Background Report

Soul Tech

Danis Nugroho
dnugroho@asu.edu
Sai Srinivas Tatwik Meesala
smeesala@asu.edu
Sriram Rama Prakash
sramapr1@asu.edu
Sabareesh Karthick Senthilkumar
ssenth26@asu.edu
Vishnu Bhargav Muthyala
vmuthyal@asu.edu

EGR 555: Mechatronics Device Innovation
February 3, 2023
3 Smart Sole Inserts

I. INTRODUCTION

For humans to function naturally in the world, having a reliable and normal gait is essential. Humans engage in physically demanding tasks daily and for some, it is difficult to walk without stressing some parts of the foot joints due to a variety of reasons. This report discusses the importance of this basic human need and the recovery process in case of damage. It also discusses the information process model for human walking motion.

II. BACKGROUND

A. Normal Gait

Gait is the continuous movement pattern that constitutes a person's walking or running motions. The process of walking makes use of different structures of the central and peripheral nervous system which can be summarized into 8 phases [1] of a cycle i.e.

1. Initial Contact is the moment the leading foot touches the ground and both feet are on the ground. Ideal gait shows 20 degrees of hip flexion and neutral alignment in the knee and ankle.

2. Loading Response: This is the transition phase from double-leg to single-leg weight bearing and shock absorption. For ideal gait, hip and knee flexion should be 20 degrees, and 5 degrees of plantar flexion in the ankle.

3. Midstance: Begins when non-stance foot lifts, ends when non-stance shin is vertical and both hip/knee are extended (20 degrees to neutral). The ankle starts at 5 degrees plantar flexion and ends at 5 degrees dorsiflexion.

4. In Terminal Stance, hip extension at 20 degrees, neutral knee, and 5-10 degrees ankle dorsiflexion occurs as the stance foot lifts and the non-stance foot touches the ground.

5. Pre-swing: Begins with non-stance foot contact, and ends with stance leg toe-off. The hip starts at 20° extension and moves back to neutral. The knee moves from neutral to ~40° flexion. Ankle moves from 10° dorsiflexion to 20° plantar flexion..

6. Initial Swing: Begins with swing foot lift, and ends when the foot is parallel to the other leg. The hip moves from neutral to 10° flexion, the knee bends to 40-60° flexion, ankle decreases from 20° plantar flexion to 5°.

7. Mid Swing starts with swing foot passing stance leg, ending with shin vertical. 20-degree hip flexion, 30-degree knee flexion, and neutral ankle occur.

8. In Late Swing, the hip flexes at 20 degrees and the knee moves to the neutral position as the swing leg is brought forward for the next gait cycle. The neutral ankle is maintained until the next cycle. Neurological or musculoskeletal factors can affect gait and balance.

B. Demographics Of Affected

Disorders of gait are frequent in older adults, and their occurrence increases with age. About 30 percent of 60-year-old and older community-based adults have gait disorders. Among adults aged 80 years and older, the rate is 60 to 80 percent [2].

Even though gait disorders are more common among the elderly, their overall prevalence and burden are not well defined.

Gait disorders are associated with reduced mobility. Neurological gait disorders in particular are associated with repeated falls, poor cognitive function, depression, and poor quality of life [3].

C. Abnormal Gait and its types

A wide range of conditions like Injuries to the legs or feet, arthritis, infections in the soft tissue of the legs, broken bones in feet and legs, birth defects, infections in the inner ear, cerebral palsy, stroke, tendonitis, conversion disorder or other psychological disorders, shin splints can lead to gait deviations[4]. Some of the major deviations include

Antalgic: A gait dysfunction where an injured leg is bearing all the weight and can be related to arthritis or a traumatic injury. This causes a gait pattern of slow and short steps or limping.

Ataxic: This results in erratic and inconsistent foot placement, often seen in people with Multiple sclerosis, stroke victims, drug or alcohol intoxication, a condition of the cerebellum.

Parkinsonian: Affects people with Parkinson's disease making them take short, shuffled steps with difficulty to start or stop walking.

Steppage: This is a type where the affected person cannot lift their foot from the ankle. They need to lift the affected leg higher, so the toe clears the ground when walking. It is seen in people with Lumbar radiculopathy, Neuropathy, and muscle weakness related to stroke.

Vestibular unsteadiness: This leads to people walking unsteadily, often falling to one side. It is associated with Vertigo, Meniere's disease, and Labyrinthitis.

Waddling: Individuals with this type of impairment walk on their toes and wobble from side to side. It usually arises from conditions such as Muscular Dystrophy, muscle disease, and weakness in the muscles of the hips and thighs.

Patients with abnormal gait after the traumatic injury often have other injuries and require therapy. The abnormality is caused by a motor control issue and may also have a psychological component. The severity can range from foot drop to dragging feet while walking.

A person who sustained a spinal cord injury in an accident is often bedridden and undergoing treatment for their spinal cord and other major organs. During their recovery, they may also need to address their abnormal gait, which can result in problems such as joint and foot damage, weakened tendons, and difficulty standing. To aid in their recovery journey, there is the potential

for an app to serve as a replacement for therapists and guide the person through their recovery process.

D. Treatment Processes

Treatment of gait disturbances initially involves diagnosing the underlying cause. Based on the diagnosis and its severity different plans like gait training, medications, assistive devices, deep brain stimulation or multimodal rehabilitation can be incorporated. Letting the abnormality grow without treatment may lead to Paralysis, Syncope, Axial skeleton fractures, Epidural/subdural trauma, Psychosocial stigma, and other injuries. The most common form of treatment is Gait training, which is a set of exercises that improves motion in lower extremity joints, improving strength and balance and as a result, correcting the gait abnormality.

In gait training, the therapist first performs gait analysis. The parameters in the analysis may include Anthropomorphic data like height, weight, or BMI; Spatio temporal data like step & stride length, cadence, velocity, and pressure at first contact, and other data like the angle of different joints during movement.

The methods of conducting gait analysis can be mainly categorized into four categories:

- Vision based
- Sensor based
- Other technologies like Electro goniometer or Magnetic systems.
- Combination of the three [5]

The patient's manner of walking can be analyzed based on factors such as the length of each step, stride length, pace, time between steps, and joint angles. Clinical gait analysis employs various techniques, including

- “Computerized video cameras to show movement in slow motion
- Markers placed on the skin to monitor motion on the camera
- Sensors on a platform to measure footstep pressure and stride length
- Electrodes placed on the skin to monitor muscle movement
- Infrared markers to measure joint movement in three dimensions” [6].

Measurement methods in clinical gait analysis

Optical systems for measuring the positions of markers on the skin in clinical gait analysis are advanced, with soft tissue movement and anthropometry being the main challenges. Joint centers and rotation axes can now be determined with functional tests. Compensating for soft tissue measurements remains a challenge, and future use of 3D imaging may replace marker-based systems.

Gait restoration is a crucial goal in neurological rehabilitation and requires a thorough evaluation before therapy. Various therapy methods, including force exercise, spasticity reduction, and musical biofeedback, are chosen based on the patient's individual needs. The spectrum of already available treatments can now be expanded to include locomotor medication, treadmill training with partial body weight support, a targeted reduction in spasticity with botulinum toxin injections, and musical biofeedback [7].

In some situations where balance is an issue, assistive aids like canes and walkers may be useful. In other situations, physical therapy and strengthening exercises may be necessary to increase balance, strength, and flexibility. Additionally, it ought to obtain fall prevention training. It might be necessary to use leg braces or in-shoe splints

to maintain normal foot alignment. If the legs are not the same length, a shoe raise may be helpful.

If the cause of the irregular gait is addressed, the patient may regain some of their functions. Treatments for underlying conditions such as multiple sclerosis, Parkinson's disease, and arthritis may include medications. For individuals with osteoarthritis, surgery or the use of prostheses such as hip and knee replacements may be recommended [8].

As an aid, the exoskeleton is an external structural mechanism having joints and linkages that are similar to those found in the human body. The majority of exoskeleton robots under development today concentrate on supporting the full gait cycle as a single unit. These robots give consistent stiff control along joint trajectories of the whole gait cycle. This implies that the patient receives assistance both during crucial gait phases and during periods during which support is not required [9].

A device with foot plates mounted on a twin crank and rocker gear system is an end-effector-based robot. Robotic-assisted gait training (RAGT) systems, which employ movable footplates to which the patient's feet are attached, serve as alternatives to powered exoskeletons. Every gadget has some kind of body weight support [10]. Assistive movement strategies for people suffering from Parkinson's disease (PD) can improve walking and balance through external cues such as white lines or rhythmical beats. These strategies can compensate for hypokinesia, a common movement disorder characterized by reduced movement amplitude and speed, and allow for longer and faster steps. Many cognitively intact individuals with PD can immediately walk with longer steps by focusing their attention.

People with PD may compensate for the neurotransmitter imbalance in the basal ganglia by avoiding the damaged basal ganglia and using the frontal cortex to control movement size or timing by deliberately thinking about the desired action. The use of long steps while walking is another technique. Others include breaking long or complex motor sequences into parts and concentrating on the performance of each segment (segmentation), avoiding dual-task performance, reading cue card instructions, and verbally repeating phrases like "think big" or "long steps" before acting [10].

Regardless of the technique, exercise treatment with walking training increased gait function; however, the time and effort needed to produce the outcomes preferred the gait trainer exercise. Early, intensive gait training improved walking ability more than standard care [11].

Patients with severe hemiplegia require significant effort for gait rehabilitation. The use of multichannel functional electrical stimulation (MFES) for these patients' gait rehabilitation has the potential to have positive results, according to preliminary research.

When conventional therapy was paired with MFES, the participants performed better than when conventional therapy was used alone. The improved motor learning achieved by the use of MFES was primarily responsible for the MFES method's superiority to traditional therapy [12].

E. Challenges of the problem

Gait disorders lead to decreased mobility, increased risk of falls, decreased

quality of life, and serious injuries such as major fractures and head injuries [2]. Major challenges hindering the process of gait rehabilitation are

- The accuracy of the equipment used for gait analysis.
- The ability of the person to complete the rehabilitation process and the accessibility of the equipment.
- The severity of the gait deviation is based on the underlying cause.

To estimate gait moments the most challenging problems that the team found are

- Complexity of the human body
- Variable gait patterns among everyone
- And noise and interface of the sensors

Greater health outcomes, enhanced efficiency and effectiveness in the provision of medical and rehabilitation services, and advancements in the fields of biomechanics and human movement science are some of the larger effects of finding a solution to the gait moment estimate challenge.

II. INFORMATION PROCESSING

Postural control depends on the efficient integration of sensory data from the visuospatial environment, the body, and the limb position. For instance, disturbances in the visual, vestibular, and proprioceptive sensory systems have an impact on standing posture. Basal ganglia are believed to play a variety of roles in postural control, including (1) sensory channel integration which will be what the patient observes and feels with the body. This includes visual and physical input where the person needs to see where they are walking as well as track their movement. (2) Selection of automatic postural reactions generated in response to the motor and sensory perturbations, such as moving visual environments; and (3) motor control flexibility and adaptability, i.e. appropriate corrective postural reactions generated in an attempt to prevent a fall. (4) Regulation of muscular moment; and (5) Modulation of the impact of cognitive factors on balance and gait.

Gait problems are associated with changes in cognitive function (and likely general cortical function). Older persons who could walk and chat at the same time were substantially less likely to fall than those who could not walk while talking ("stopped walking while talking"). Walking and talking are two attention-demanding tasks that may compete for cognitive resources or make it difficult for the brain to properly prioritize the two tasks, a process known as "posture-first."

Patients with modest, early dual-tasking disorders frequently have selective cognitive impairments, especially executive function, and attentional deficiencies. Dual-tasking is an executive cognitive function that is highly reliant on working memory and attentional functions. When multiple tasks must be completed simultaneously, gait and balance are put to the test, which could increase gait variability.

Motor control or neuromuscular interaction, and psychological limitations are the main causes of abnormal gait. Because aberrant gait is typically accompanied by other issues that may or may not have impacted the patient's psychological well-being and judgment, it is challenging to determine whether it is a psychological restriction [13].

REFERENCES

[1] K. Vandi, "The 8 phases of walking gait: What ideal walking form looks like," Competitive Edge, 29-Apr-2022. [Online]. Available: https://compedgept.com/blog/phases-of-walking-gait/. [Accessed: 02-Feb-2023].

[2] M. Ronthal, "Causes and evaluation of neurologic gait disorders in older adults," UpToDate. [Online]. Available: https://www.uptodate.com/contents/causes-and-evaluation-of-neurologic-gait-disorders-in-older-adults#references. [Accessed: 03-Feb-2023].

[3] P. Mahlknecht, S. Kiechl, B. R. Bloem, J. Willeit, C. Scherfler, A. Gasperi, G. Rungger, W. Poewe, and K. Seppi, "Prevalence and burden of gait disorders in elderly men and women aged 60-97 years: A population-based study," PloS one. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/23894511/.[Accessed: 03-Feb-2023].

[4] "Physical therapy guide to gait dysfunctions," Choose PT, 24-Jan-2023. [Online]. Available: https://www.choosept.com/guide/physical-therapy-guide-gait-dysfunctions. [Accessed: 02-Feb-2023].

[5] C. Prakash, R. Kumar, and N. Mittal, "Recent developments in human gait research: Parameters, approaches, applications, machine learning techniques, datasets, and Challenges - Artificial Intelligence Review," SpringerLink, 12-Sep-2016. [Online]. Available: https://link.springer.com/article/10.1007/s10462-016-9514-6. [Accessed: 02-Feb-2023].

[6] "Gait analysis," Gait Analysis Orthopedic Medical Center. [Online]. Available: https://www.orthomedctr.com/gait-analysis.php#:~:text=Gait%20analysis%2C%20also%20known%20as,pain%20while%20standing%20or%20walking. [Accessed: 03-Feb-2023].

[7] Mauritz, K.-H. (2002), Gait training in hemiplegia. European Journal of Neurology, 9: 23-29. https://doi.org/10.1046/j.1468-1331.2002.0090s1023.x

[8] "Gait disorders," Cleveland Clinic. [Online]. Available: https://my.clevelandclinic.org/health/symptoms/21092-gait-disorders#:~:text=What%20can%20be%20done%20to,improve%20balance%2C%20strength%20and%20flexibility. [Accessed: 03-Feb-2023].

[9] P. Sale, M. Franceschini, and S. Hesse, "Use of the robot assisted gait therapy in rehabilitation of patients with stroke and spinal cord injury," European journal of physical and rehabilitation medicine. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/22543557/. [Accessed: 03-Feb-2023].

[10] Meg E. Morris, Clarissa L. Martin, Margaret L. Schenkman, Striding Out With Parkinson Disease: Evidence-Based Physical Therapy for Gait Disorders, Physical Therapy, Volume 90, Issue 2, 1 February 2010, Pages 280–288, https://doi.org/10.2522/ptj.20090091

[11] S. H. Peurala, O. Airaksinen, P. Huuskonen, P. Jäkälä, M. Juhakoski, K. Sandell, I. M. Tarkka, and J. Sivenius, "Effects of intensive therapy using gait trainer or floor ... - researchgate." [Online]. Available: https://www.researchgate.net/profile/Ina-Tarkka/publication/24027328_Effects_of_intensive_therapy_using_Gait_Trainer_or_floorwalking_exercises_early_after_stroke/links/57ce58a008ae83b37460ec62/Effects-of-intensive-therapy-using-Gait-Trainer-or-floorwalking-exercises-early-

after-stroke.pdf. [Accessed: 03-Feb-2023].

[12] Uroš Bogataj, Nuša Gros, Miroljub Kljajić, Ruža Aćimović, Matija Maležič, The Rehabilitation of Gait in Patients With Hemiplegia: A Comparison Between Conventional Therapy and Multichannel Functional Electrical Stimulation Therapy, Physical Therapy, Volume 75, Issue 6, 1 June 1995, Pages 490–502, https://doi.org/10.1093/ptj/75.6.490

[13] N. I. Bohnen, R. L. Albin, M. L. T. M. Müller, and K. Chou, "Advances in therapeutic options for gait and balance in parkinson's disease," US neurology, 01-Nov-2011. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3859869/. [Accessed: 03-Feb-2023].

Contributions

Danis: Arranged all the data in accordance with the assignment
Tatwik: Arranged all the data in accordance with the assignment
Sriram: Researched and provided references for information processing
Sabareesh: Researched and provided references for the background of the problem
Vishnu: Researched and provided references for information processing model and formatted the flow of the paper

Everyone attended the team meeting outside the class and worked together on a document.