "wish I would have one now - would give me a lot more security to do more walking which I do not do now". This quote summed up the feelings of individuals with an iSCI and the perceived benefits of walking with a rehabilitation dog.

The ABC Scale results suggest that the group with iSCI had lower balance confidence than the control group. Of the additional questions asked, the most interesting responses were related to walking without a walking aid, walking with a walking aid, and walking with a rehabilitation dog. For normal walking, both groups felt more confident walking with the rehabilitation dog compared to walking with a walking aid and walking without a rehabilitation dog. It was interesting to find that the control group felt also more confident walking with the rehabilitation dog reinforcing the benefits of walking with a rehabilitation dog. The group with iSCI reported more confidence walking with a rehabilitation dog than walking with their traditional assistive device. For tandem walking, balance confidence was reportedly higher for both groups when walking with a rehabilitation dog compared to walking with a walking aid and walking without a walking aid. Tandem walking provides more of a walking challenge and even with the increase in difficulty, both groups found the rehabilitation dog beneficial.

For FES-I results, all participants felt the least concern about falling while walking with the rehabilitation dog, followed by walking with a walking aid, and lastly, they had their highest concern about falling while walking without any assistance for both normal and tandem walking. Paired with the results of the additional ABC Scale questions, the participant perceptions suggest increased balance confidence and reduced concern about falling when walking with the rehabilitation dog.

4.2 The Role of Vision During Walking

Overall, the results of this study show that with eyes closed, participants were reliant on vision to maintain stability. During normal walking trials, stride velocity decreased, step width increased and became more variable, step length decreased, ML MOS Av was more variable, and AP MOS Av decreased with eyes closed. Walking with eyes closed has been shown to increase step width variability suggesting lateral control of balance is more reliant on vision (93, 94). A slower walking speed while eyes are closed could mean that participants are taking more time to maneuver through an environment to avoid the risk of a fall (10), which was present in both groups for this study while walking eyes closed. The lack of change in the ML MOS Av could be due to the decrease in stride velocity and increasing step width. Decreasing the step width and step length causes a smaller BOS, which can result in less stability leading to loss of balance. The decreased MOS in the AP direction with eyes closed likely comes from the shift in the BOS becoming smaller which would create less space between the xCOM and BOS boundary.

With eyes closed during tandem walking, steps were wider, and variability of stride velocity, double support time, and step width increased. The increase in step width may have been an attempt to increase the size of the BOS. The increase in variability during tandem shows the challenges of walking with a consistent pattern when a sensory system (i.e., vision) is impaired.

The results of this study show that walking eyes closed challenges the sensorimotor system and dynamic balance. A study by Yelnik and colleagues (109) found that healthy adult participants walked slower and increased double support time while their eyes were closed, similar to this study. Both studies saw changes in gait velocity with eyes closed even though the populations were different. This suggests that whether it is healthy adults (control) or someone with an iSCI, individuals tend to adjust their stride velocity and/or double support to increase stability and decrease the chance of falling (11).

4.3 Balance Control, Balance Confidence, and Falls Self-Efficacy

The MiniBESTest was used to evaluate balance control. The group with iSCI had lower the MiniBESTest scores than the control group similar to previous research for people with an iSCI (110) and with a stroke (111) suggesting impaired balance control. A score of 0/2 was assigned when individuals did not want to complete a task. Three iSCI participants scored 0/2 for the tasks assessing anticipatory balance (ex. sit to stand, rise to toes, stand on one leg) highlighting the challenges individuals had completing tasks due to their decreased balance control.

The ABC Scale was used to examine balance confidence. It was no surprise to see that the iSCI group's mean confidence score was lower than the control group which is similar to previous research (60) and aligns with the MiniBESTest scores. The iSCI participants felt the least confident when completing tasks that required them to alter their BOS to complete a task (ex. stepping on a chair to reach something, going on their tip toes, stepping off an escalator holding onto groceries). This aligns with the kinematic data showing iSCI participants had decreased balance control when not using a walking aid to use as support to complete tasks.

The similarity of FES-I scores between the control group and the group of people with iSCI was surprising as the percentage of individuals with an iSCI who fall is greater than older adults (28-30%), individuals post stroke (50%), and individuals with PD (62-68%) (6). With 78% of ambulatory people with a SCI falling at least once within a year (113), it was expected that the iSCI group would have a higher concern for falling than the control group. It may be important to consider that the FES-I questionnaire is the gold standard for assessing concerns about falling in an older population (40). A Falls Concern Scale (FCS) for people with SCI was created to assess concerns about falling for individuals who are dependent on manual wheelchairs for ambulation (114). This tool is quite similar to the FES-I but was explored for validity and reliability in individuals with a SCI who are dependent on manual wheelchairs. The FES-I and FCS could be compared and further explored to determine which scale is most appropriate for individuals with an iSCI who are also independently ambulatory.

4.4 Challenges

There were many challenges when it came to working with the rehabilitation dog that could have influenced the outcomes of this study. During the COVID-19 pandemic when the University of Saskatchewan paused many research studies, the rehabilitation dog remained with one of the dog handlers. During this time there was minimal training with the dog to help maintain the ability to assist individuals. One year after research was paused, I was able to resume research, but we noticed the rehabilitation dog needed some training on campus to regain his former abilities. After months of training, the dog could finally start working with participants who have an iSCI.

The original location for data collection of the Runway Lab at Merlis Belsher Place (MBP) was chosen because it was a large open space with more than 20 m of walkway length. MBP was turned into a field hospital during the pandemic, and so pilot testing for this study took place in the Biomechanics of Balance and Movement (BBAM) lab which has a smaller space to walk in (11m length walkway). The BBAM Lab space turned out to be too small for the rehabilitation dog as he appeared to be uncomfortable and had trouble focusing in that area. Fortunately, the field hospital at MBP closed and research was able to resume in the Runway lab, which benefited the dog. The pause in the ability to conduct research and the delay waiting for the dog to be ready impacted the total number of participants that could be included in this thesis.

The rehabilitation dog also had some challenges walking with participants. He would sometimes walk faster or slower than the participants which made participants feel like the dog was pulling them or they were dragging the dog, respectively. Before the extra training, the rehabilitation dog would sometimes cut in front of participants when they held onto the harness which could have been a falling hazard. After months of training, this behaviour was reduced in frequency but was still sometimes present. Since the completion of data collection for this study, the rehabilitation dog was able to return to the Mira organization for additional training and it is expected that the challenges faced in this study would not be present in future work with Loki.

Another challenge arose when it came to communicating with the rehabilitation dog. He was trained in Quebec, so understood commands in French. Fortunately, the dog handler for this study knew French as well and was able to communicate with the dog. The dog handler gave French cues to each of the participants so they could help command the dog while walking with him. The challenge with the language barrier was relevant for participants. Participants were told about the various commands for the rehabilitation dog but during walking trials, participants would forget commands and use English instead. This communication barrier could have impacted the behaviour of the dog.

4.5 Limitations

This study has some limitations to consider in addition to the dog-related challenges outlined above. The sample size was smaller than originally planned. The participants ended up being five iSCI and five controls compared to the goal of 20 iSCI and 20 controls. The COVID-19 pandemic caused challenges with recruitment due to necessary institutional restrictions on research during the 2020-2021 academic year which significantly impacted the timeline of this project. The research team decided that a smaller sample size would be obtained for a more exploratory study to prevent further delays in completing an MSc program. The smaller sample size reduced the statistical power of the study. There was a consideration about whether to set a level of significance at $\alpha \leq 0.05$ or $\alpha \leq 0.01$. Statistics were run for both levels. When the statistical analyses were run for more conservative statistics ($\alpha \leq 0.01$) the rationale was that this would be a stricter approach to account for the smaller sample and decrease the chance of type 1 error (false positive); however, there was almost nothing showing as significant, which could indicate a possible Type 2 error (false negative). As a learning experience, the decision was made to be less conservative and use an $\alpha \leq 0.05$ to support exploration into the possible impacts of walking with a rehabilitation dog. In addition, the kinematic data were transformed prior to analysis, complicating interpretation of the results.

Another limitation to this study relates to the system used to collect kinematic data. The challenges arose when calculating the MOS. The BOS is the area beneath the participant that is in contact with the ground. The BOS is expanded to include the rehabilitation dog when participants hold onto the handle of the harness; however, the sensors did not measure the increased BOS with the rehabilitation dog and so the BOS was limited to the participant's feet when calculating the MOS.

The findings of this study should be viewed with caution and further research with larger samples is needed.

Conclusion

The results of this study suggest that a rehabilitation dog had an effect on walking balance in individuals with an iSCI. During normal walking, individuals with an iSCI walked more slowly and with shorter steps, causing a smaller AP MOS Av than controls. Individuals with an iSCI also had a higher %DS, %DS SD and wider step than controls without the dog. The dog appeared to help reduce some group difference in terms of the control of relative timing (i.e., %DS) and size of the ML BOS (e.g., step width). When walking with the dog, participants with an iSCI had more similar %DS (mean and SD) to controls and reduced the impact of eyes closed on %DS which suggests walking with the dog might help regulate timing in the gait cycle. The challenges with the rehabilitation dog may have caused the control group to walk slower with shorter steps and a more variable %DS, and both groups to walk with a more variable step length and smaller AP MOS. This could be due to the lack of practice due to COVID-19 and inexperience of the participants walking with the rehabilitation dog; therefore, further investigation is required.

Tandem walking overall appeared to be more challenging for individuals with iSCI. The benefit of walking with the rehabilitation dog during tandem walking resulted in a similar AP MOS AV between both groups but throughout tandem walking, the rehabilitation dog seemed to have minimal impact.

Overall, this study showed participants with iSCI improved their walking balance control with the rehabilitation dog compared to the control group. It seemed the dog did help improve walking balance for individuals with an iSCI but might have negatively affected the control group as seen by a decreased stride velocity and step length. Further research will need to explore how a more experienced rehabilitation dog impacts walking with different iSCI participants. Participants did feel the rehabilitation dog was easy to walk with, felt more confident and comfortable, and that balance control was positively impacted suggesting they would walk with a rehabilitation dog again. The combination of both objective and subjective results suggest walking with a rehabilitation dog should be further explored in individuals with an iSCI and other populations with walking balance impairments.

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Appendix A

UNIVERSITY OF SASKATCHEWAN

PARTICIPANT INFORMATION AND CONSENT FORM

STUDY TITLE: Rehabilitation Dogs: A novel approach to improving walking and balance for individuals living with neurological conditions

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PRINCIPAL INVESTIGATOR:

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TELEPHONE: (306) 966-3230

SUB-INVESTIGATORS:

Alison Oates, Associate Professor, Kinesiology, University of Saskatchewan

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Dylan Koshman, MSc Student, College of Kinesiology, University of Saskatchewan

Funded by Saskatchewan Health Research Foundation (SHRF)

INTRODUCTION

You are invited to take part in this research study because you are over the age of 8, living with a neurological condition and currently able to walk at least 10 meters at a time **OR** you are an individual not living with a neurological condition, over the age of 8, and serving as an age-matched control participant for this research study.

Your participation is voluntary. It is up to you to decide whether or not you wish to take part. If you wish to participate, you will be asked to sign this form. If you do decide to take part in this study, you are still free to withdraw at any time and without giving any reasons for your decision.

If you do not wish to participate, you will not lose the benefit of any medical care to which you are entitled or are presently receiving. It will not affect your relationship with Sarah Donkers or any other study members.

Please take time to read the following information carefully. You can ask the researcher to explain any words or information that you do not clearly understand. You may ask as many questions as you need. Please feel free to discuss this with your family, friends or family physician before you decide.

WHO IS CONDUCTING THE STUDY?

The study is being conducted by a group of researchers with expertise in gait and balance, physiotherapy, service dogs and/or pediatrics at the University of Saskatchewan and is funded by the Saskatchewan Health Research Foundation. However, neither the institution nor any of the investigators or staff will receive any direct financial benefit from conducting this study.

WHY IS THIS STUDY BEING DONE?

This study is being done because optimizing walking for children is an important aspect of function, growth and development, and favorable quality of life. Using a rehabilitation dog is one potential solution to safely maximize walking ability, increase walking and balance confidence and allow a child to more freely interact with their environment.

A rehabilitation dog is specifically trained to assist a person in developing gait and balance abilities during rehabilitation. The dog is specifically trained in a number of tasks, stays with the physiotherapist and is used with many different clients. The use of rehabilitation dogs may improve gait speed, balance and neuromuscular control compared to walking with other assistive devices. It may also improve ease, confidence and enjoyment in walking and walking training. Using a rehabilitation dog is an innovative way to increase mobility for individuals living with neurological conditions which affect balance.

This project is expected to show that using a rehabilitation dog as a walking and training aid is a feasible and valuable intervention to improving walking and balance function for individuals living with neurological conditions.

WHO CAN PARTICIPATE IN THE STUDY?

This study aims to recruit 30 participants each for five different types of neurological conditions (cerebral palsy, stroke, multiple sclerosis, Parkinson's disease, and spinal cord injury), plus a range of age-matched individuals not living with a neurological condition. You are eligible to participate in this study if you are 8 years of age or older with a medically confirmed diagnosis of either cerebral palsy, stroke, multiple sclerosis, Parkinson's disease, or spinal cord injury, and are able to walk for at least 10 meters at a time. Individuals with severe cognitive or intellectual involvement impacting their ability to follow instructions, who are unable to travel to data collection sites, or have an uncontrolled allergy or fear of dogs are not able to participate. You are also eligible to participate if you are 8 years of age or older, not living with a neurological condition, able to walk 10 meters at a time, and willing to serve as an age-matched control participant for this research study.

WHAT DOES THE STUDY INVOLVE?

If you choose to participate in this study, you will first undergo a baseline assessment estimated to take 60-90 minutes and scheduled to occur at either the University of Saskatchewan (Saskatoon), Merlis Belsher Place Movement Analysis lab or a Saskatchewan Health Authority Site (e.g Wascana Rehab) as appropriate. At this assessment you will be asked to walk in a straight line for 10 meters at a self-selected pace using any regular walking aid you routinely need for walking, and then again with the rehabilitation dog. You may also be asked to walk in tandem (heel to toe) with your eyes open and eyes closed if you are able. You will be asked to wear 17 small inertial sensors on the wrists, ankles, lower back, and trunk, and surface electrodes (EMG) to capture muscle activity. In addition to the walking trials you will be asked to complete a Quality of Life questionnaire, and the Activity Specific Balance Confidence Scale (ABC Scale--a 16-item self-reported questionnaire). If you are living with a neurological condition, after this baseline research assessment we will schedule a pre-intervention assessment in 2 months' time. If you are acting as a control participant, you will only be asked to complete this baseline assessment and not any of the intervention or post-intervention testing.

During the pre-intervention session you will be asked to repeat the tests described above as well as meet with a study physiotherapist. This will occur in the same location as your baseline assessment and is estimated to take 120 minutes. After this session, an 8 week walking and balance training intervention will start and you will be asked to attend weekly sessions with a physiotherapist.

If you are part of the intervention, your 8 week training will include weekly sessions with a physiotherapist and the rehabilitation dog to work on improving walking and balance. Your intervention program will be individualized and created based on standard care gait training principles, but with the rehabilitation dog as the gait training aid as opposed to a standard assistive device. This intervention will include activities such as walking forward, backward, sideways, changing direction and navigating obstacles. It will also include as appropriate activities to work on posture and balance. During this time, the physiotherapist will keep training session notes that will be shared with the researchers through regular meetings. This information may include details on the activities and the time spent with the dog during your training session.

After 8 weeks, you will be asked to return for a post-intervention assessment. This would include the same test used at baseline assessment (described above). At this assessment we would also like to ask you questions to evaluate your enjoyment, motivation, and perceived benefits of the intervention. We will invite you to participate in an exit interview using a mix of visual analog rating scales and open-ended questions. This interview is estimated to take 20-30 minutes and will be audio recorded.

Study data is being collected for research purposes only. The clinical significance of the gait training using a rehabilitation dog is unknown, hence the need for this study. It is our expectation that the results of this study will help in developing the use of rehabilitation dogs as an eventual standard of care treatment tool.

WHAT ARE THE BENEFITS OF PARTICIPATING IN THIS STUDY?

If you choose to participate in this study, you may benefit from having access to an expert physiotherapist and rehabilitation dog to provide an individualized program to help improve your walking and balance. Improving your mobility and walking and balance confidence has numerous health benefits. It is hoped the information gained from this study can be used in the future to benefit other people with a similar condition. If you are acting as a control participant, there are no known benefits aside from walking with a rehabilitation dog.

ARE THERE POSSIBLE RISKS AND DISCOMFORTS?

If you choose to participate in this study, you may experience possible mild discomfort with repeated walking trials. All assessments will be administered and supervised by trained professionals to minimize this risk. There is a chance that you may accidentally get hurt by the dog in some way (e.g., bite, knock you over); however, the dog is a trained and certified service dog specialized as a rehabilitation dog and so the chances of being hurt by the dog are extremely small. When you are walking with the dog you will be supervised by an experienced physiotherapist dog handler. There is a risk of your personal health information being inadvertently released. The researchers have taken measures to protect the privacy of your information and this risk is considered very small. There is a risk of COVID-19 transmission during data collection. There will be parts of data collection where social distancing will not be maintained. To help minimize the risk, proper PPE, sanitizing, disinfecting equipment and social distance when possible will be implemented.

WHAT HAPPENS IF I DECIDE TO WITHDRAW?
Your participation in this research is voluntary. You may withdraw from this study at any time. You do not have to provide a reason. There will be no penalty or loss of benefits if you choose to withdraw. Your future medical care will not be affected.

If you choose to enter the study and then decide to withdraw later, all data collected about you during your enrolment will be retained for analysis.

WILL I BE INFORMED OF THE RESULTS OF THE STUDY?
The results of the study will be available in 2020 - 2021 from Sarah Donkers. If you would like a copy of the results sent to you, you can indicate this on the last page of the consent form. Results will also be published in a peer reviewed research manuscript, a participant friendly report and presented at both academic and clinical conferences.

WHAT WILL THE STUDY COST ME?
You will not be charged for any research-related procedures. You will not receive any compensation, or financial benefits as a result of data obtained from research conducted under this study. You will be reimbursed for parking expenses. Only part of this study is funded for people with cerebral palsy and so if you are an individual living with cerebral palsy, you will be provided with a $50 honorarium for participation.

WHAT HAPPENS IF SOMETHING GOES WRONG?
By signing this document, you do not waive any of your legal rights. In the case of a medical emergency related to the study, you are advised to seek immediate care as soon as possible. Inform the medical staff you are participating in a research study. Necessary medical treatment will be made available at no cost to you. By signing this document, you do not waive any of your legal rights against the investigators or anyone else.

WILL MY TAKING PART IN THIS STUDY BE KEPT CONFIDENTIAL?

In Saskatchewan, the *Health Information Protection Act (HIPA)* defines how the privacy of your personal health information must be maintained so that your privacy will be respected. Your confidentiality will be respected. No information that discloses your identity will be released or published without your specific consent to the disclosure, or as required by law. However, research records and medical records identifying you may be inspected in the presence of the Investigators and the University of Saskatchewan Research Ethics Board for the purpose of monitoring the research. However, no records, which identify you by name or initials, will be allowed to leave the Investigators' offices. The results of this study may be presented in a scientific meeting or published, but your identity will not be disclosed. Your study records will be de-identified and assigned a study participant number. They will be kept for 5 years after the study in a secure area (locked file cabinet and office), in the School of Rehabilitation Science, University of Saskatchewan. Personal information related to participants for contact tracing for COVID-19 will be stored in a password-protected file on a secure password-protected University of Saskatchewan server. Information relating to COVID-19 contact tracing will be kept until direction is given to permanently delete.

WHO DO I CONTACT IF I HAVE QUESTIONS ABOUT THE STUDY?

If you have any questions or desire further information about this study before or during participation, you can contact Sarah Donkers at (306) 966-3230.

If you have any concerns about your rights as a research participant and/or your experiences while participating in this study, contact the Chair of the University of Saskatchewan Research Ethics Board, at 306-966-2975 (out of town calls 1-888-966-2975). The Research Ethics Board is a group of individuals (scientists, physicians, ethicists, lawyers and members of the community) that provide an independent review of human research studies. This study has been reviewed and approved on ethical grounds by the University of Saskatchewan Research Ethics Board.

UNIVERSITY OF SASKATCHEWAN

CONSENT TO PARTICIPATE

Study Title: Rehabilitation Dogs: A novel approach to improving walking and balance for individuals living with neurological conditions

- I have read (or someone has read to me) the information in this consent form.
- I understand the purpose and procedures and the possible risks and benefits of the study.
- I was given sufficient time to think about it.
- I had the opportunity to ask questions and have received satisfactory answers.
- I understand that I am free to withdraw from this study at any time for any reason and the decision to stop taking part will not affect my future relationships or medical care.
- I give permission to the use and disclosure of my de-identified information collected for the research purposes described in this form.
- I understand that by signing this document I do not waive any of my legal rights.
- I will be given a signed copy of this consent form.

I agree to participate in this study:

Printed name of participant:	Signature	Date
Printed name of legal guardian of participant:	Signature	Date
Printed name of person obtaining consent:	Signature	Date
Printed name of researcher:	Signature	Date

☐ I wish to be sent the results of the study

Appendix B

Activities-Specific Balance Confidence (ABC) Scale

The Activities-specific Balance Confidence (ABC) Scale is used to determine the participants self confidence regarding different activities(59). It provides a wider continuum of activity difficulty to examine their confidence. The ABC scale represents internal validity and good test-retest reliability.(59). With more broad range of questions, it is more suitable to examine loss of balance confidence. This scale will be given to participants to answer questions based on their perceptions on the various activities.

For each of the activities, please specify your level of self-confidence by choosing a number from the rating scale below:

0% 10 20 30 40 50 60 70 80 90 100%

No confidence completely confident

"How confident are you that you will <u>not</u> lose your balance or become unsteady when you…

1. . . . walk around the house? ___%
2. . . . walk up or down the stairs? ___%
3. . . . bend over and pick up a slipper from front of a closet floor? ___%
4. . . . reach for a small can off a shelf at eye level? ___%
5. . . . stand on tip toes and reach for something above your head? ___%
6. . . . stand on a chair and reach from something? ___%
7. . . . sweep the floor? ___%
8. . . . walking outside the house to a car parked in the driveway? ___%
9. . . . get into or out of a car? ___%
10. . . . walk across a parking lot to the mall? ___%
11. . . . walk up or down a ramp? ___%
12. . . . walk in a crowded mall where people rapidly walk past you? ___%
13. . . . are bumped into by people as you walk through the mall? ___%
14. . . . step onto or off of an escalator while you are holding onto a railing? ___%
15. . . . step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? ___%
16. . . . walk outside on icy sidewalks? ___%

Additional questions will be asked pertaining to this study regarding different activities that will be conducted that could alter their balance confidence.

Again, for each of the activities, please specify your level of self-confidence by choosing a number from the rating scale below:

0% 10 20 30 40 50 60 70 80 90 100%

No confidence completely confident

"How confident are you that you will <u>not</u> lose your balance or become unsteady when you…

17. . . . walking without the use of a walking aid? ___%
18. . . . walking with a walking aid? ___%
19. . . . walking in tandem without a walking aid? ___%
20. . . . walking in tandem with a walking aid? ___%
21. . . . walking in tandem eyes closed without a walking aid? ___%
22. . . . walking in tandem eyes closed with a walking aid? ___%
23. . . . walking normally eyes closed with a walking aid? ___%
24. . . . Walking normally eyes closed with a walking aid ___%
25. … walking normally with a rehabilitation dog? ___%
26. . . . walking in tandem with a rehabilitation dog? ___%
27. . . . walking normally eyes closed with a rehabilitation dog? ___%
28. . . . walking in tandem eyes closed with a rehabilitation dog? ___%

Appendix C

The Falls Efficacy Scale-International (FES-I)

The FES-I is an easy and short tool to measure the level of concern regarding falls during 16 social and physical activities outside and inside the home(115). The FES-I has represented excellent internal validity (Cronbach's alpha = 0.96) and test-retest reliability (ICC = 0.96)(116). Due to the reliability of this assessment, it will be implemented within this research project do get a better understanding of the participants fear of falling. Participants will be asked to answer the following questions to the best of their ability to gain an understanding on their perceptions regarding the fear of falling:

		Not at all concerned 1	Somewhat concerned 2	Fairly concerned 3	Very concerned 4
1	Cleaning the house (e.g. sweep, vacuum, or dust)	1	2	3	4
2	Getting dressed or undressed	1	2	3	4
3	Preparing simple meals	1	2	3	4
4	Taking a bath or shower	1	2	3	4
5	Going to the shop	1	2	3	4
6	Getting in or out of a chair	1	2	3	4
7	Going up or down stairs	1	2	3	4
8	Walking around in the neighbourhood	1	2	3	4
9	Reaching for something above your head or on the ground	1	2	3	4
10	Going to answer the telephone before it stops ringing	1	2	3	4
11	Walking on a slippery surface (e.g. wet or icy)	1	2	3	4
12	Visiting a friend or relative	1	2	3	4
13	Walking in a place with crowds	1	2	3	4
14	Walking on an uneven surface (e.g. rocky ground, poorly maintained pavement)	1	2	3	4
15	Walking up or down a slope	1	2	3	4

16	Going out to a social event (e.g. religious service, family gathering or club meeting)	1	2	3	4
	Subtotal				
				Total	/64

An additional 12 questions will be asked that pertain to this study as we explore the participants perceptions on fear of falling during different activities.

		Not at all concerned 1	Somewhat concerned 2	Fairly concerned 3	Very concerned 4
1.	Walking normally without a walking aid	1	2	3	4
2.	Walking in tandem without a walking aid	1	2	3	4
3.	Walking normally with eyes closed without a walking aid	1	2	3	4
4.	Walking in tandem with eyes closed without a walking aid	1	2	3	4
5.	Walking normally with a walking aid	1	2	3	4
6.	Walking in tandem with a walking aid	1	2	3	4
7.	Walking normally with eyes closed with a walking aid	1	2	3	4
8.	Walking in tandem with eyes closed with a walking aid	1	2	3	4
9.	Walking normally with a rehabilitation dog	1	2	3	4
10.	Walking in tandem with a rehabilitation dog	1	2	3	4
11.	Walking normally with eyes closed with a rehabilitation dog	1	2	3	4

12.	Walking in tandem with eyes closed with a rehabilitation dog	1	2	3	4
	Subtotal				
				Total	/48

Greenberg, S. A. (2019). Assessment of fear of falling in older adults: The Falls Efficacy Scale-International (FES-I). *Try This: Best Practices in Nursing Care to Older Adults*.

Yardley, L., Beyer, N., Hauer, K., Kempen, G., Piot-Ziegler, C., & Todd, C. (2005). Development and initial validation of the Falls Efficacy Scale-International (FES-I). *Age and Ageing*, 614-619.

Appendix D

Visual Analog Scales for Qualitative assessment of walking with and without a rehabilitation dog

Draw a vertical line where you feel best indicates your response to the following questions.

1. How easy did you find **using the rehabilitation dog** while walking?

Extremely Easy Extremely Difficult

2. Do you think **using the rehabilitation dog *improved*** your balance during walking?

Did not improve at all Definitely improved

3. Do you think **using the rehabilitation dog *impaired*** your balance during walking?

Did not impair at all Definitely impaired

4. How likely are you to **use a rehabilitation dog** while walking if there was a rehabilitation dog available?

Extremely unlikely Extremely likely

Please expand on your rating for the question above:

1. How easy did you find **walking without a rehabilitation dog?**

Extremely Easy Extremely Difficult

2. Do you think walking **without a rehabilitation dog *improved*** your balance?

Did not improve at all Definitely improved

3. Do you think **NOT using a rehabilitation dog *impaired*** your balance during walking?

Did not impair at all Definitely impaired

4. How likely are you to choose the option of **NOT using a rehabilitation dog** while walking if they were available?

Extremely unlikely Extremely likely

Please expand on your rating for the question above:

5. Would you prefer to use a rehabilitation dog or without a rehabilitation dog if both were available? (Circle one)

With the Rehabilitation Dog **Without the Rehabilitation dog**

Why would you make the choice you made above?

Follow-up: Do you have anything else to add about your opinion of using either the rehabilitation dog or without the rehabilitation dog during walking?