# Enhancing Gait Symmetry: The Impact of Prolonged Sitting and the Efficacy of Flexibility Exercises

Author

Habib Ullah Khan

Registration Number

329146

Supervisor

Dr Asim Waris

DEPARTMENT of Biomedical Engineering

SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY

ISLAMABAD

December,2023

# Enhancing Gait Symmetry: The Impact of Prolonged Sitting and the Efficacy of Flexibility Exercises

Author

Habib Ullah Khan

Regn Number

394146

A thesis submitted in partial fulfillment of the requirements for the degree of

MS Biomedical Engineering

Thesis Supervisor:

Dr Asim Waris

Thesis Supervisor's Signature: ____________________

DEPARTMENT of Biomedical Engineering

SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY,

ISLAMABAD

December, 2023

# THESIS ACCEPTANCE CERTIFICATE

Certified that final copy of MS/MPhil thesis written by **Regn No. 00000329146 Habib ullah Khan** of **School of Mechanical & Manufacturing Engineering (SMME) (SMME)** has been vetted by undersigned, found complete in all respects as per NUST Statues/Regulations, is free of plagiarism, errors, and mistakes and is accepted as partial fulfillment for award of MS/MPhil degree. It is further certified that necessary amendments as pointed out by GEC members of the scholar have also been incorporated in the said thesis titled. **Enhancing Gait Symmetry: The Impact of Prolonged Sitting and the Efficacy of Flexibility Exercises**

**Signature:**

**Name (Supervisor):** Muhammad Asim Waris

**Date:** 28 - Dec - 2023

**Signature (HOD):**

**Date:** 28 - Dec - 2023

**Signature (DEAN):**

**Date:** 28 - Dec - 2023

# Declaration

I certify that the research work "Improving Gait Symmetry: The Effect of Extended Sitting and the Effectiveness of Flexibility Exercises" is original to me. The work hasn't been submitted for evaluation elsewhere else. All used content from external sources has been correctly cited and credited.

Signature of Student

Habib Ullah Khan

2020-NUST-Ms-BMES-329146

# Acknowledgements

I am grateful to my Creator, Allah Subhana-Watala, for guiding me at every turn and for putting new ideas into my head to help me with this work. Without Your invaluable assistance and direction, I truly could not have accomplished anything. It was Your will that anyone assist me with my thesis, be it my parents or anyone else, so You alone are deserving of all the gratitude.

I have no words to express how grateful I am to my parents, who raised me even before I could walk and have supported me in every aspect of my life.

Additionally, I would like to thank my supervisor, Dr. Asim Waris, in particular for his assistance with my thesis and for teaching me biostatics and rehabilitation in his courses. It's safe to say that, aside from the subjects he has taught, I haven't studied any other engineering subject in such depth.

Additionally, I want to express my gratitude to Dr. Nabeel Anwar for all of his help and cooperation. He always had the answer when I got stuck on something. My thesis would not have been finished if it weren't for his assistance. I am grateful for his understanding and direction during the entire thesis.

Additionally, I would like to thank Adnan Habib for his assistance and Drs. Aneeqa Noor and Adeeb Shehzad for serving on my thesis guidance and evaluation committee.

I express my gratitude to Amir Khan and Awais Falak for their assistance and collaboration.

In conclusion, I just wanted to say thank you to everyone who helped me out with my research.

*Dedicated to my amazing parents and beloved siblings, whose unwavering cooperation and support helped me achieve this amazing feat.*

# Abstract

Due to advancement in technology, we have seen a shift in the modern work environment. A notable surge has been seen in the percentage of people with jobs requiring prolonged sitting. There is a strong link between sedentary behavior and health risks down the road. Gait of a person is also linked to sedentary behavior which is believed to be significantly affected by prolonged inactivity. Gait asymmetry can be a very good indicator of overall physical health and that is why it used extensively to assess the physical health of subjects.

Due to prolonged sitting, tightening of certain muscles, reduction in core strength and reduction in joint flexibility can lead to various Gait abnormalities. Our study is designed to compare the Gait asymmetry of physically active individuals with those of inactive individuals. We took into account various gait related features to find out the gait asymmetry between the right and left limb. We then also assessed the impact of exercise on gait symmetry and introduce flexibility training to the Sedentary group. Sedentary group performed Flexibility Training for 4 weeks every day. The exercises were performed thrice every day for 30 minutes. Results were substantial in supporting the link between sedentary behavior and increased gait asymmetry. Results also showed improvements in gait symmetry using flexibility training exercises.



**Key Words:** *Gait Symmetry, Cadence, Stride Length, Stride Time, Swing to Stance Ratio*

# Table of Contents

# List of Figures

# List of Tables

# CHAPTER 1: INTRODUCTION

## 1.1 Background

The modern professional scene, shaped by the unrelenting advancement of the digital era, has seen a paradigm shift in the way work is performed. Technological advancements have not only increased output to unprecedented levels, but they have also ushered in a new era of convenience and efficiency. While this transition is undeniably beneficial, it is not without problems. Among these issues is an increase in sedentary behavior in the workplace, a phenomenon that requires further investigation to fully appreciate its far-reaching ramifications for human health.

### 1.1.1 The Evolution of Work Practices

The growth of work practices, inextricably linked to technology advancement, has reshaped how people approach their professional obligations. The introduction of computers, cellphones, and other digital technologies has simplified work, removing hurdles to efficiency. As a result, a working culture characterized by continual connectedness and a continuous flow of information has emerged, transcending traditional time and space barriers.

Sedentary Work Culture: The digital age's conveniences, on the other hand, have given rise to a sedentary work culture. The majority of jobs are now completed in front of computer displays, with employees spending significant amounts of time sitting. This shift represents a departure from traditional work roles that frequently required physical labor, emphasizing the importance of investigating the consequences of prolonged sitting.

### 1.1.2 The Dominance of Sedentary Behavior

Sedentary behavior has become a feature of modern work environments, as characterized as tasks requiring an energy expenditure rate equal to or less than 1.5 Metabolic Equivalents (METs) in a sitting or reclining position [1]. According to the World Health Organization (WHO), physical inactivity is the fourth largest cause of death [2], emphasizing the importance of sedentary behavior as a ubiquitous and consequential component of modern living.

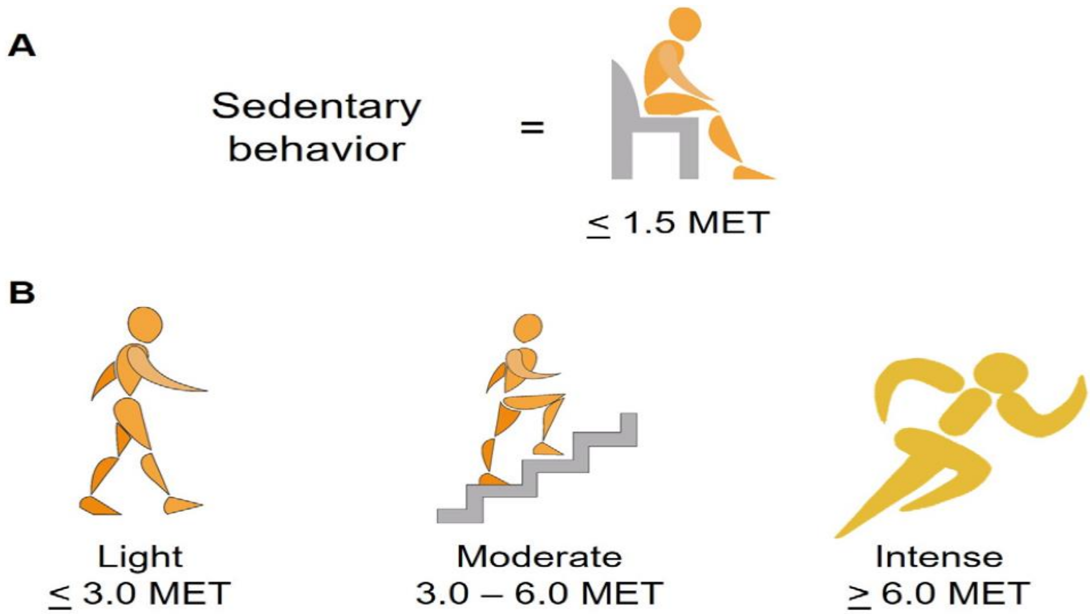


**Figure 1:** Shows Metabolic equivalent for different activities. courtesy of [3].

Statistics on Sedentary Behavior: The statistics on sedentary behavior are startling. A sizable proportion of the global workforce is engaged in tasks that require little physical effort, resulting in a worrisome increase in sedentary work patterns. Sedentary behavior is becoming more common as digital duties become more integrated into professional obligations.

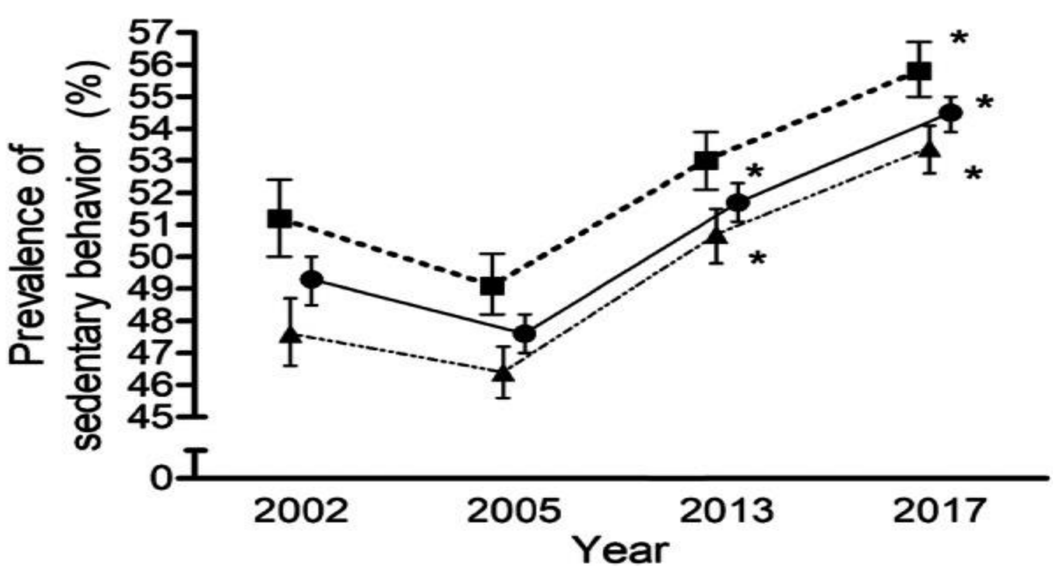


**Figure 2:** shows prevalence of sedentary behavior in European adults between the years 2002 to 2017. Courtesy of [4].

It has also been seen that the prevalence of sedentary behavior has increased tremendously in European population over the years. The data was collected from 2002 to 2017 and it showed considerable increase in sedentary behavior in European population [4]. Research suggest that working adults spend 70-80% of their working time in sedentary behavior [2] and also more than 30% of the individuals with over 15 years of age are categorized as physically inactive [2], [5].

### 1.1.3 The Health Toll of Sedentary Lifestyles

While there are indisputable benefits to sedentary labor, the toll it takes on human health is cause for concern. Sedentary behavior is unambiguously linked to a range of negative health consequences, highlighting the critical need to deconstruct the complicated links between the modern work environment and human well-being.

Obesity and Metabolic Consequences: Sedentary behavior has been identified as a major factor to obesity [2], [6]. Prolonged sitting has metabolic implications, including alterations in glucose metabolism and insulin sensitivity, which exacerbate the health risks associated with sedentary lifestyles.

Diabetes link: A convincing body of data indicates a clear association between sedentary behavior and the establishment of type 2 diabetes [7]. Prolonged sitting has been found to have a negative influence on glucose metabolism, contributing to insulin resistance and an increased risk of developing diabetes. Understanding this link is critical to understanding the many health ramifications of sedentary behavior.

Metabolic Syndrome: Sedentary behavior is linked to the development of metabolic syndrome in addition to diabetes [8]. This group of disorders, which includes abdominal obesity, high blood pressure, excessive blood sugar, and abnormal cholesterol levels, poses a significant risk to cardiovascular health. A more in-depth examination of how sedentary labor leads to metabolic syndrome is required for a complete grasp of its health implications.

The association between sedentary behavior and cardiovascular disease is widely known [9], [10]. Long periods of sitting contribute to a variety of cardiovascular risk factors, demanding a deeper look at the cardiovascular health consequences of sedentary work habits.

### 1.1.4 Gait Symmetry: A Neglected Dimension of Health Assessment

The impact of sedentary behavior on gait symmetry is a feature that is frequently overlooked in the large discourse on the health implications of such behavior. The balanced synchronization of motions between the left and right sides of the body when walking is reflected in gait symmetry, a basic aspect of human motion. In health evaluations, gait symmetry is still a measure that is often disregarded, despite its potential to serve as an early warning system for underlying health problems.

During the walking cycle, limb movements should be balanced and synchronized. It is the synchronization of several elements, such as cadence, stride length, gait speed, and temporal and spatial characteristics. Due to its complexity, gait symmetry is a useful measure of general health, with variations perhaps indicating underlying medical issues.

In addition to being useful in identifying some neurological disorders like Parkinson's and Alzheimer's, gait symmetry is a comprehensive indicator of a person's physical health. Deciphering the complex connection between contemporary work practices and general health requires an understanding of how sedentary behavior affects gait symmetry.

## 1.2 Rationale

The symmetry of gait becomes apparent in the complex dance of human mobility as a significant determinant of a person's physical health. The coordinated movement of the right and left limbs during the complex gait provides an insight into an individual's general state of health. Often used to evaluate motor function, gait symmetry goes beyond the mechanics of movement to offer important information about neurological diseases including Parkinson's and Alzheimer's [11]. Beyond its ability to diagnose, gait symmetry is a dependable surrogate that provides a sophisticated perspective for assessing a person's overall health [11].

The understanding that extended sitting times, or sedentary behavior, construct a complicated tapestry of physiological alterations that ripple through the subtleties of gait symmetry, is the fundamental finding of this study. Long periods of sitting have been linked to decreased range of motion in the joints, stiffness in key muscle groups, and a decrease in core strength [12]. Being the motor coordination's sentinel, gait symmetry serves as a visible indicator of the detrimental consequences of inactivity on the body's dynamic balance.

Core strength, joint mobility, and gait quality are all impacted by sedentary lifestyles [13], [14]. A decrease in core strength is a characteristic that is closely related to gait quality. Aberrations in gait may become the quiet messengers of the physiological alterations brought on by prolonged inactivity when the central support structure decreases. The complex interplay of joint mobility, gait symmetry, and core strength tells the story of how sedentary behavior ruins the fluid choreography of human movement.

As people age, the effect of inactivity on gait symmetry becomes much more significant. Research suggests that growing older in conjunction with a sedentary lifestyle leads to a deterioration in the quality of one's stride, a condition that is most noticeable in the elderly [15]. This study aims to provide insights that go beyond the immediate context of the modern workforce by examining the complex interactions between age, inactivity, and gait symmetry.

Sedentary behavior has knock-on implications to more general health issues, such as obesity and slowed gait. An intriguing six-year longitudinal research found a strong correlation between obesity, physical inactivity, and a decrease in gait speed in older people experiencing knee pain [16]. This emphasizes how weight-related problems, sedentary behavior, and the complex mechanics of gait are all intertwined.

Gait symmetry which is the synchronization of the right and left limbs during a walking cycle is a very good predictor of individual physical health. Beyond assessing motor function, gait symmetry can offer valuable insights into neurological conditions such as Alzheimer's and Parkinson's [11]. Moreover, gait symmetry serves as a reliable proxy for evaluating an individual's general state of health. This close relationship is influenced by a number of things.

Siting for long hours can cause certain muscle groups to become stiff, core strength and can also reduce joint mobility [12]. Since aberrant gaits may arise from these physiological changes, gait symmetry acts as a sentinel signal of the detrimental consequences of sedentary behavior on health. Inactivity causes a decrease in core strength [13], [14], and it may also cause a decline in gait quality. It has been that specifically older people gait have been decreases due to inactivity [15]. Furthermore, in older individuals with knee discomfort, a six-year longitudinal study discovered a strong association between fat, physical inactivity, and gait speed [16].

Despite the extensive connections between sedentary behavior and gait symmetry, a crucial study gap persists. Long periods of sitting have been shown to have negative effects on musculoskeletal health, but little is known about the precise relationship between sedentary behavior and asymmetrical gait. Additionally, there is currently a dearth of research on the effectiveness of flexibility training as a possible mitigate of gait asymmetry in inactive adults.

Against this complex background, this work is well positioned to decipher the quiet conversation between sedentary behavior and the rhythmic harmony of gait symmetry. Through exploring the uncharted territories of this relationship, the study hopes to offer subtle insights that go beyond the traditional confines of health research.

## 1.3 Research Objective

This study begins a thorough investigation of the complex relationship between sedentary behavior and the essential component of human movement—gait symmetry—in the context of the modern professional environment, which is marked by extended sitting. This study's central concept is gait symmetry, which refers to the balanced synchronization of the left and right limbs during walking. A comprehensive analysis of many gait metrics, including stride length, gait speed, cadence, and stride time, is included in the study. The main goal is to identify the significant impact of extended sitting on these critical gait-related characteristics using a systematic and quantitative approach.

### 1.3.1 Primary Objective

To fully understand the complex effects of prolonged sitting on gait symmetry, we will be analyzing features of gait like stride length, stride time, swing and stance time and cadence of each leg. We will then look for any asymmetry present in each leg during walking. The individual asymmetries will then be used to calculate an overall asymmetry index. The asymmetry index will then tell us whether our initial assumption is correct or wrong.

### 1.3.2 Secondary Objective

Provide a well-structured three-week program of flexibility exercises to a group of inactive individuals. The objective is to analyze and understand how certain flexibility exercises might help reduce the asymmetries brought on by extended sitting times.

Analyze flexibility exercises' effect on gait symmetry methodically in order to uncover the treatments' transformational potential. This goal goes beyond only assessing gait symmetry to evaluate the comprehensive effects of flexibility training on general health and wellbeing.

The flexibility training program duration was four weeks. The subjects performed these four exercises every day for dour weeks and then data was recorded afterwards. The exercises names along with their picture are given below.

**Figure 3:** Shows hip flexor stretch which stretches hip flexors responsible for stabilization of hip joint.

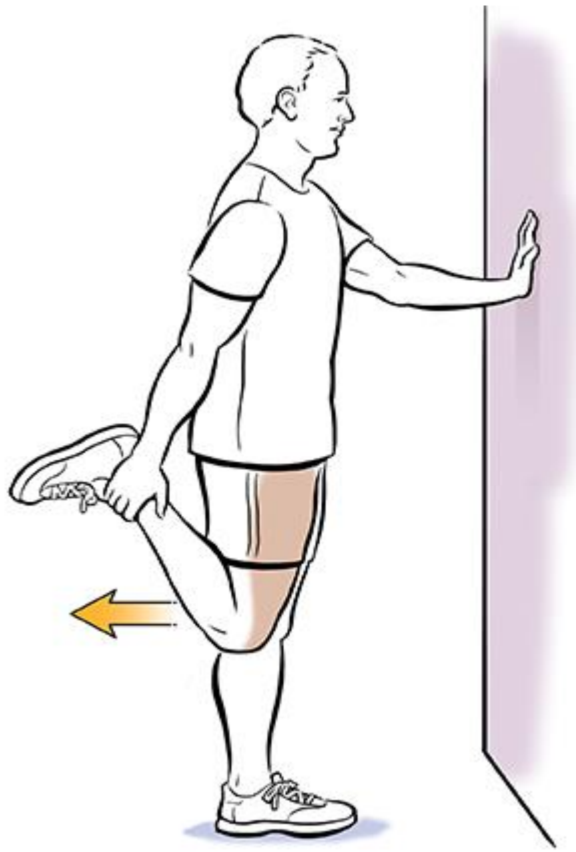

**Figure 4:** Standing quadriceps stretch for stretching the quadriceps muscle.

**Figure 5:** Hamstring Stretch for stretching the hamstring muscles.

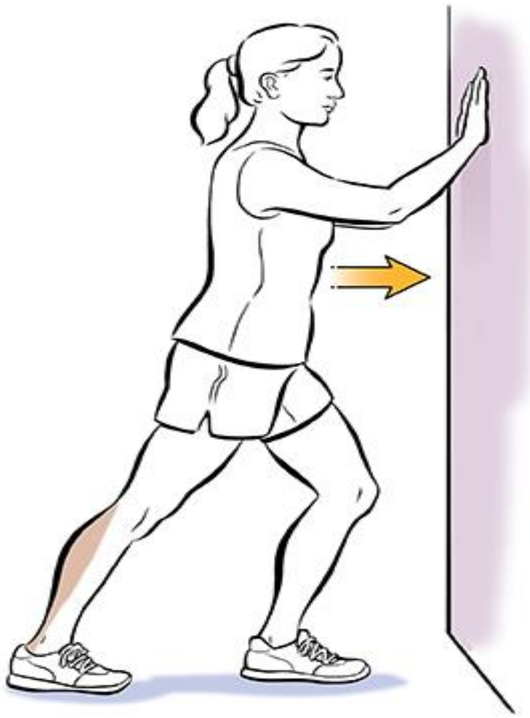

**Figure 6:** Calf stretch for stretching the calf muscles.

All these exercises target muscle groups and joints that are responsible for gait related movement. It is believed that if we can fix problems associated with the joints and muscle groups, we will see a positive effect on gait symmetry.

This study, which has a clear headings and a fluid narrative, aims to close important gaps in our knowledge of the complex relationship between sedentary behavior and gait symmetry and to provide light on potential avenues for interventions that go beyond the accepted limits of movement dynamics. Through the careful consideration of these main and secondary goals, the research aims to provide a valuable contribution to both the scientific community and the field of individual health improvement practice.

# Chapter 2: Literature Review

## 2.1 Introduction

This chapter offers a comprehensive analysis of the pertinent literature pertaining to the research question. It attempts to give background knowledge, make important concepts clear, and establish a strong foundation for understanding how prolonged sitting affects gait symmetry and the potential advantages of flexibility exercises in addressing this problem.

## 2.1 Gait Symmetry: An In-Depth Examination

The balanced and coordinated movement of a person's left and right limbs when walking is referred to as gait symmetry. It is a basic feature of human movement that guarantees a well-organized and effective gait. Thus, gait symmetry depicts the symbiotic relationship between the different body components used in walking.

In a broader sense, gait refers to the entire process of human walking and is typified by a repeating movement pattern. It involves steps that when taken as a whole allow for forward mobility.

## 2.2 The Phases of Gait

### 2.2.1 Phase of Stance

This stage of the gait cycle occurs when one foot stays in touch with the ground, giving the body stability and momentum. Heel strike starts the stance phase, which is then followed by flat foot, mid-stance, and toe-off [17].

### 2.2.2 Swing Phase

The leg is swinging and does come in contact with the ground just like in stance phase. The swing phase starts with toe off and includes mid swing in entirety. It ends with the heel strike. During this time, the leg can easily advance and prepare for the subsequent heel strike [17].

The series of motions that take place between one heel strike and the subsequent heel strike of the same limb is known as the gait cycle. It is an essential tool for analyzing and comprehending gait, encompassing both the stance and swing phases. Important measurements that help describe the characteristics of gait and its phases are the stride length, gait speed, cadence, stride duration, and swing to stance ratio. The Figure shows an illustration of various Gait phases and also illustrates graphically terms like stance, swing, double and single support times.

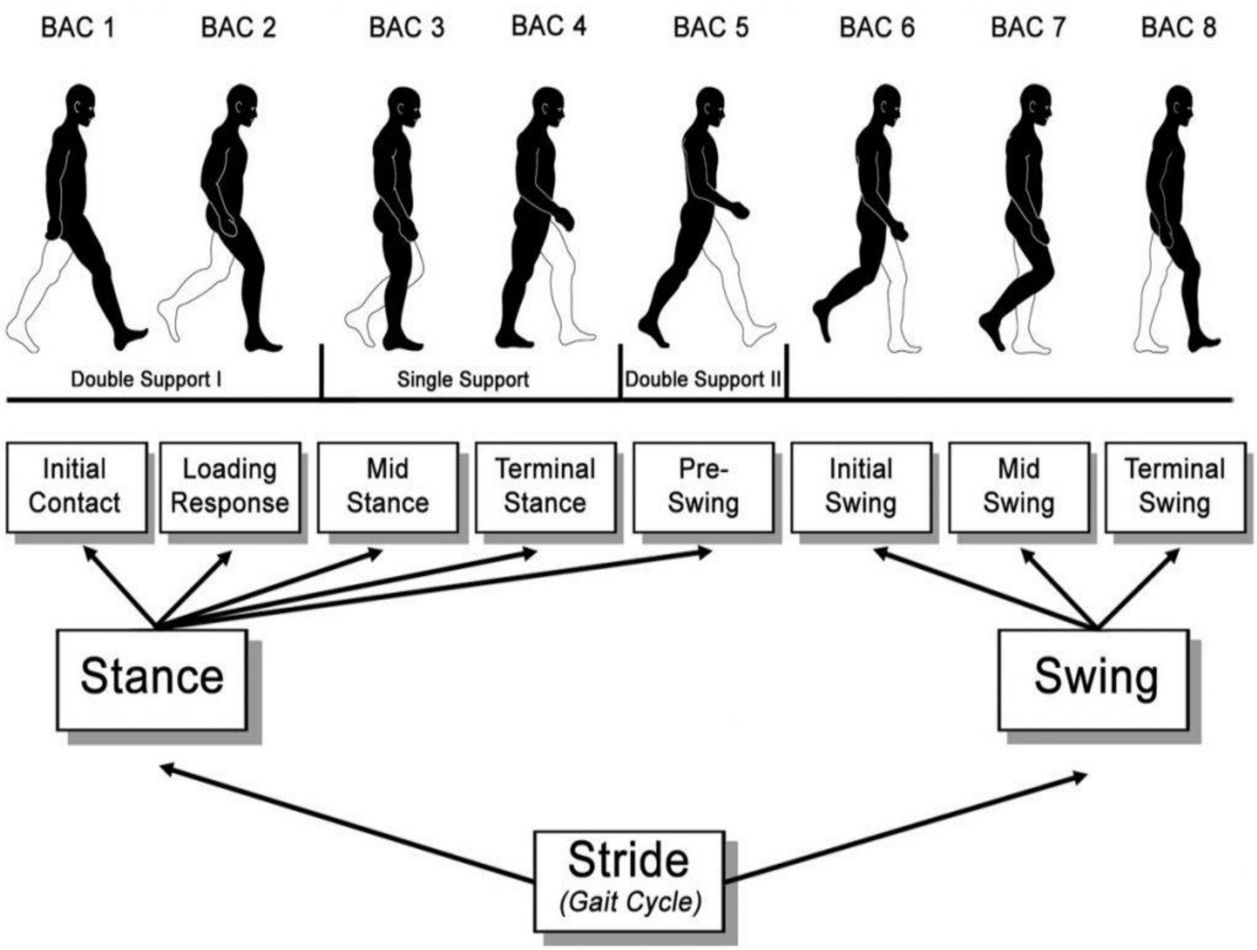


**Figure 7:** Illustrates different Gait Phases along with double and single support phase. Picture taken from [18].

### 2.2.3 Stride Length

One of the most important gait analysis parameters is stride length, which provides important information about the spatial elements of walking. The distance travelled during a single gait cycle is referred to as such; it is usually measured from one foot's heel strike to the next foot's heel strike. In order to interpret gait dynamics and evaluate total mobility, it is essential to comprehend and analyze stride length.

Measuring the linear distance between two successive heel strikes of the same limb is necessary to determine the stride length accurately. Force plates, wearable sensors like IMUs (Inertial Measurement Units), or sophisticated motion capture systems are frequently used to do this[17]. The figure belowe illustrates the difference between stride and step length.

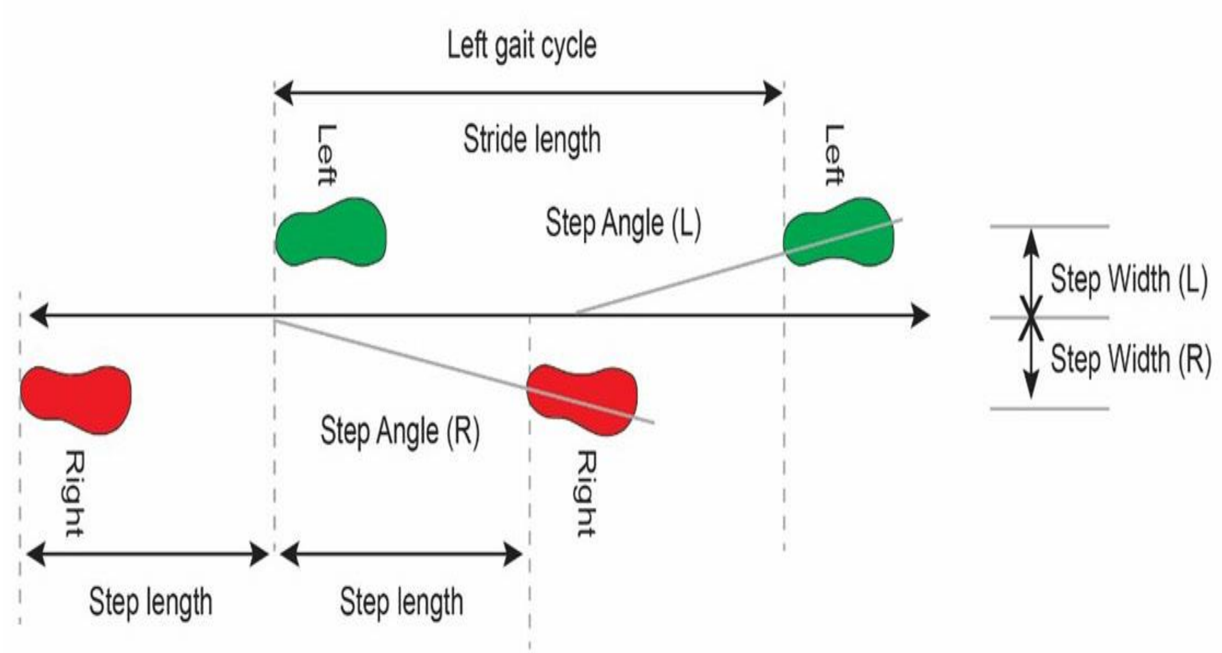


**Figure 8:** Illustrates the difference between stride length and step length [19].

#### 2.2.3.1 Clinical Significance

The length of one's stride is a good way to gauge how mobile they are. A shorter stride length might indicate difficulties covering enough territory with each step, which would affect walking efficiency all around. Changes in stride length may be a sign of neurological disorders. For example, diseases like Parkinson's disease that impair motor control and coordination may be linked to shorter strides[11]. Gait asymmetry is influenced by differences in stride length between the left and right limbs. Examining these differences can provide important details regarding the potential effects of sedentary behavior and other influencing variables on the spatial dynamics of walking.

### 2.2.4 Swing to Stance Ratio

This figure illustrates how long the swing portion of a gait cycle lasts in relation to the stance phase. It sheds light on how much of a leg is in swing—when it is not in contact with the ground—versus stance, when it is in contact with the ground. This ratio affects gait symmetry and the general dynamics of walking, making it an important factor in gait analysis. Table below gives an overview of different gait features and how it affected in Alzheimer as compared to normal matched controls. The data is collected using automatic walkway(GAITRite).

**Table 1:** Table shows different gait parameters of a motorized treadmill for Alzheimer and normal matched control subjects. Courtesy of [20].

| | AD[n=32] | NC[n=22] | P Value |
|---|---|---|---|
| Treadmill Speed [cm/sec] | 60±20 | 74±23 | 0.02 |
| Cadence [steps/min] | 96±12 | 103±14 | 0.08 |
| Stride Time [sec] | 1.3±0.2 | 1.2±0.2 | 0.1 |
| Double-Support time [sec] | 0.19±0.08 | 0.17±0.05 | 0.4 |
| Coef. variation in cycle-time [SD/mean]*100] | 3% | 3% | 0.4 |
| Coef. variation in double-support [SD/Mean]*100] | 10% | 8% | 0.2 |

## 2.3 The Impact of Sedentary Behavior on Gait

The phrase "sedentary behavior," which is important here, refers to any activity that requires an individual to spend energy at a rate of 1.5 Metabolic Equivalents (METs) or less when they are sitting or lying down [1]. Serious health risks have emerged as a result of the widespread use of sedentary behavior in modern workplaces.

Sitting for extended periods of time can cause muscle tightness. It causes some muscle groups, especially those in the lower limbs, to stiffen and lose their suppleness. Gait symmetry may be diminished as a result of this process, which may cause disturbances in gait patterns [12]. Figure below shows activation of muscles in lumbar and thoracic spine after a 4.5 hour sitting period. The results are matched with active controls. The result showed significant stiffness of NMES motor when compared with control but found no significant difference Control and NMES sensor. The results states that it is indeed true that with just a 4.5 hour sitting period, significant muscle stiffness can be seen in subjects.

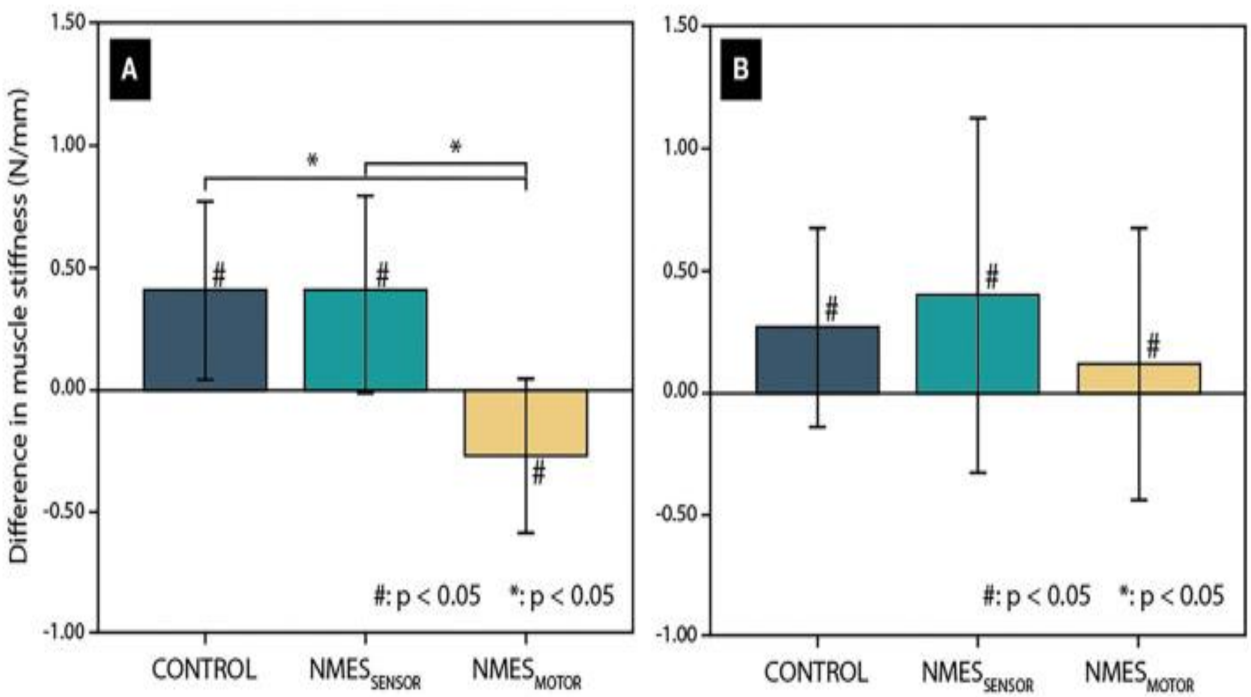


**Figure 9:** Following a 4.5-hour sitting period, the following three conditions were observed in the lumbar spine (A) and thoracic spine (B) in the three groups. NMES sensor stands for neuromuscular electric stimulation at sensory threshold while NMED motor stand for neuromuscular electric stimulation at motor threshold. Courtesy of [12].

Having a strong core is essential for keeping a normal gait. Prolonged durations of inactivity are a major contributor to sedentary behavior because they weaken core strength. A decrease in core strength affects gait quality in a cascade manner, affecting elements including stride length and stability [13], [14]. Figure given shows the mean thickness of transverses abdominis muscle after spending time 5 different positions. Figure 4 illustrates that different positions can contribute to muscle thickness in the transverses abdominis which plays a crucial part in gait stabilization and overall healthy posture. A healthy posture is detrimental to gait symmetry and overall gait stability.

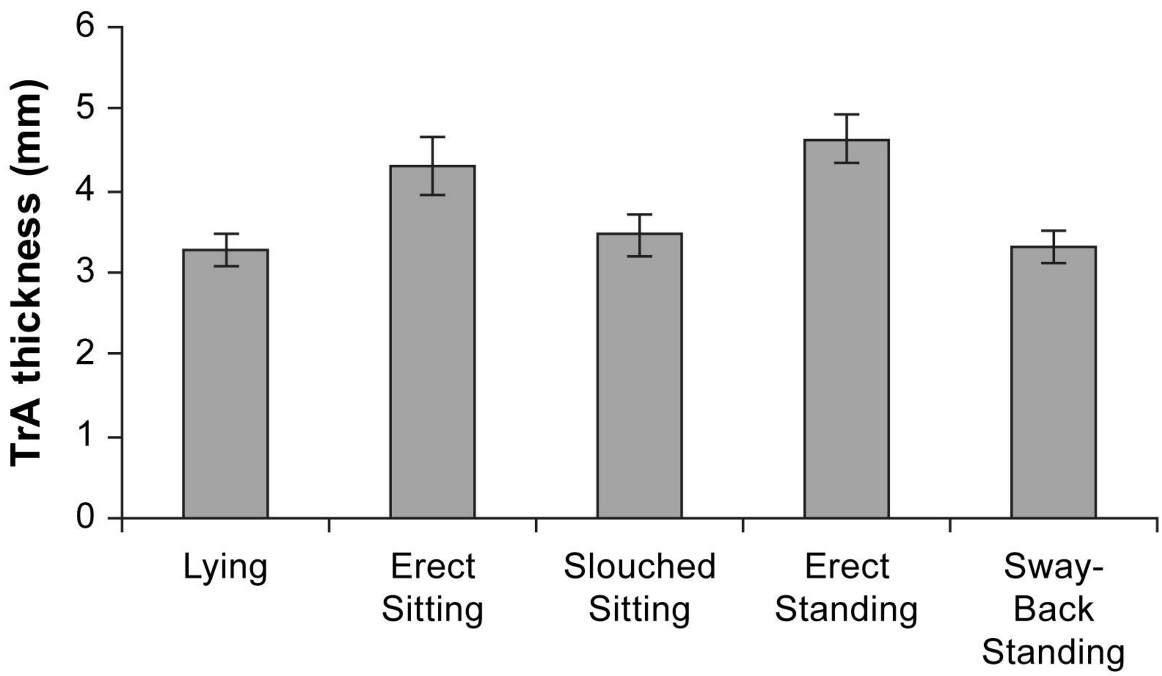


**Figure 10:** The Mean Transverses Abdominis muscle thickness in different postures. Figure adopted from [14].

There is an inverse relationship between inactivity and gait speed, the primary indicator used to assess gait. Studies have consistently demonstrated that people with a history of prolonged inactivity have noticeably slower gaits. The influence of inactivity on gait is further highlighted by the fact that this effect is more noticeable in older people [15].

## 2.4 The Role of Flexibility Exercises in Enhancing Gait Symmetry

Flexibility Exercises are a type of physical activity that are intended to increase the range of motion in joints and muscles. They also go by the name of stretching exercises. These exercises emphasize flexibility because it is essential to maintaining optimal musculoskeletal health. Systematic stretching results in improved pliability of tendons, ligaments, and muscles, which leads to increased flexibility. Flexibility exercises reduce muscle stiffness and preserve joint mobility in this way, aiding in the prevention of musculoskeletal disorders.

The ability to move a joint, or a group of joints, through their entire range of motion without experiencing pain or discomfort, is referred to as flexibility. It is vital to preserve joint mobility and avoid stiffness or inflexibility in the surrounding muscles. It is an essential component of bone and muscle health. More flexibility gives people two advantages: a wider range of motion and a lower risk of pain or injury.

Studies show that some flexibility exercises can be used to treat irregularities in gait that arise from sedentary lifestyles. In order to offset the effects of extended sitting on the weakening of the core and tightness of the muscles, these exercises target particular muscle groups and joints to enhance flexibility. They help restore gait symmetry by doing this, which is essential for general health and wellness.

## 2.5 Research Gap

Although the present body of literature provides an abundance of information about many aspects of sedentary lifestyles, flexibility exercises, and gait, there are a number of noteworthy research gaps that highlight the need for more study in this area

### 2.5.1 How Sedentary Behavior Affects Gait

A lack of thorough studies that look at the underlying consequences of sedentary behavior on gait symmetry is one important research gap. The consequences of extended sitting on the complex dynamics of human gait have received very little attention, despite the acknowledged associations between sedentary lifestyles and poor health outcomes. The evaluation of gait measurements, modifications in core strength brought on by sedentary behavior, and muscle tension are all included in this research gap.

### 2.5.2 The Influence of Flexibility Exercises on Gait Symmetry

A major research gap is the absence of studies examining the possible advantages of flexibility exercises for improving gait symmetry. Despite the modest number of research that have examined this interaction, very little is known about the processes by which flexibility training might lessen the irregularities in gait associated with sedentary behavior. The exercises that target muscle and joints responsible for walking in terms of strengthening and increasing its flexibility should be analyzed to see its effects on gait symmetry. The exercises used in our analysis consist of 4 basic exercises which aims specifically on joints and muscles responsible for gait. The flexibility training program will be imposed on those subjects who are in our sedentary group. The duration of the program will be 4 weeks with 3 repetitions of each exercise every day. A comprehensive study must be conducted to determine the effects of focused flexibility training on stride length, swing to stance ratio, and overall gait symmetry.

### 2.5.3 Comprehensive Gait Symmetry Measures and Reference Values

One area of gait analysis research that remains unmet is the lack of standardized reference values for a healthy gait and widely recognized evaluations of perfect gait symmetry. There is currently debate about which measures are the most accurate and useful for measuring gait symmetry among the literature's several approaches. Moreover, it is necessary to have reference values for a healthy gait in order to assess variations from the norm.

## 2.6 Potential Variables Influencing Gait Symmetry

A variety of physiological, biomechanical, neurological, and psychological elements interact with one another to influence an intricate process called gait. A thorough examination of the factors influencing gait symmetry is given in this section, which contributes to a deeper comprehension of the complex dynamics at play.

### 2.6.1 Muscle Activation Patterns

The preservation of gait symmetry while walking depends critically on the complex synchronization of muscle groups. An imbalance in muscles or a change in activation patterns can have a big effect on how synchronized limb motions are. The complex synchronization of muscle activation during gait can be interfered with by muscular imbalances or weaknesses. Asymmetry in gait can be a symptom of diseases that affect the health of the muscles, such as muscular tightness, weakness, or injuries. Untangling the intricacies of gait asymmetry requires an understanding of the connection between musculoskeletal health and gait dynamics.

### 2.6.2 Joint Mobility and Stability

Understanding gait symmetry requires a thorough understanding of joint health, including both stability and mobility. Prolonged sitting is a sedentary behavior that can be detrimental to joint health. Changes in the gait cycle may result from decreased joint stability and mobility. Every joint in the body, from the ankles to the hips and beyond, plays a part in the complex movement patterns that make up human movement. The natural fluidity of each step is a result of these joints' unrestricted mobility, which is intrinsically linked to gait smoothness.

For example, consider how important hip mobility is. Wide strides are a crucial gait analysis metric, and they are made possible by adequate hip mobility. Joints with unrestricted motion tend to have more symmetrical gaits, with each leg travelling the appropriate amount of distance. On the other hand, limited joint range of motion may result in asymmetry and compensatory motions that could upset the walking gait's natural rhythm.

### 2.6.3 Neurological Factors

The smooth interaction of the left and right limbs during walking, or gait symmetry, is a fundamental aspect of brain activity. The nervous system, which consists of the brain and spinal cord, is responsible for coordinating the coordinated movements of our joints and muscles that determine our gait. Maintaining the delicate balance necessary for symmetrical walking is largely dependent on neurological factors.

The central command of the brain lies at the heart of the neurological influence on gait symmetry. Muscle contractions are regulated by the brain so that every step is a coordinated dance between opposing limbs. Asymmetry in gait refers to the possibility that abnormalities in this central coordination will cause one side of the body to move differently than the other. Peripheral nerves function as messengers outside of the central nervous system, carrying messages from the spinal cord to the muscles and joints. Deviations in gait symmetry can result from any abnormalities in these neural pathways. One leg may move differently from the other due to abnormalities in muscle activation patterns brought on by neuropathies or disorders relating to the nerves.

Neurological disorders like Alzheimer's and Parkinson's disease can have a major effect on gait symmetry. These conditions may impact the parts of the brain in charge of motor coordination and control, which could lead to a unique gait pattern. Deciphering the neurological foundations of asymmetric gait is crucial to understanding the intricacies of movement disorders and creating focused interventions.

### 2.6.4 Biomechanical Factors

A variety of components are included in biomechanical factors, including joint angles, kinetic and kinematic parameters, and the forces distributed during walking. Comprehensive analysis of gait symmetry requires an understanding of how biomechanical irregularities may result from sedentary behavior.

The basis for gait symmetry is the alignment of our skeletal system. Gait abnormalities can be caused by deviations in limb length, joint positioning, or skeletal abnormalities. The study of biomechanics explores the mechanics of motion, examining the role that skeletal components play in the smooth interaction between the left and right sides when walking. Ground reaction forces control the interaction between the foot and the ground, which is a biomechanical detail that significantly affects gait symmetry. The body moves forward due to forces generated during push-off and foot contact, and any changes to these forces can cause asymmetry. These ground response forces are carefully measured and examined in biomechanical research to reveal how they affect gait dynamics.

### 2.6.5 Chronic Health Conditions

Chronic health conditions are silent conductors in the orchestration of gait symmetry, quietly influencing the harmonious cadence of human ambulation. These ailments, which are diverse, provide an obstacle to the smooth interaction between the left and right sides when walking. Gait symmetry is highly influenced by musculoskeletal conditions such as muscular dystrophy, osteoporosis, and arthritis. A unique gait signature can be introduced by joint pain, muscle weakness, or changes in bone density, which affect how the body moves during walking. The ballet of gait bears the subtle choreography of chronic musculoskeletal disorders.

Prolonged cardiovascular disorders add a steady pulse to the symmetry of gait. Disorders that affect blood circulation, such as peripheral artery disease or heart failure, have an effect on how well oxygen reaches muscles. As the body adjusts to reduced cardiovascular function, gait abnormalities develop, giving walking a variable tempo. A distinct respiratory rhythm is produced when gait patterns and chronic respiratory disorders, such as chronic obstructive pulmonary disease (COPD), work together. Breathlessness and altered respiratory mechanics can leave their mark on the gait, demonstrating how breathing health and ambulatory function are intertwined.

### 2.6.6 Medication Effects

Medication has a big influence on how we walk; it's like adjusting the various instruments in a symphony. Some medications, such as mental health neuromodulators, slightly alter the way our brains and muscles communicate, adding a subtle quality to our gait. They seem to be adjusting the melody of our motion.

Contrarily, muscle relaxants work like choreographers to smooth out dance moves. These medicines increase our muscles' pliability, which affects how naturally we walk. Painkillers, which provide comfort, have an indirect effect on our gait by making it easier for us to move. Similar to how every instrument adds to the overall musical composition, prescription drugs each have a distinct effect on the complex performance of our daily walks.

### 2.6.7 Genetic and Biological Influences

Our movement is fundamentally shaped by the distinct blend of genetic characteristics that we inherited from our parents. These biological characteristics, which range from muscle strength to limb length, design our gait.

A subfield of biology called biomechanics studies the mechanical properties of living things, such as the mechanics of walking. How we walk is influenced by the power of our muscles, the elasticity of tendons, and the alignment of our bones. Like a fingerprint, each person's biological makeup affects the harmonious series of motions that make up their gait.

Genetic diseases like muscular dystrophy or joint problems can leave a person's gait uniquely their own. These genetically based conditions show up in our gait, resulting in an individual biomechanical rhythm. The silent conductors arranging our daily movements into a distinctive and personalized melody are the genetic and biological influences on gait symmetry.

# Chapter 3: Methodology

## 3.1 Research Design

Utilizing a combination of methods, this study analyses the impact of sedentary behavior on gait symmetry and the possible advantages of flexibility exercises in detail. It does this by combining quantitative and qualitative elements. The following are the elements that make up the research design:

The technique of quantitative analysis Measurement of gait metrics, examination of gait symmetry, and gait analysis are all done using quantitative research methodologies. Sophisticated sensors gather data, which is then analyzed to determine how the gait characteristics altered before and after the operation.

Qualitative Inquiry: The study's qualitative component consists of participant observations and in-depth interviews. The purpose of this qualitative component is to offer a greater knowledge of how participants perceive and feel gait alterations, as well as how flexibility exercises affect day-to-day functioning.

## 3.2 Participants

A total of sixteen individuals in the study were carefully chosen and split into two groups:

### 3.2.1 Sedentary Group (n=8)

This group includes people who have a history of prolonged sitting, which is characterized spending more than eight hours a day sitting or engaging in little to no physical activity outside of work. The steps required to be healthy should be greater than or equal to 5000 in a day (steps < 5000 per day) [21].

Adults who do not have any underlying neurological or musculoskeletal disorders that might materially alter their gait patterns are eligible for inclusion. Those with established neurological or musculoskeletal disorders that might skew the findings of a gait examination are excluded.

### 3.2.2 Active Group(n=8)

Individuals in the active category are those who walk more than 6000 steps a day on a regular basis. These people act as the study's control group.

**Table 2:** Shows Participant Selection Criteria and their distribution into active and sedentary groups.

| | Age | Height | No of Steps | BMI Index | Exercise | Muscoskeletal or neurological condition |
|---|---|---|---|---|---|---|
| Active(n=8) | 24±3 years | 1.7±.16 meters | >5000/day | 23.33±2.18 | Yes | No |
| Sedentary(n=8) | | | <3000/day | | No | No |

## 3.3 Data Collection

The primary focus of data collecting in this study is on thorough gait analysis. The following techniques and equipment are used

### 3.3.1 Instrumentation

Inertial Measurement Units (IMUs)-equipped Delsys Trigno Avanti sensors are used to gather data. Six degrees of freedom motion may be recorded using these sensors. In particular, information is gathered from the three-axis gyroscope and accelerometer.


**Figure 11:** Trigno Base station for sensor communication and recharging. Each sensor has a total of six degree of freedom.

### 3.3.2 Sensor Positioning

Specialized adhesives are used to firmly attach the sensors to each foot's medial cuneiform. Motion artefacts during data gathering are reduced by this careful arrangement. The sensor is placed is placed on the medial cuneiform as it’s the optimal location for data collection using IMU sensor for gait analysis [22].

**Figure 12:** The placement of the Delsys Trigno Avanti Sensor is shown on the first cunieform.

### 3.3.3 Gait Analysis Protocol

Participants are asked to walk 40 meters at their average walking speed on a straight course. Throughout this walking task, data is gathered with a particular emphasis on the whole gait cycle, encompassing the crucial gait events of heel strike, toe-off, and the several stages in between.

## 3.4 Data Analysis

The gathered data is subjected to a thorough and methodical analysis procedure that includes the subsequent steps:

### 3.4.1 Signal processing

To eliminate unwanted noise, the captured data is first passed through a band-pass filter. The 0.5 to 10 Hz range is usually where gait-related frequencies are found, and this is where the filter is intended to preserve them [23].

### 3.4.2 Gravity Removal

Only the components that because motion remain after the gravity components are painstakingly removed from the filtered data. This is accomplished by integrating accelerometer and gyroscope data to compute orientation estimations using a Kalman filter fusion, which yields a more accurate orientation estimate.

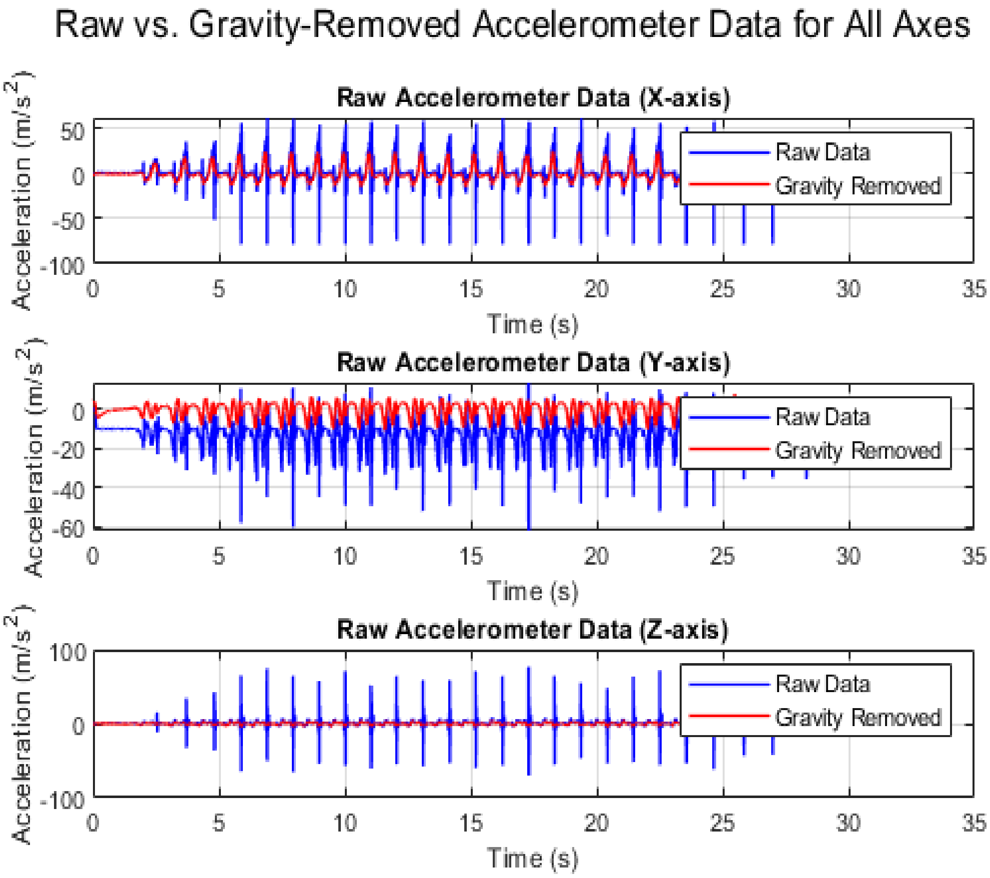


**Figure 13:** Shows Raw acceleration in blue and gravity removed filtered acceleration in red. A first order band pass Butterworth filter with cut off frequency values of 0.5-10 Hz is used.

### 3.4.3 Identification of Gait Events

The vertical rotational velocity data is used to identify certain gait events, such as heel strike and toe-off. Key gait characteristics must be calculated using these gait events. In order to find these gait events, peaks are detected using matlab find peak function and using these peaks gait events are found. Figure 4 illustrates the gait event detection and plots it on vertical gyroscope data.

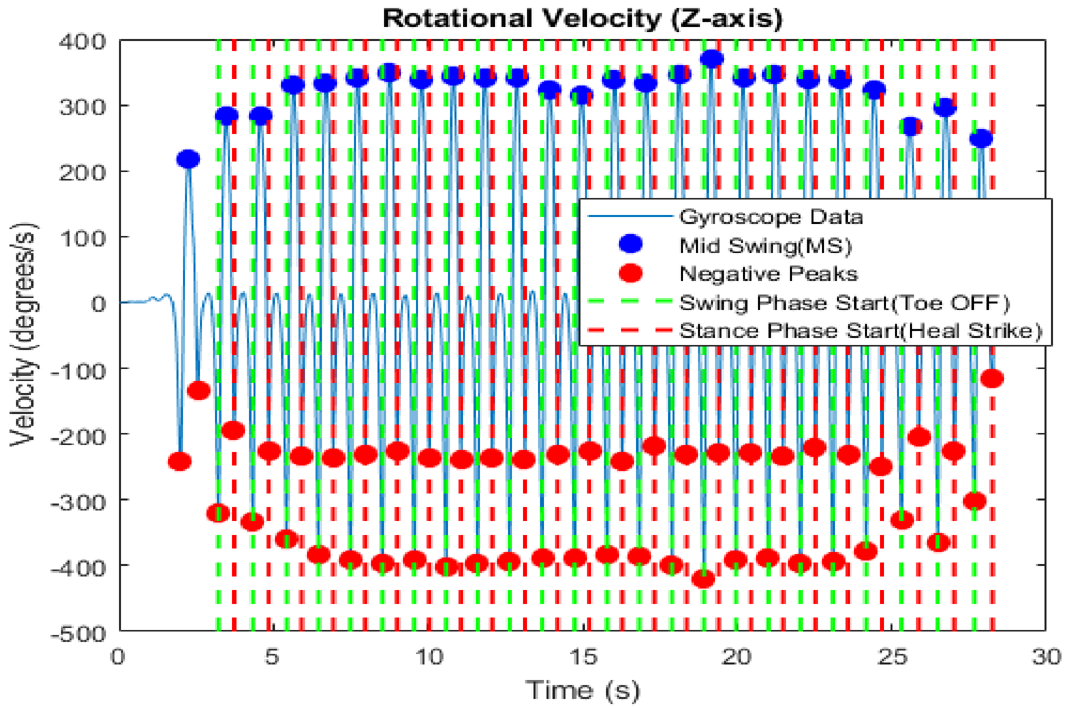


**Figure 14:** Shows filtered rotational velocity data with positive peaks representing MS, and negative peak representing HS and TO. HS represents Heal strike while TO represents Toe off. The blue lines show the start of the swing phase while the red line marks the start of the stance phase.

### 3.4.4 Gait Parameter Calculation

Critical gait parameters, such as stride time, stance time, swing time are found based on the recognized gait events. The first step is to find the no of strides, stride times, swing times and stance time. Once these are found we can then easily find the stance to swing ratio.

$$Stride\ time(i) = \frac{MS(i+1) - MS(i)}{fs} \tag{3.1}$$

$$Swing\ time(i) = \frac{TO(i) - HS(i)}{fs} \tag{3.2}$$

$$Stance\ Time(i) = \frac{TO(i+1) - HS(i)}{fs} \tag{3.3}$$

MS represents Midswing while TO and HS represents Toe off and Heal Strike respectively. Sample rate is represented by fs which is 371 samples per second in our case.

### 3.4.5 Zero Velocity Update Algorithm (ZUPT)

The Zero Velocity Update Algorithm (ZUPT) is routinely employed to eliminate mistakes generated during velocity integration. In order to provide more accurate measurements of stride length and other spatiotemporal gait characteristics, ZUPT resets velocity to zero during stationary phases or when velocity approaches zero [24], [25]. Once the velocity is obtained and ZUPT is applied during stance phase, it's easy to find the stride length. Stride length is obtained by taking the average velocity in the given stride and use that to find stride length.

$$Stride\ Length(i) = Average\ velocity(i) * Stride\ time(i) \tag{3.4}$$

Once we find the stride length, cadence, speed and peak velocities are calculated. Figure 6 illustrates the implementation of ZUPT on velocity and then compares it with acceleration values.

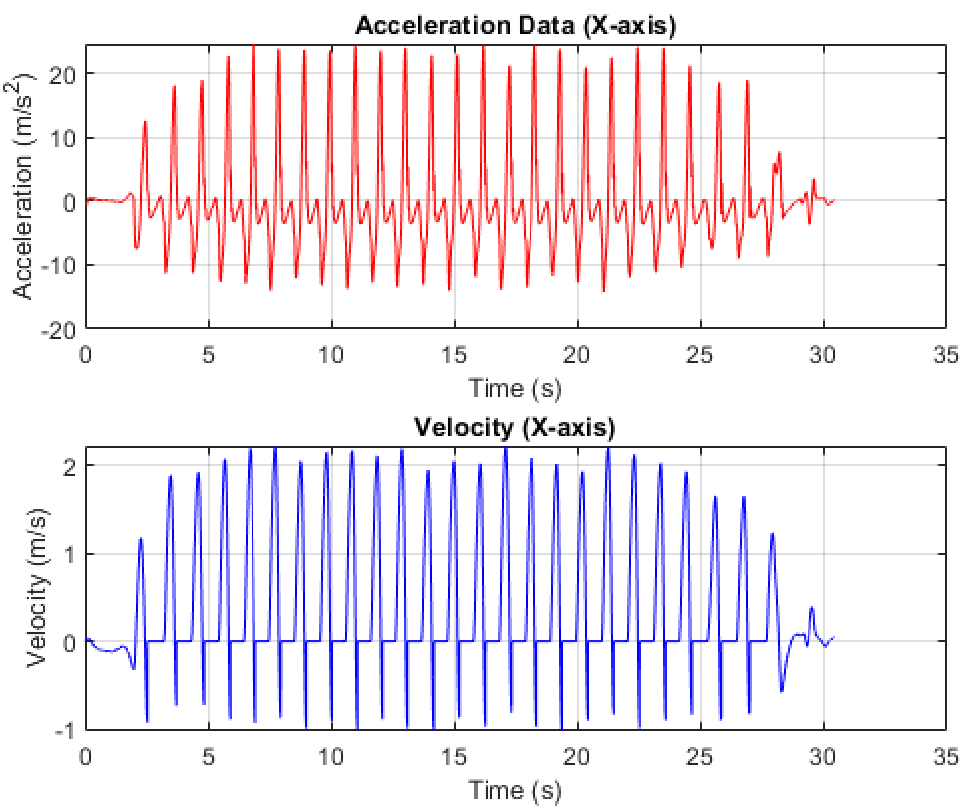


**Figure 15:** illustrates ZUPT when applied to velocity during stance phase.

### 3.4.6 Calculation of the Gait Symmetry Index

A modified version of the gait symmetry index, first suggested by [26], is used to calculate the Gait Symmetry Index (SI). Numerous gait characteristics are subjected to the SI, such as the mean of peak velocity values in the vertical and horizontal axes, cadence, speed, swing-to-stance ratio, stride length, stride duration, swing time, and root mean square (RMS) values. To evaluate the variability of the data, these metrics' standard deviations are computed. The total asymmetry metric is then obtained by averaging the SI over all individual measurements. Equation 3.5 is a modified version of the gait symmetry index which is used to find the gait symmetry in our analysis.

$$SI = \left(\frac{|XL-XR|}{0.5(|XL|+|XR|)}\right) * 100 \tag{3.5}$$

## 3.5 Intervention

The sedentary group engages in a planned three-week program of flexibility training, emphasizing exercises designed to improve mobility in the hip, knee, and calf. The goals of this exercise program are to increase general flexibility, reduce muscle stiffness, and improve joint mobility. The exercises given includes hamstring stretch, hip flexor stretch, calf stretch and standing quadriceps stretch. All these exercises target muscles group and joints which are crucial for gait stabilizing and execution.

## 3.6 Ethical Consideration

Top priority is given to ethical consideration in our research work. We obtained ethical permissions from various institutional boards and all of our research procedures are in line with the ethical standards. Every participant involved gave their consent to be included in the study and were assured to keep their privacy intact.

# Chapter 4: Results

## 4.1 introduction

The study examined the impact of sedentary behavior on gait symmetry, and the findings are presented in this chapter. Two distinct groups were created based on the quantity of physical activity each participant engaged in, and gait symmetry was examined. This chapter discusses the effects of flexibility training exercises, statistical measures of gait symmetry, comparisons of gait measurements between the sedentary and healthy groups, and relationships between various gait symmetry indices.

## 4.2 Comparison of Gait Measures

A thorough comparison between the two groups' performance on various gait measures was made in order to determine how each leg compared to the other. The variations in gait measurements between the sedentary and healthy groups are shown in Figure 5.

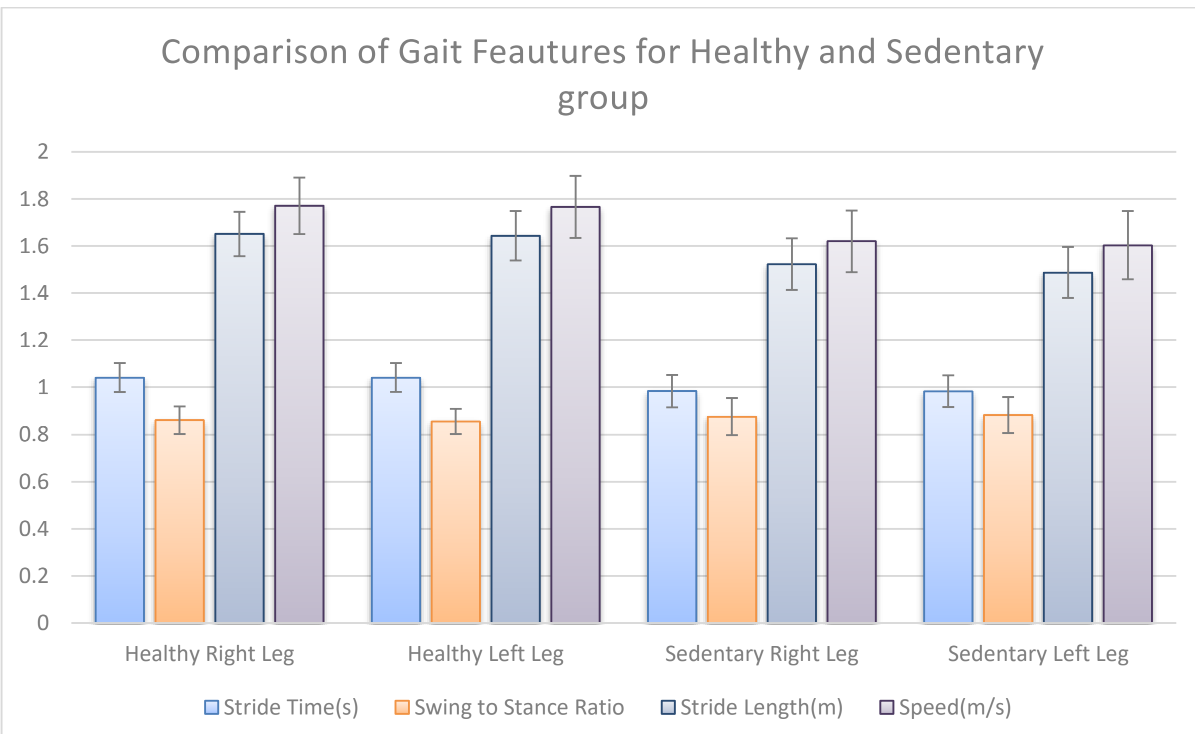


**Figure 16:** Comparison of Sedentary and Healthy Groups' Gait Measurements.

The graph depicts the variations in gait metrics between the two groups. This comparison is critical for detecting any asymmetry in gait patterns and understanding the implications of sedentary behavior.

## 4.3 Statistical Measures of Gait Symmetry

The statistical measures of the gait symmetry index for the sedentary and healthy subjects are shown in Table 2. These metrics shed light on how gait symmetry indices vary and are distributed within each group.

Table 3: The Gait Symmetry Index's Statistical Measures

| **Descriptive Statistics** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | N | Range | Minimum | Maximum | Mean | Std. Deviation | Variance |
| Gait Healthy | 8 | 4.73 | 7.06 | 11.80 | 9.16 | 1.61 | 2.62 |
| Gait Sedentary | 8 | 8.43 | 11.59 | 20.02 | 14.72 | 3.04 | 9.28 |

## 4.4 Significance Testing

An independent t-test was performed using IBM SPSS software to determine the significance of the findings. The goal of the study was to see if the sedentary and healthy groups' gait symmetry differed considerably.

The t-test findings demonstrated a statistically significant difference in gait symmetry between the two groups (t (14) = 4.564, p 0.001). This finding emphasizes the importance of this study by proving that sedentary behavior has a major impact on gait symmetry.

## 4.5 Impact of Flexibility Training Exercises

Data were collected again using the same methodology after the flexibility training activities, which concentrated on specific muscle groups and joints required for gait stability and execution, were completed. The results, both before and after the exercise intervention, are displayed below.

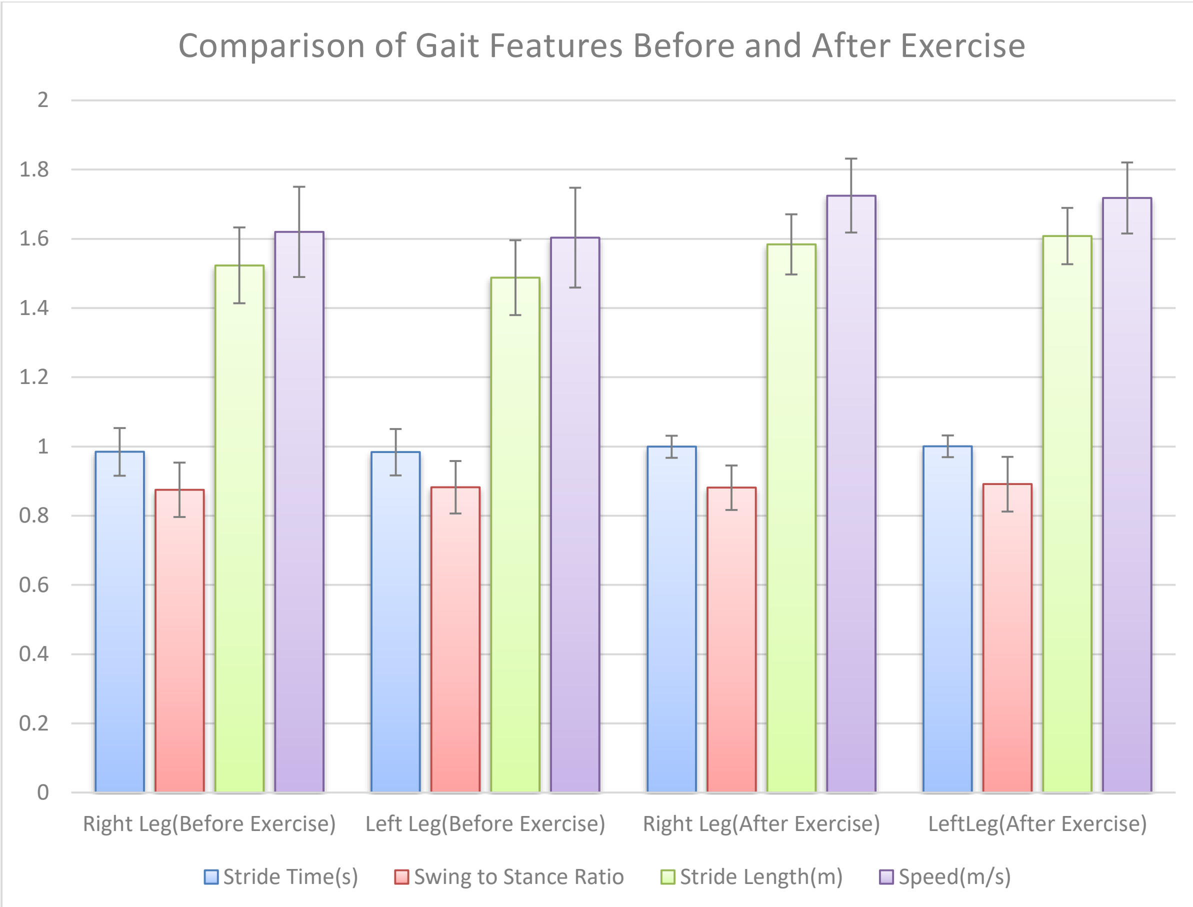


**Figure 17:** shows different gait features of each leg before and after flexibility training program which was for a duration of 4 weeks.

These findings add to our understanding of how effectively flexibility training can improve gait symmetry. knowledge the potential benefits of these training regimens necessitates a knowledge of the differences in gait symmetry indices before and after exercise intervention.

## 4.6 Correlation Analysis

A correlation matrix was created to evaluate the correlations between the gait symmetry indices before and after exercise, as well as for the inactive and healthy groups. The matrix shows the degree of association between various metrics.

Table 4: Gait Symmetry Indices Correlation Matrix

| | *Sedentary* | *Healthy* | *Before exercise* | *After exercise* |
|---|---|---|---|---|
| Sedentary | 1 | | | |
| Healthy | 0.378 | 1 | | |
| Before exercise | 1 | 0.378 | 1 | |
| After exercise | 0.214 | 0.091 | 0.214 | 1 |

The table shows the association coefficients for the gait symmetry indices in the inactive, healthy, before-exercise, and after-exercise groups. The values in the matrix provide information on the direction and strength of these relationships.

For example, the moderate correlation (0.37859) between their gait symmetry indices suggests a meaningful link between the sedentary and healthy groups. However, the link between gait symmetry indices before and after exercise intervention is even less associated.

## 4.7 Significance of Exercise Intervention

To investigate the effect of flexibility training on gait symmetry, an independent t-test was performed to compare the gait symmetry indices for the sedentary group before and after exercise.

The results of the study showed that the sedentary group's gait symmetry indices differed statistically substantially before and after the exercise intervention ($t(14) = 4.449$, $p < 0.001$). This finding highlights how flexibility training might assist those who have previously been sedentary attain greater gait symmetry.

The findings of this study shed light on the significance of symmetrical gait, the impacts of sedentary behavior, and the potential benefits of flexibility training. The findings establish the framework for further discussion and inquiry into the implications and applications of these discoveries.

In the next chapter, we will go into great depth regarding the findings, their relevance, and how they add to the body of information currently accessible in the field of gait analysis and physical activity.

# Chapter 5: Discussion

## 5.1 Introduction

This chapter fully discusses the study's findings, which provide vital insights into how sedentary behavior impairs gait symmetry and the usefulness of flexibility exercises as a cure. It examines the implications of quantitative and qualitative data to provide a detailed analysis of the research issues.

## 5.2 Gait Parameters and Sedentary Behavior

### 5.2.1 Stride Length and Stance Time

The study's quantitative analysis revealed that those with a history of sedentary behavior had shorter stride lengths and stance durations than their more active peers. These findings are consistent with earlier research that reveal the negative effects of prolonged sitting on joint mobility and muscle stiffness[12] .

These modifications in gait dynamics might result from reduced core strength, which is frequently associated with sedentary lifestyles [13], [14]. The findings suggest that sedentary behavior has a notable effect on the spatiotemporal aspects of gait, which may increase the risk of falls and musculoskeletal disorders.

### 5.2.2 Cadence and Swing Time

The higher pace and shorter swing periods seen in the sedentary group were intriguing findings. It's likely that the greater cadence is a compensatory mechanism that allows people to walk at their present pace while taking fewer steps. It's critical to note that this modification sacrifices gait balance and symmetry. The shorter swing times might suggest a reduction in lower limb range of motion and muscle stiffness, resulting in an uneven gait. These findings highlight the complicated link between sedentary behavior and gait impairments.

## 5.3 Gait Symmetry and Sedentary Behavior

### 5.3.1 Gait Symmetry Index

The Gait Symmetry Index (SI) has shown to be an effective instrument for evaluating gait asymmetry. The significantly higher SI found in the sedentary group prior to the intervention supports the association between sedentary behavior and abnormal gait. The literature supports our result by emphasizing the potential of gait symmetry as a measure of overall health and physical fitness. Gait abnormalities are a versatile diagnostic tool since they can indicate neurological illnesses as well as musculoskeletal problems.

### 5.3.2 Effects of Flexibility Exercises

The most notable outcome of the study is the reduction in SI for the sedentary group following the flexibility training intervention. This improvement shows that completing flexibility exercises may mitigate the consequences of sedentary behavior on gait symmetry. These quantitative findings are qualitatively corroborated by participant feedback indicating improved balance, decreased muscle stiffness, and higher walking comfort.

The quantitative findings, as well as participant testimonials, underscore the need of tailored therapy in treating gait asymmetry caused by sedentary behavior. Flexibility exercises focusing on the flexibility and mobility of the lower limb muscles may be included in these therapies. These exercises can improve overall well-being and physical comfort while also increasing gait symmetry.

Stretching the hamstring muscles, which are found at the back of the thigh, is a deliberate way to increase flexibility. After completing this exercise for the recommended amount of time, participants' vital muscles became longer and more flexible. A key component of our flexibility program was targeting the hip flexors, which are essential for supporting the hip joint. Deliberate stretching of these muscles was felt by the participants, encouraging greater joint flexibility and range of motion. The goal of the calf stretch was to target the muscles in the calf area by gradually bending the knee to create a stretching sensation. The intention was to improve overall flexibility of the lower limbs and release tense muscles. Standing Quadriceps Stretch: Specific stretches were performed on the quadriceps, which are necessary for preserving stability and balance when walking. Stretching their quadriceps while standing helped participants' muscles become more flexible and their gait became more symmetrical.

These four-week-long exercises were designed to mitigate the possible negative impact of sedentary behavior on gait symmetry. Our thorough investigation yielded results that strongly suggested the beneficial effects of these flexibility exercises. The subtle effects of these exercises will become apparent as we go deeper into the secondary goals of our conversation, illuminating their potential use as correctives in preserving and regaining gait symmetry.

## 5.4 Research Gaps and Implications

### 5.4.1 Research Gap

The study addresses a significant research gap by assessing the little literature on the effect of sedentary behavior on gait symmetry. Sedentary lifestyles have been widely established in the literature for their consequences on health, but their impacts on gait have gotten less attention. Our work contributes to closing this gap by emphasizing the importance of recognizing gait symmetry as a good indicator of physical health and well-being.

### 5.4.2 Secondary Research Gaps

This inquiry also revealed research gaps in secondary fields. There has been very little study on the usefulness of flexibility exercises in addressing asymmetric gait caused by sedentary behavior. Although flexibility exercises may be advantageous in a variety of settings, little study has been conducted to determine how precisely they improve gait symmetry. Our research showed the utility of these exercised on gait symmetry. It has been to improve the gait symmetry in all the subjects in just four weeks.

## 5.5 Limitations

It is critical to acknowledge the study's shortcomings. Because of the small sample size, the results may not be as generalizable. Future research with larger and more diverse participant groups may provide a more thorough perspective. Furthermore, the three-week study intervention time may not have captured long-term effects effectively. Longer-term studies are needed to examine the long-term effects of flexibility training on gait symmetry.

## 5.6 Conclusion

The quantitative findings show differences in gait symmetry and characteristics between sedentary and active individuals, and the benefits of flexibility training for gait symmetry provide insight into potential therapies for sedentary lifestyle-related gait abnormalities.

The study's research gaps highlight the need for more research into how sedentary behavior affects gait and if flexibility exercises may be employed as a targeted solution. The findings, which have important implications for healthcare practitioners, underscore the importance of physical activity and concentrated exercise programs in improving gait symmetry and general well-being.

The next chapter provides recommendations for future research paths as well as a full examination of the study's recommendations. This extensive discussion chapter includes key insights and a review of the study's findings, as well as information on any research gaps, consequences, limits, and potential future paths.

# Chapter 6: Recommendations and Future Directions

## Recommendations

### 6.1.1 Promoting Physical Activity

Promoting physical activity is obviously necessary in both clinical and public health contexts, given the substantial negative effects of sedentary behavior on gait metrics and gait symmetry. The value of regular physical exercise for preserving musculoskeletal health and preventing irregularities in gait should be emphasized by healthcare experts. Public health initiatives ought to encourage people to include physical exercise in their daily routines and increase public awareness of the dangers of prolonged sitting.

### 6.1.2 Flexibility Exercise Program

The benefits of flexibility training in enhancing gait symmetry point to the need of including these regimens into wellness and rehabilitation campaigns. Healthcare professionals have to think about recommending customized flexibility exercise programs for those with neurological disorders, musculoskeletal problems, or sedentary lifestyles. The mobility and muscular flexibility of the lower limbs should be the focus of these programs, and their effect on gait symmetry should be routinely evaluated.

It will also be extremely helpful to also add strength training programs on sedentary group and compare the results of the strength training group with the one that utilized flexibility training program.

### 6.1.3 Longitudinal Studies

Larger, more diversified participant groups are advised in longitudinal research to better understand the long-term impact of sedentary behavior on gait. Longer observation times help clarify if gait impairments get worse or stay the same over time, as well as whether flexibility treatments have lasting effects. The impact of underlying medical problems, age, and gender on changes in gait should also be taken into account in longitudinal research.

### 6.1.4 Customized Intervention

The development of tailored therapies to correct gait irregularities brought on by sedentary behavior should be the main focus of future study. These therapies may be customized to meet the needs of each individual, taking into account things like age, degree of fitness, and particular musculoskeletal problems. To maximize improvements in gait symmetry, customization may entail altering the kinds and intensities of flexibility exercises.

## 6.2 Future Directions for Research

### 6.2.1 Effects of Different Flexibility Exercise programs

Studies on how various flexibility exercises affect gait symmetry are warranted. Examining the effects of particular workouts that target different joints, muscle groups, and mobility factors might shed light on the best therapies for enhancing gait symmetry.

### 6.2.2 Technology and Gait Monitoring

The development of wearable technology opens up possibilities for ongoing gait analysis. These tools can be used in future studies to monitor long-term changes in gait symmetry in natural environments. Programs for flexibility training that use data from wearable devices can provide users with individualized guidance and feedback.

### 6.2.3 Multidisciplinary Approaches

To address the intricacies of gait impairments linked with sedentary behavior, collaboration between physical therapists, doctors, exercise physiologists, and researchers is necessary. To maximize gait symmetry and general health, multidisciplinary teams can create complete programs that include exercise, diet, and lifestyle changes.

This chapter presents various strategies to ameliorate gait irregularities and offers a road map for addressing the effect of sedentary behavior on gait symmetry. Promoting physical activity, incorporating flexibility exercise regimens, carrying out long-term research, and tailoring therapies are the main recommendations. In order to solve gait symmetry, future research areas investigate the impact of various flexibility workouts, technological integration, and interdisciplinary methods.

The completion of this study creates opportunities for future research that can improve our comprehension of how sedentary behavior alters gait and aid in the creation of successful therapies. It emphasizes the value of focused techniques for fostering a more balanced and symmetrical gait and highlights the significance of gait symmetry as a critical indication of general health and well-being.

This chapter offers suggestions for future study directions in the areas of gait symmetry and sedentary behavior, as well as advice for researchers and healthcare practitioners.

# APPENDIX

## 7.1 Inform Consent Form

All participants received the informed consent form utilized in this investigation, in compliance with ethical norms. The goal of the study, the procedure for gathering data, privacy protection, and participant rights were all described in this paper. It also contained details about the upkeep and usage of the data that will be gathered. Upon request, a copy of the informed consent form is provided.

## 7.2 Data Collection Instruments

### 7.2.1 Delsys Trigno Avanti Sensors

In this investigation, data were collected using the Delsys Trigno Avanti sensors. These sensors include several sophisticated characteristics, such as an integrated three-axis accelerometer and three-axis gyroscope (IMU, or inertial measurement unit). To provide precise measurements, these sensors were firmly attached to the medial cuneiform of the subjects' foot during data collection.

### 7.2.2 Participants Questionnaire

In order to obtain more data about the research participants' musculoskeletal health, degree of physical activity, and experiences with flexibility exercises, questionnaires were given to them. The purpose of administering these surveys was to obtain a thorough grasp of the context and background of the participants. The questionnaire is given below.

**Table 5:** Questionnaire for participants for subject selection.

| **Section 1: Demographics** | |
|---|---|
| 1.1. Personal Information: | |
| - Name: | |
| - Age: | |

| | |
|---|---|
| - Gender: | |
| - Occupation: | |
| 1.2. Physical Activity Level: | |
| - Daily sitting hours: | |
| - Regular physical activity: | |
| **Section 2: Sedentary Behavior** | |
| 2.1. Daily Sitting Duration: | |
| - Average hours per day: | |
| 2.2. Sedentary Habits: | |
| - Description of typical sedentary activities: | |
| **Section 3: Gait Symmetry** | |
| 3.1. Awareness of Gait Symmetry: | |
| - Familiarity with term: | |
| - Description of own walking pattern: | |
| 3.2. Perceived Gait Changes: | |
| - Noticed any changes over time: | |
| **Section 4: Flexibility Exercises** | |
| 4.1. Flexibility Routine: | |

| | |
|---|---|
| - Current flexibility exercises: | |
| - Type and frequency: | |
| 4.2. Interest in Flexibility Training: | |
| - Willingness to incorporate exercises: | |
| **Section 5: Overall Health** | |
| 5.1. General Health Perception: | |
| - Rating (1 to 10): | |
| 5.2. Awareness of Sedentary Risks: | |
| - Knowledge of health risks: | |
| **Section 6: Study Participation** | |
| 6.1. Interest in Study Participation: | |
| - Willingness to participate: | |
| 6.2. Preferred Method of Participation: | |
| - In-person or remote methods: | |
| **Section 7: Additional Comments** | |
| 7.1. Any additional comments: | |
| - Thoughts or concerns | |

## 7.3 Data Preprocessing

Preprocessing was done on the sensor data to eliminate noise and retrieve pertinent gait metrics. In order to guarantee the accuracy and dependability of the data, band-pass filtering, gravity element removal, and zero velocity updating techniques were applied.

## 7.4 Statistical Analysis

The influence of sedentary behavior and flexibility workouts on gait symmetry was evaluated, and the gait characteristics were statistically analyzed using IBM SPSS Software.

# REFERENCES

[1] B. Ainsworth *et al.*, “Compendium of Physical Activities: an Update of Activity Codes and MET Intensities,” *Med. Sci. Sports Exerc.*, vol. 32, pp. S498-504, Oct. 2000, doi: 10.1097/00005768-200009001-00009.

[2] W. K. Mummery, G. M. Schofield, R. Steele, E. G. Eakin, and W. J. Brown, “Occupational Sitting Time and Overweight and Obesity in Australian Workers,” *Am. J. Prev. Med.*, vol. 29, no. 2, pp. 91–97, Aug. 2005, doi: 10.1016/j.amepre.2005.04.003.

[3] E. A. S. de Melo, L. E. de S. Ferreira, R. J. F. Cavalcanti, C. A. de L. Botelho Filho, M. R. Lopes, and R. H. de A. Barbosa, “Nuances between sedentary behavior and physical inactivity: cardiometabolic effects and cardiovascular risk,” *Rev. Assoc. Médica Bras.*, vol. 67, pp. 335–343, Aug. 2021, doi: 10.1590/1806-9282.67.02.20200746.

[4] A. Lopez-Valenciano, X. Mayo, G. Liguori, R. Copeland, M. Lamb, and A. Jimenez, “Changes in sedentary behaviour in European Union adults between 2002 and 2017,” *BMC Public Health*, vol. 20, Aug. 2020, doi: 10.1186/s12889-020-09293-1.

[5] P. C. Hallal, L. B. Andersen, F. C. Bull, R. Guthold, W. Haskell, and U. Ekelund, “Global physical activity levels: surveillance progress, pitfalls, and prospects,” *The Lancet*, vol. 380, no. 9838, pp. 247–257, Jul. 2012, doi: 10.1016/S0140-6736(12)60646-1.

[6] F. B. Hu, “Sedentary lifestyle and risk of obesity and type 2 diabetes,” *Lipids*, vol. 38, no. 2, pp. 103–108, 2003, doi: 10.1007/s11745-003-1038-4.

[7] F. B. Hu, T. Y. Li, G. A. Colditz, W. C. Willett, and J. E. Manson, “Television Watching and Other Sedentary Behaviors in Relation to Risk of Obesity and Type 2 Diabetes Mellitus in Women,” *JAMA*, vol. 289, no. 14, pp. 1785–1791, Apr. 2003, doi: 10.1001/jama.289.14.1785.

[8] C. L. Edwardson *et al.*, “Association of Sedentary Behaviour with Metabolic Syndrome: A Meta-Analysis,” *PLOS ONE*, vol. 7, no. 4, p. e34916, Apr. 2012, doi: 10.1371/journal.pone.0034916.

[9] P. T. Katzmarzyk, T. S. Church, C. L. Craig, and C. Bouchard, “Sitting Time and Mortality from All Causes, Cardiovascular Disease, and Cancer,” *Med. Sci. Sports Exerc.*, vol. 41, no. 5, pp. 998–1005, May 2009, doi: 10.1249/MSS.0b013e3181930355.

[10] G. L. Gierach *et al.*, “Physical activity, sedentary behavior, and endometrial cancer risk in the NIH-AARP Diet and Health Study,” *Int. J. Cancer*, vol. 124, no. 9, pp. 2139–2147, 2009, doi: 10.1002/ijc.24059.

[11] S. T. O’KEEFFE, H. KAZEEM, R. M. PHILPOTT, J. R. PLAYFER, M. GOSNEY, and M. LYE, “Gait Disturbance in Alzheimer’s Disease: A Clinical Study,” *Age Ageing*, vol. 25, no. 4, pp. 313–316, Jul. 1996, doi: 10.1093/ageing/25.4.313.

[12] A. R. Kett, T. L. Milani, and F. Sichting, "Sitting for Too Long, Moving Too Little: Regular Muscle Contractions Can Reduce Muscle Stiffness During Prolonged Periods of Chair-Sitting," *Front. Sports Act. Living*, vol. 3, p. 760533, Nov. 2021, doi: 10.3389/fspor.2021.760533.

[13] A. Y. L. Wong *et al.*, "Do different sitting postures affect spinal biomechanics of asymptomatic individuals?," *Gait Posture*, vol. 67, pp. 230–235, Jan. 2019, doi: 10.1016/j.gaitpost.2018.10.028.

[14] A. Reeve and A. Dilley, "Effects of posture on the thickness of transversus abdominis in pain-free subjects," *Man. Ther.*, vol. 14, no. 6, pp. 679–684, Dec. 2009, doi: 10.1016/j.math.2009.02.008.

[15] J. Z. Willey *et al.*, "Physical Inactivity Predicts Slow Gait Speed in an Elderly Multi-Ethnic Cohort Study: The Northern Manhattan Study," *Neuroepidemiology*, vol. 49, no. 1–2, pp. 24–30, Aug. 2017, doi: 10.1159/000479695.

[16] S. M. Bindawas and V. Vennu, "Longitudinal Effects of Physical Inactivity and Obesity on Gait Speed in Older Adults with Frequent Knee Pain: Data from the Osteoarthritis Initiative," *Int. J. Environ. Res. Public. Health*, vol. 12, no. 2, Art. no. 2, Feb. 2015, doi: 10.3390/ijerph120201849.

[17] A. Rampp, J. Barth, S. Schülein, K.-G. Gaßmann, J. Klucken, and B. M. Eskofier, "Inertial Sensor-Based Stride Parameter Calculation From Gait Sequences in Geriatric Patients," *IEEE Trans. Biomed. Eng.*, vol. 62, no. 4, pp. 1089–1097, Apr. 2015, doi: 10.1109/TBME.2014.2368211.

[18] G. Cicirelli, D. Impedovo, V. Dentamaro, R. Marani, G. Pirlo, and T. D'Orazio, "Human Gait Analysis in Neurodegenerative Diseases: A Review," *IEEE J. Biomed. Health Inform.*, vol. PP, pp. 1–1, Jun. 2021, doi: 10.1109/JBHI.2021.3092875.

[19] "The Gait Cycle: Phases, Parameters to Evaluate & Technology | Gait Cycle Analysis | Tekscan." Accessed: Dec. 11, 2023. [Online]. Available: https://www.tekscan.com/blog/medical/gait-cycle-phases-parameters-evaluate-technology

[20] N. K. Nadkarni, E. Mawji, W. E. McIlroy, and S. E. Black, "Spatial and temporal gait parameters in Alzheimer's disease and aging," *Gait Posture*, vol. 30, no. 4, pp. 452–454, Nov. 2009, doi: 10.1016/j.gaitpost.2009.07.003.

[21] C. Tudor-Locke and D. R. Bassett, "How many steps/day are enough? Preliminary pedometer indices for public health," *Sports Med. Auckl. NZ*, vol. 34, no. 1, pp. 1–8, 2004, doi: 10.2165/00007256-200434010-00001.

[22] A. R. Anwary, H. Yu, and M. Vassallo, "Optimal Foot Location for Placing Wearable IMU Sensors and Automatic Feature Extraction for Gait Analysis," *IEEE Sens. J.*, vol. 18, no. 6, pp. 2555–2567, Mar. 2018, doi: 10.1109/JSEN.2017.2786587.

[23] J. Slemenšek *et al.*, “Human Gait Activity Recognition Machine Learning Methods,” *Sensors*, vol. 23, no. 2, p. 745, Jan. 2023, doi: 10.3390/s23020745.

[24] R. P. Suresh, V. Sridhar, J. Pramod, and V. Talasila, “Zero Velocity Potential Update (ZUPT) as a Correction Technique,” presented at the Proceedings - 2018 3rd International Conference On Internet of Things: Smart Innovation and Usages, IoT-SIU 2018, Institute of Electrical and Electronics Engineers Inc., Nov. 2018. doi: 10.1109/IoT-SIU.2018.8519902.

[25] L. Ojeda and J. Borenstein, “Non-GPS Navigation for Security Personnel and First Responders,” *J. Navig.*, vol. 60, no. 3, pp. 391–407, Sep. 2007, doi: 10.1017/S0373463307004286.

[26] R. Queen, L. Dickerson, S. Ranganathan, and D. Schmitt, “A novel method for measuring asymmetry in kinematic and kinetic variables: The Normalized Symmetry Index,” *J. Biomech.*, vol. 99, p. 109531, Jan. 2020, doi: 10.1016/j.jbiomech.2019.109531.