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Outpatient Neurological and Orthopedic Physical Therapy Management for an Individual Diagnosed with a Cervical Central Spinal Cord Lesion: A Case Report

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Abstract

Background: Geriatric patients commonly present to rehabilitation having multiple co-morbidities. One example occurred in an outpatient clinic where the patient presented with a central cord lesion and knee range of motion deficits. Central cord injuries commonly lead to motor impairment, with the upper extremities being affected more than the lower extremities. The rehabilitation for addressing these two conditions often do not have much overlap. However, for patients with unrelated co-morbidities, therapists need to rely on multiple strategies to optimize patient care. **Purpose:** The purpose of this case report is to illustrate the outpatient plan of care, including both neurological and orthopedic strategies, for an individual with a cervical central cord lesion and bilateral reduced knee range of motion. **Case Description:** The patient was a 61-year old male who sustained a cervical central spinal cord lesion at the C1-C4 level. He had a history of bilateral total knee arthroplasties over 10 years ago, with notable knee range of motion and functional limitations. He achieved 40 degrees of knee flexion on the left and 85 degrees of knee flexion on his right at initial evaluation. **Intervention:** Neurological interventions of task specific repetitive practice along with orthopedic interventions of joint mobilizations and exercise were administered with the patient. **Outcomes:** Outcomes used included: 10 Meter Walk Test, 5x Sit to Stand, Lower Extremity Functional Scale, and goniometry. **Discussion:** The patient improved in all outcome measures and reported improvement in home and community function. This is one case outlining a patient with both neurological and orthopedic impairments, thus further research into patients with multiple co-morbidities is warranted to improve clinicians' evidence-based approach and provide optimal patient care.

Keywords: Central cord lesion, knee range of motion, outpatient neurological, outpatient orthopedic, physical therapy rehabilitation

Background

Physical therapy has been an integral part of neurological rehabilitation dating as far back as the field's inception in the 1940s. Included in this population base are individuals that have undergone a spinal cord injury (SCI). According to the 2019 National Spinal Cord Injury Statistical Center (NSCSC) there are approximately 291,000 people in the USA living with a SCI. NSCSC reported that the highest cause of SCI injuries is due to vehicle crashes at 39.3%. Falls were the second highest reported incidence with 31.8%. NSCSC's statistics indicate that incomplete tetraplegia is the most commonly diagnosed neurological category at 47.6% [1]. One type of incomplete tetraplegia includes central cord injuries, or injuries to the central regions of the corticospinal tract.

The common clinical presentation of a patient with a central cord injury includes: motor impairment of the extremities with the upper extremities (UE) being more affected than the lower extremities (LE), bladder dysfunction including urine retention, and differing amounts of sensory loss below the level of lesion [2]. Anatomically the medial aspect of the corticospinal tract, or the anterior horn gray matter, is what typically get encroached on or lesioned when a patient has a presentation that fits with a central cord injury [2, 3]. Since the medial aspect of the corticospinal tract carries the axons from the brachial and cervical plexus, the upper extremities are more severely affected by an injury than the lower extremities. Central cord injuries in the elderly, defined as over 50 years of age by Harrop et al., can occur when a cervical spondylotic spine undergoes a hyperextension movement causing a compression of the anterior central cord from buckled ligamentum flavum [2, 3].

Prognosis, in terms of neurological recovery, for this population is heavily influenced by the age of the person. Penrod et al. found that individuals under the age of 50 are more likely to have enough neurological recovery for the ability to independently ambulate and resume their activities of daily living [4]. Similarly, Newey et al. followed individuals below and above 50 years of age, for a mean of 8.6 years, and found that those who were under 50 years of age when experiencing their central cord injury were more likely to ambulate independently and have full bladder control than those who were injured after the age of 50 [5].

In addition to neurological recovery, in the older adult there may be multiple other factors that can limit functional progression, such as musculoskeletal impairments. While there are many orthopedic impairments that could limit activity of daily living performance, this case report will primarily focus on the knee joint. Common activities of daily living for people include: performing stairs, sitting, standing, and walking. All these activities require various amounts of knee ranges of motion to perform effectively. Swing phase of gait requires about 67 degrees of knee flexion, effective stair navigation requires between 83 to 100 degrees for ascension and decent respectively, and 93 – 105 degrees for performing a sit to stand maneuver depending on the height of the chair [6, 7]. In the elderly population it is not uncommon for activities of daily living to become limited due to knee joint pain, progressing osteoarthritis, or other knee pathologies. A standard surgical procedure to help alleviate knee pathology is a total knee arthroplasty (TKA).

Total knee arthroplasties have been successfully documented as alleviating knee pain. Although it is a common surgery, it can have complications. In the acute setting, problems such as infection, blood loss, and thromboembolisms are preemptively and ongoingly monitored. Long term complications such as aseptic loosening, commonly for those that get a TKA under 50 years old, can cause poor joint congruency and eventually a revision of the surgery to occur. On the other end of the spectrum, arthrofibrosis of the knee joint can occur due to scar tissue formation and limit knee ROM [6].

Viewed separately the rehabilitation for central spinal cord injury and knee range of motion limitations do not have much overlap. The former is seen as neurological rehabilitation where emphasis is commonly on repetitive task-specific training, and the latter is seen as orthopedic rehabilitation where manual therapy and therapeutic exercise are more commonly seen in practice. However, in the geriatric population it is not uncommon to see patients with multiple co-morbidities that can be affecting participation with activities of daily living. Physical therapy research on how to treat patients with multiple co-morbidities is often lacking due to the rarity of specific combinations and unique presentations that can occur across individuals. Thus, the purpose of this case report is to illustrate the

outpatient plan of care, including both neurological and orthopedic strategies, for an individual with a cervical central cord lesion and significant bilateral reduced knee range of motion associated with complications with past TKAs'.

Case Description

History

The patient was a 61-year old male who presented to an outpatient physical therapy clinic following a cervical central spinal cord lesion he had suffered 10 weeks prior to his arrival at the clinic. Initial injury occurred when the patient fell down the stairs and lost feeling and motor control of his upper and lower extremities. The patient was sent to the emergency department where he underwent a spinal decompression surgery with anterior fusion at the C4-C5 level due to subluxation of a C4-unilateral facet joint on C5. The fall also resulted in a T8 transvertebral fracture, T9-T10 compression fractures, and C1-C4 lesion of the central spinal cord. In addition, posterior spinal fusion surgery was completed at the T5-T9 levels a few days later due to the other fractures sustained in the fall.

Within the week of the injury, the patient began acute care physical therapy. The patient received 8 days of acute rehabilitation focusing primarily on bed mobility, tolerating sitting edge of bed, and transfers. Once discharged from acute care, the patient underwent inpatient rehabilitation for approximately 8-9 weeks. By discharge from inpatient rehabilitation physical therapy, the patient was deemed a community ambulator with a front wheeled walker (FWW) over level surfaces that could navigate stairs with bilateral railings. He was further discharged to outpatient physical therapy for continued care.

Clinical Impression pre-examination

The patient entered the outpatient physical therapy clinic with a front wheeled walker. He required assistance of two therapists to stand up from the waiting room chair which was of standard height (18 inches) with bilateral arm rests. During gait analysis it was observed that the patient had intermittent left foot floor clearance problems during swing phase of gait. Upon patient interview, he reported that his biggest activity of daily living complaints were the inability to get out of a low chair around the community and having to use a front wheeled walker everywhere. He also complained of muscle spasms in both his lower and upper extremities, with the upper extremity spasms being painful enough to disrupt his sleep. Pain was also reported in the left upper extremity and left lower extremity as a general ache. His goals included being able to get out of low chairs without help, ambulate without a front wheeled walker, improve his ambulation endurance, and generally get stronger in his upper and lower extremities.

Upon further patient interview and system's review, the patient reported a history of bilateral total knee arthroplasties over 10 years ago. He indicated that he never received any formal physical therapy after his surgery. A few years after the surgeries his left knee "locked up," and he was placed in a knee extension brace for weeks. He reported that the last time his knees were measured, he was able to achieve ~38-40 degrees of active range of motion knee flexion on his left and ~80 degrees of active knee flexion range of motion on his right. The uniqueness of this patient, with both neurological and orthopedic deficits, was the primary reason for choosing this case to demonstrate the outpatient treatment strategies for a patient with multiple challenging co-morbidities.

Examination

The tests and measures chosen to perform based on the patient's goals were: 10 Meter Walk Test, 5x Sit to Stand, Functional Gait Assessment, Lower Extremity Functional Scale (LEFS), and goniometry for measuring knee range of motion. A 10 Meter Walk Test was chosen to measure functional mobility and gait speed with the patient's least restrictive assistive device. Measuring walking speed has shown to be a good predictor of recurrent falls in patients with an SCI [8]. For people with a SCI the 10 Meter Walk Test also has good concurrent validity with the 6 Minute Walk Test (6MWT), which is a common

test used for ambulation endurance [9]. The patient achieved a time of .67 m/s while using a front wheeled walker during the 10 Meter Walk Test.

Five times Sit to Stand was chosen for two different reasons. One reason is because one of the patient's main goals was to be able to perform sit to stands out of low chairs in the community, and the patient was really motivated to achieve this as he was stuck in the waiting room of the clinic until he received assistance from two therapists. The other reason was as a measure of lower extremity strength in a functional manner, as opposed to just physical therapy manual muscle testing. The patient achieved a time of 17 seconds during the 5x Sit to Stand test.

The Lower Extremity Functional Scale is commonly used as an intake form and was used to evaluate how the impairment to the lower extremity was affecting the individual's function. The patient reported to be 32.5% functional level with their responses on the LEFS. Goniometric measurements were taken each session before and after therapy interventions to track if and how progress was made with knee range of motion. Both of his knees were significantly under what is deemed "normal" knee flexion range of motion, and they were both lacking some degrees for full extension of 0 degrees. All the functional tests protocols can be found on the Shirley Ryan AbilityLab website with data that can include but is not limited to information about the tests' validity, reliability, minimal clinical important difference, and minimal detectable change in regard to different patient populations [10, 11, 12, 13].

Table 1 gives relevant information on each test's validity and reliability with the different types of validity and reliability specified. Validity and reliability for the LEFS in Table 1 is regarding German patients that have undergone TKA and used the LEFS, not those that have sustained any level of SCI [14]. The goniometry validity and reliability data reported on in Table 1 is also not specifically taken from patients with a SCI, but instead was extrapolated by correlating universal goniometry knee flexion and extension measurements from different physical therapists to radiographs [15]. A Spearman, Pearson, Intra Class, or point biserial correlation coefficient was used as deemed appropriate by the authors referenced.

For the SCI population, validity of 10 Meter Walk Test correlates well with the following tests: 6MWT, the Walking Index for Spinal Cord Injury II (WISCI II) 11-20 score range, and the Functional Independence Measure Locomotor (FIM-L) [9, 16]. Reliability for 10 Meter Walk Test has been demonstrated to be strong in terms of: interrater, intrarater, and test/retest [9, 17]. The 5x Sit to Stand test for persons' with SCI demonstrated fair-good validity with the FIM-L and had good intertester reliability [16].

Table 1

Functional Test	**Validity**	**Reliability**
10 Meter Walk Test	Concurrent Validity with: 6MWT (p = -.95, n= 62) [9] WISCI II scores 11-20 (p = -.068, n = 47) [9] FIM-L (r_{pb} = .778, n = 66) [16]	Interrater (r = .974, p < .001) [9] Intrarater (r = .983, p < .001) [9] Test/Retest (ICC = .97) [17]
5x Sit to Stand	Concurrent Validity with: FIM-L (r_{pb} = -.595, n = 66) [16]	Intertester (ICC = .997-1.0) [16]
Functional Gait Assessment***	Concurrent Validity with: ABC (r = .053, p<.001) [18] BBS (r = .84, p<.001) [18] TUG (r = -.84, p<.001) [18]	Interrater (ICC = .93) [19]
LEFS***	Construct Validity with: Oxford Score (r = .80) [14] WOMAC pain (r = .70) [14] WOMAC stiffness (r = .52) [14] WOMAC function (r = .88) [14]	Reliability (ICC = .98) [14]

Universal Goniometry***	Concurrent Validity with: Flexion Radiograph (r = .975 - .987) [15] Extension Radiograph (r = .390 - .423) [15]	Intratester (ICC = .972-.997) [15] Intertester (ICC = .893-.997) [15]

Note: ***Data on validity and reliability not solely specific to the SCI population

During the initial evaluation the 10 Meter Walk Test, 5x Sit to Stand, LEFS, and goniometry were completed. The results of the outcomes from the initial evaluation can be found in Table 2. For the patient to complete all the outcome measure tests at initial evaluation, certain aspects of the outcome measure were administered generously.

The Functional Gait Assessment was completed later in the therapy plan of care during one of the patient's progress update session. The validity and reliability data for the Functional Gait Assessment located in Table 1 is for community dwelling adults in the geriatric population. Validity measures of the Functional Gait Assessment were determined with correlations to the Activities-Specific Balance Confidence Scale (ABC), Berg Balance Scale (BBS), and Timed Up and Go Test [18]. Reliability was demonstrated to be high with the Functional Gait Assessment, when the raters were given a training session prior to administration of the test [19].

Table 2: Initial evaluation outcome measures.

Patient's Initial Evaluation Outcomes	Results	Notes
10 Meter Walk Test	-15 seconds = .67 m/s	-Used a FWW
5x Sit to Stand	-17 seconds	-21-inch table height -UE use for push off from table -Feet staggered due to knee range of motion
LEFS	-26/80 = 32.5% functional	-Completed as intake form
R knee ROM	-85 degrees flexion -Lacking 6 degrees to extension	-Active range of motion measurement in supine
L knee ROM	-40 degrees flexion -Lacking 3 degrees to extension	-Active range of motion measurement in supine

Clinical Impression post-examination

Based on the initial examination it was determined the patient had greatest difficulty with sit to stand transfers, ambulation without a front wheeled walker, and gait speed. Various activities reported on the LEFS were also deemed difficult by the patient and included: stairs, putting on shoes, lifting objects, and getting out of a car. This fit with the initial clinical impression gathered from chart review, patient interview, and system's review. These activity and participation deficits were deemed to be a result of both his neurologic central cord injury as well as his severely limited range of motion and knee weakness associated with his poor TKA outcomes.

Based on the examination and evaluation of the data collected, it was determined that task specific repetitive practice would be a focus of the patient's therapy. However, it was also determined the patient would benefit from orthopedic interventions as he wanted to partake in activities that would be difficult given the current range of motion in his knees. Due to the lack of knee range of motion, manual therapy followed by therapeutic exercise to reinforce range of motion changes would be a focus of the patient's therapy. Progress in knee range of motion would be measured each session before and after physical therapy interventions.

The patient was seen twice a week throughout their physical therapy plan of care for 45-minute sessions. Half of each session was designated to task specific repetitive practice, and the other half was designated to manual therapy and therapeutic exercise. In addition to physical therapy, the patient was referred to outpatient occupational therapy. Thus, physical therapy focused more on gait and lower extremity deficits, and occupational therapy focused more on upper extremity deficits. While the patient continued to receive therapy on an ongoing basis due to his many limitations, yet continued gradual progress, this case highlights the strategies used and his initial response to treatment over an eight-week interval.

Intervention

Interventions performed throughout the plan of care fit into three main categories. Category one is task specific repetitive practice for improving performance with activities of daily living the patient had difficulty with. The second category involved manual therapy interventions, tailored specifically to the patient's knees and trying to improve knee flexion. The third category involved therapeutic exercise targeting the patient's lower extremity strength, range of motion, and activity tolerance. See Table 3 for the general progression of interventions used to target each category over an eight-week interval. If the intervention was part of the patient's home exercise plan (HEP) then it was marked as such in Table 3. If a certain intervention replaced a previous intervention as part of the patients HEP it can be seen in the Timeframe column.

Since the patient's goals were to improve his ability in sit to stands and replace the front wheeled walker for a single tipped cane (STC), those two tasks were put at the initial forefront of patient therapy sessions along with improving knee range of motion. Progression for all interventions were based on patient's report of ease, and his performance with the task throughout therapy sessions. For sit to stand practice the patient started with a 19-inch-high table. Progression to an 18-inch table occurred when the patient was able to demonstrate 7-10 sit to stands without assistance on the 19-inch-high table. This same progression was used until the patient reached the minimum height of the table at 16.5 inches. Cues to keep the patient's feet on the floor throughout the entirety of the sit to stand maneuver improved patient's performance with the movement.

The outpatient clinic where therapy was administered had what was called a Solo Track. The Solo Track is a harness that was attached to a pulley system on the ceiling and would keep the patient from falling on the floor during ambulation and balance training. An example of the Solo Track in use is shown in Figure 1. Much of the ambulation and balance training was first practiced in the Solo Track, and later progressed outside the Solo Track.

Challenges such as an agility ladder were used to help improve the patient's step length during gait with the use of a single tipped cane. The patient was tasked with going through the agility ladder with forward gait, backward gait, and lateral gait. Steps of various heights from 6-8 inches were used to practice proper cane use with curbs and stairs all while harnessed to the Solo Track.

Single leg stance, with a cane in right upper extremity, was practiced to improve confidence in stance time on the left lower extremity. An exercise called "step catching," was used to help the patient catch their balance if their left lower extremity didn't make foot clearance during swing phase. This was seen commonly with the patient in their walker, likely due his left side being more affected by the spinal cord lesion and the decrease in knee flexion ROM. This involved kicking over a tall cone with the left lower extremity, and then stepping over a shorter cone without the lower extremity touching the ground. It can be seen being practiced in Figure 1. Once these were consistently demonstrated without any loss of balance in the Solo Track, they were progressed to being practiced outside of the Solo Track.

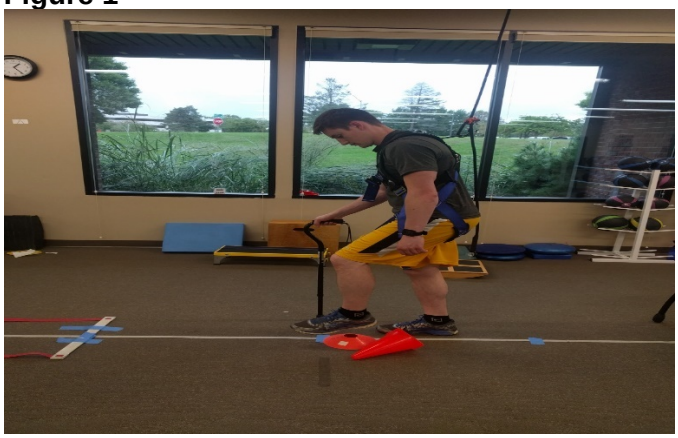
Ambulation outside with a cane was also one of the patient's goals. This was gradually progressed after the patient demonstrated consistent sessions with no loss of balance practicing stairs, step catching, agility ladder, and ramps. The patient then practiced use of a cane outside in the clinic parking lot where there were stairs with and without rails, ramps, uneven sidewalks, and grassy areas.

In terms of manual therapy progression, many of the manual therapy interventions focused on improving knee flexion with posterior tibial glides and patellar mobilizations. This was performed with

the knee propped up in some degree of flexion using a half foam roller. The foam roller also doubled as a stabilizing force for the femur. Afterwards, the knee was taken up to end range flexion for more posterior tibial glides. Patellar mobilizations were performed in all planes at end range extension. This was done throughout the entirety of the eight-week plan of care.

For therapeutic exercise, the patient was given a passive exercise to take advantage of creep. With the patient's tibia hanging off the edge of their bed, with or without an ankle weight around the tibia, they were tasked with letting the tibia hang there and promote knee flexion via gravity and the ankle weight. The patient was told to do this for up to 30 minutes, or for as long as they could tolerate being in a supine position with their painful muscle spasms in the upper and lower extremity. Supine heel slides were to follow this exercise to help promote active range of motion knee flexion. Instructions for this exercise was to try and push for more knee flexion with each repetition. This was eventually progressed to standing knee flexion assist with stairs as patient felt they hit a plateau with supine heel slides.

Figure 1



Note: Figure 1 does not depict the individual that the case report is about. The figure does depict use of the Solo Track, cane use, step catching exercise, and agility ladder use with 1 step per rung for promotion of adequate step length.

Table 3: Timeline of physical therapy interventions administered

Category of Intervention	Timeframe	Intervention
Task Specific Repetitive Practice	Week 1	HEP: Sit to Stand practice 19-inch-high table
	Week 1	HEP: Ambulation to tolerance with FWW in home and community
	Week 2-3	Ambulation in Solo Track using Single Tip Cane (STC) step catching, navigating stairs, single leg stance (SLS) practice, agility ladder use
	Week 2-3	HEP: Ambulation to tolerance with STC in home
	Week 2-8	HEP: Sit to Stand practice 18-inch-high table
	Week 2-8	HEP: Sit to Stand practice 17-inch-high table
	Week 3	Ambulation outside of Solo Track using STC
	Week 3-8	HEP: SLS with contralateral LE toe taps to water bottle forward and out laterally with countertop support as needed for 3x30 seconds.
	Week 4	Ambulation outside in clinic parking lot for 50 feet with supervision
	Week 4	HEP: Ambulation with STC <50 feet outside home with supervision
	Week 4-8	Ambulation outside of Solo Track using STC navigating stairs, cones, ramps, step catching, and agility ladder with supervision
	Week 7-8	HEP: Sit to Stand practice 16.5-inch-high table
	Week 8	Ambulation outside clinic with STC navigating stairs, grassy areas, ramps, and tight corners with supervision
	Week 8	HEP: Ambulation to tolerance with STC outside home with supervision

Manual Therapy	Week 1-8	Bilateral posterior tibial glides grade 4 with 30 oscillations x3 with knee propped up using a half foam roller for stabilization of femur.
	Week 1-8	Bilateral posterior tibial glides grade 4 with 30 oscillations x3 with knee at end range flexion.
	Week 1-8	Bilateral Inferior, Superior, Medial, Lateral grade 4 patellar glides with 30 oscillations x3 with knee at end range extension.
Therapeutic Exercise	Week 1-8	HEP: Hanging tibia over bed with ankle weight for taking advantage of creep for 5-30 minutes based on patient supine tolerance
	Week 1-4	HEP: Supine heel slides 3x8 with 5 second holds
	Week 4-8	HEP: Knee flexion ROM using stairs 3x8 with 8 second holds

Outcome Measures

The patient's progress after eight-weeks of outpatient therapy is provided in Table 4. Since the standard height of a chair is 18 inches, the 5x Sit to Stand test was performed at this height along with 21 inches like during the initial evaluation. The patient would continue therapy beyond the designated eight-weeks of therapy, and thus it was deemed appropriate to include further outcome measures to track patient progress. The Functional Gait Assessment was performed with the patient for a better understanding of the patient's dynamic balance and motor task completion when ambulating. The results of the Functional Gait Assessment can be found in Table 4.

When comparing the outcome measures from the initial evaluation to the progress session, it is clear to see progress was made in the eight-weeks of therapy. For the 10 Meter Walk Test, the patient improved from .67 m/s to 1.1 m/s. This exceeds the minimal detectable change, for patients with a spinal cord injury, of .13 m/s set by Lam et al. [20]. For a 21-inch table height, the patient improved from 17 seconds to 13 seconds with the 5x Sit to Stand test. With an 18-inch table height patient achieved a time of 15 seconds. While no minimal detectable change or minimal clinically important difference has been reported for patients with a spinal cord injury, Buatois et al. established that performing a 5x Sit to Stand test above 15 seconds puts patients at a moderate risk for recurrent falls in community dwelling adults [21].

He reported a 15-point increase in the LEFS from initial evaluation to the progress session. This means the minimal detectable change of 9 points, established Binkley et al., was exceeded [22]. His active knee range of motion improved from (-6)-85 to (-1)-95 after the 13 sessions for his right knee, and (-3)-40 to 0-51 for his left knee. While improved, the patient was still not within functional knee ranges of motion, as demonstrated by Laubenthal et al., for activities of daily living [7]. Finally, the Functional Gait Assessment was completed to a score of 18/30 with the use of a single tipped cane.

Table 4: Progress outcome measures after eight-weeks of therapy.

Patient's Progress Outcomes	Results	Notes
10 Meter Walk Test	-9 seconds = 1.1 m/s	-Used a STC
5x Sit to Stand	-13 seconds	-21-inch table height -UE use for push off from table -Feet staggered due to knee range of motion
5x Sit to Stand	-15 seconds	-18-inch table height -UE use for push off from table -Feet staggered due to knee range of motion
LEFS	-41/80 = 51.25% functional	-Completed as intake form
Functional Gait Assessment	-18/30	-Used a STC

R knee ROM	-95 degrees flexion -Lacking 1 degrees to extension	-Active range of motion measurement in supine prior to any therapy intervention -Could get to 97 with therapist over pressure
L knee ROM	-51 degrees flexion -0 degrees extension	-Active range of motion measurement in supine prior to any therapy intervention -Could get to 55 with therapist over pressure

Discussion

After eight-weeks of physical therapy sessions, the patient improved in their outcome measures and reported improved function at home and in the community. It should be noted that some leniency was given on the specific requirements when administering the outcome measurement tests. For example, during the 5x Sit to Stand test a 21-inch table height was used as that was the only height that the patient was able to complete at initial evaluation. Based on the 5x Sit to Stand reference from the Shirley Ryan Ability Lab, used as the basis of the test, the table height should have been set to 16 inches. A standard height chair in the clinic was 18 inches, but the patient would have been unable to complete the task if the chair height was set at 16 or 18 inches high at initial evaluation. Thus 19, 20, and 21 inches were trialed, and it was at 21 inches that the patient was able to complete the task at initial evaluation with the use of his upper extremities. However, as the patient progressed throughout the eight-weeks, lower table heights were practiced closer to the standardized 16 inches.

The interventions performed as a part of therapy were tailored to the patient's goals and setting up the patient to succeed in their activities of daily living. Task specific interventions and exercises were used to help improve the patient practice their activities of daily living. Improving the patient's gait speed and confidence with use of a cane can be linked to a reduction in fall risk [8]. Given that the patient initially sustained their central cord injury from a fall down the stairs, reducing risk of further falls was an important part of the patient's therapy. Challenging the patient's ambulation in the clinic and outside were likely important interventions for improving skill with a cane and improve the patient's confidence.

Repetitive and progressive sit to stand practice continually makes the patient use their lower extremity muscles to perform the movement. It has been documented that spinal cord injuries lead to altered muscle gene expression, reduced hormone levels that influence muscle hypertrophy, and decreased muscle mass [23]. The continued use of the lower extremity muscles to perform a sit to stand maneuver likely lead to promotion of muscle hypertrophy and thus helped combat the muscle atrophy effects that occurred as a result of the SCI.

Manual therapy intervention coupled with exercises that promote knee flexion range of motion were used to also help the patient achieve their activities of daily living. While no criteria is used to diagnose it, a complication that leads to decreased knee range of motion due to scar tissue formation after a total knee arthroplasty is called arthrofibrosis [6]. The patient in this case report could have a diagnosis similar to this as he never underwent any formal physical therapy after surgery. While ideally over 100 degrees of knee flexion would be the goal for proper activity of daily living performance, referenced by Laubenthal et al*.,* the range of motion progress made by the patient in therapy likely helped improve the patient's functional outcome measures [7]. However, there is also the possiblity that task specific intervention practice and continued neurological recovery were contributing factors to the improved knee range of motion.

In terms of the relevancy of this case for clinical practice, there are many geriatric patients that have multiple co-morbidities affecting their daily function that could benefit from physical therapy. This case report is just one patient and example of that. A multifacet approach taking aspects from both neurological physical therapy and orthopedic physical therapy were invovled in the making of this patient's plan of care. This approach worked well for this patient, but further research into multiple co-morbidity patients would further benefit the field of physical therapy and rehabiliation. The combination of neurological and orthopedic impairments alone provide a lot of options for further research.

While there may be limited direct observational research to help inform the care of this patient with a central cord injury and long-standing knee joint deficits from prior total knee arthroplasties, a modeling study by Young Lee et al. reinforces some the the clinical issues observed with this case report. Young Lee et al. performed a sit to stand analysis on clients with hemiparesis post stroke, and had them perform it at different knee flexion ranges of motion [24]. They determined that the different knee flexion range of motions changed the clients trajectory and lower extremity force outputs during the sit to stand maneuver [24]. In general, this modeling study simarily found that limiting knee range of motion resulted in increased difficulty in performing a sit to stand task which mimics the complications we observed with our patient in performing the sit to stand task.

This type of study design could be applied to different joint ranges of motion with different neurological condiditions including SCI and central cord injuries. If a joint, such as a knee joint, was fixed at different angles in a patient with a neurological condition it could theoretically simulate a patient with mutliple co-morbidities. This could further the physical therapy and rehabilitation research and allow clinicians to use a more evidence based approach with a patient with both neurological and orthopedic impairments.

This case provides one example of how two potentially unrelated co-morbidities must be taken into consideration when providing care to a patient in the outpatient setting. While a cervical central spinal cord injury was the primary diagnosis and reason for referral, a long-standing history of notable knee range of motion deficits further influenced his therapeutic interventions. Thus requiring specific strategies more typically applied in outpatient neurological as well as strategies more often associated with the outpatient orthopedic setting.

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