8-2024

Effects of Increasing Cycling Cadence on Post-Cycling Gait Velocity: An Experimental Study

Nitu Lama

EFFECTS OF INCREASING CYCLING CADENCE ON POST-CYCLING GAIT VELOCITY: AN EXPERIMENTAL STUDY

by

Nitu Lama

A Thesis
Submitted to the Graduate School,
the College of Education and Human Sciences
and the School of Kinesiology and Nutrition
at The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Master of Science

Committee:

Dr. Tanner Thorsen, Committee Chair
Dr. Nuno Oliveira
Dr. Paul Donahue
Dr. Christopher Keating

August 2024

Published by the Graduate School

THE UNIVERSITY OF SOUTHERN MISSISSIPPI®

ABSTRACT

Previous research has shown that increasing cycling cadence, rather than the workrate, can result in improved post-cycling gait velocity. However, the specific threshold of cycling cadence required to bring about clinically meaningful changes in gait velocity remains unknown. To address this knowledge gap, our study aimed to determine the minimum incremental increase in cycling cadence that would lead to a significant improvement in post-cycling gait velocity. A total of 42 young adults participated in our study and were randomly assigned to one of three groups: TEN, TWENTY, and THIRTY. Each group was assigned to cycle at a cadence at the corresponding percentage higher than the participant's self-selected gait cadence. Each participant engaged in a 15-minute cycling session at their respective assigned cycling cadence. Before and after the cycling phase, the participants completed a 10 Minute Walk Test while measurements of velocity, other spatiotemporal parameters of gait, ground reaction forces, lower extremity kinematics, and kinetics were recorded. A two-way ANOVA test revealed no statistically significant changes in spatiotemporal, ground reaction force, kinematics, and kinetics variables pre- and post-cycling. However, there were both statistically significant and clinically meaningful changes in post-cycling gait velocity in THIRTY only. This suggests that a cycling cadence of 30% or higher is the minimum requirement to produce a clinically significant improvement in gait velocity.

ACKNOWLEDGMENTS

I express my sincere gratitude to Dr. Thorsen, Dr. Oliveira, Dr. Donahue, and Dr. Keating for providing me with the invaluable opportunity to contribute to their research laboratory. I am also deeply appreciative of my lab mates (Rials, John, Natalie, Mathew, Destin) for their assistance in collecting the necessary data. My experience here at Southern Miss has been truly fulfilling, and I cannot emphasize enough how grateful I am. Lastly, I am very thankful to my parents (Bir Bahadur Henjan, Dilli Maya), siblings (Basanti, Ambika, Tika, Amit), and Rajesh for their love and support throughout this journey.

DEDICATION

To mom, dad, and Riaan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BMI	Body Mass Index
BW	Body Weight
CV	Coefficient of Variation
DF	Dorsiflexion
DLS	Double Limb Support
GRF	Ground Reaction Force
HS	Heel Strike
LR	Loading Response
MDC	Minimal Detectable Change
m/s	Meter Per Second
MWT	Meter Walk Test
Nm/Kg	Newton Meter Per Kilogram
PF	Plantarflexion
PO	Push-off
RPM	Rotation Per Minute
s.d.	Standard Deviation
SPM	Steps Per Minute
TO	Toe-off
VC	Varying Cadence

CHAPTER I – INTRODUCTION

Background

Falls are a significant concern among the elderly population, as they constitute the primary cause of both injuries and mortality (Sterling et al., 2001; Tinetti et al., 1986). Every year, one in three adults aged 65 and older experiences a fall and out of these falls 20% to 30% result in injuries (Ambrose et al., 2013). The World Health Organization has provided estimates indicating that over 37 million individuals worldwide seek medical attention for injuries resulting from falls. Furthermore, reports indicate that the financial burden placed on federal, state, insurance, and private payers due to non-fatal falls surpasses $50 billion annually within the United States (Florence et al., 2018). Falls can result in serious injuries such as hip fractures, head trauma, and lacerations (Sadigh et al., 2004; Zethraeus et al., 1997). Falls can also have psychological consequences, including the fear of falling which can result from decreased mobility and this can be the cause of loneliness and frustration in older adults (Legters, 2002). Falls are often caused by a combination of risk factors, such as aging-related changes in physical function, chronic health disorders, medication usage, environmental hazards, and lifestyle factors such as physical inactivity and poor nutrition (Terroso et al., 2014). Identifying risk factors and managing them can help the older population lead a better quality of life.

Previous exercise interventions targeting fall risk reduction in older adults have traditionally focused on addressing specific physical impairments that contribute to diminished gait function, such as weakness, balance deficits, or limited range of motion (El-Khoury et al., 2015; Iwamoto et al., 2009; Sherrington et al., 2011). Other interventions have involved teaching participants to adapt to changing conditions or postures, such as practicing on moveable floors, walking on surfaces with varying compliance, learning Tai Chi, or undergoing virtual reality gait training (Gillespie et al., 2012; Lee, 2021; McCrum et al., 2017). Gait velocity or walking speed is considered to be functional or sixth vital sign and it is responsive like heart rate or blood pressure to the different factors such as disease, cognition, training status, training status (Keating et al., 2024; Middleton et al., 2015). This sensitivity to change highlights the importance of gait velocity as a valuable indicator in assessing individuals' functional abilities and overall health. The change in gait velocity serves as an objective and highly sensitive assessment of changes observed in diverse populations and circumstances (Alfaro-Acha et al., 2007; Peel et al., 2013; Perera et al., 2006a; Schrack et al., 2015), as long as the difference between testing sessions exceeds the minimal detectable change (MDC) specific to the population being evaluated. Previous works suggest that clinically meaningful change in gait velocity can be considered as 0.05 - 0.1 m/s (Chui et al., 2012; Perera et al., 2006). Gait velocity has been recognized as a valuable predictor of fall risk as well in older adults (Shin & yoo, 2015), and enhancing gait velocity may be an effective technique for lowering fall risk. A decrease in gait velocity, besides increasing the risk of falls, can also impact a person's health and overall well-being in other ways. Decreased gait velocity can pose difficulties in carrying out daily activities and navigating the environment which can result in social isolation and a deterioration in the overall quality of life (Shankar et al., 2017).

The similarity between walking and using a bicycle ergometer lies in the concept that both activities elicit comparable neuromuscular facilitation in the lower extremities, as evidenced by brain activation studies during walking and pedaling (Christensen et al., 2000; Raasch & Zajac, 1999). Stationary cycle ergometers offer a low-impact, cost-effective, and safe exercise option for improving health parameters in older individuals. This low-impact nature of stationary cycling is particularly advantageous for older adults experiencing joint pain or other health conditions. Furthermore, the versatility of stationary cycle ergometers allows for indoor and outdoor use, making it a year-round activity option. Recent research has demonstrated that cycling can enhance gait cadence and velocity in older individuals with various disease states (Ridgel & Ault, 2019; Tsushima et al., 2015).

According to a preliminary investigation from our laboratory (Keating et al., 2024), it has been observed that cycling at a cadence higher than one's self-selected gait cadence can lead to an increase in gait velocity. Gait velocity is the product of gait cadence and step length. The typical range of average gait cadence for adults is between 100 to 120 steps per minute, which is equivalent to 50 to 60 steps per foot per minute. In this investigation, participants cycled at a rate of 75 rotations per minute (RPM), which was a 36% increase in gait cadence from the typical 110 steps per minute (SPM). The results of this investigation showed that this increase in cycling cadence led to an average increase in gait velocity of 0.1 m/s in younger adults. However, it is important to note that cycling at higher workrates did not have the same effect on gait speed, suggesting that an increase in cycling RPM is necessary to achieve an increase in gait speed.

Nevertheless, it is currently unknown how much the cycling RPM must be increased to achieve a significantly faster gait velocity. Although previous work from our laboratory has demonstrated that cycling at cadences higher than walking cadence positively improves gait velocity, exactly how much faster cycling cadence needs to be prescribed to increase gait velocity remains unknown.

Purpose of the Study

Our study aimed to examine the minimal increment in cycling cadence required to produce a meaningful improvement in post-cycling gait velocity. Our primary variables of interest were gait velocity and the coefficient of variation for each participant. Secondary variables included other spatiotemporal variables such as stride length, stride width, cadence and double limb support time. Our tertiary explanatory variables were kinematics, kinetics, and ground reaction force (GRF).

Research Hypotheses

In our preliminary study, we observed that there was no change in post-cycling gait velocity when the cycling cadence was maintained at the participant's self-selected gait velocity (Keating et al., 2024). However, when the cycling cadence was increased by 36% above the typical gait cadence of 110 SPM, there was an 8.4% increase in post-cycling gait velocity. This finding is consistent with a similar study conducted by Tsushima et al. (2015) who reported an 8% increase in gait velocity above the pre-cycling levels when the cycling cadence was raised by 18% above the self-selected cycling cadence. Based on our observations, we hypothesize that incrementally increasing cycling cadence above self-selected gait cadence will result in a non-linear increase in post-cycling gait velocity and spatiotemporal parameters of gait across all experimental conditions.

CHAPTER II – LITERATURE REVIEW

Introduction

Gait velocity refers to the speed at which an individual walks on level ground, measured in meters per second. Median values for gait speed differ across age groups and genders, ranging from 1.08 m/s to 1.38 m/s for male and 0.92 m/s to 1.41 m/s for female (Kasović et al., 2021). Previous research has highlighted the increased risk of falls and secondary health complications when gait velocity drops below 0.6 m/s (Abellan Van Kan et al., 2009). Diminished gait velocity in the elderly is linked to an increased risk of falls (Abu Samah et al., 2016) which can result in fall-related injuries and mortality, thereby deteriorating their quality of life. Studies have shown that gait velocities ranging from 0.6 to 1.0 m/s are associated with a high risk of falls among older adults (Abu Samah et al., 2016). Improving gait velocity has resulted in more stability and balance during walking, leading to a reduction in the fall rate (Espy et al., 2010). The use of varying cadence (VC) bicycle ergometry as an intervention based on their finding that a single 5-minute session of VC bicycle training could lead to the same level of improvement in gait performance as 12 weeks of resistance training in the elderly (Tsushima et al., 2015). Cycling at a higher RPM than the typical cadence for walking can result in an 8.4 % increase in gait velocity (Keating et al., 2024). However, the relationship between cycling RPM and walking cadence is still unknown. Therefore, the purpose of this literature review is to discuss the biomechanics of gait, age-related changes influencing gait velocity, current literature using a stationary cycle ergometer for improving gait function, and the effects of a stationary cycle ergometer on gait velocity.

Stationary Cycle Ergometer

The stationary cycle ergometer operates on the principle that similar neural activation occurs in the lower extremities during both walking and pedaling (Christensen et al., 2000) This characteristic makes it a favorable intervention for older populations due to its low-impact nature and cost-effectiveness. Moreover, the convenience of indoor use allows older adults to engage in year-round exercise, regardless of weather conditions.

Frail older individuals often experience age-related physical and biomechanical changes that can be targeted through therapeutic exercise programs (Mollinedo Cardalda et al., 2019). These workouts aim to address the overall improvement of physical function and biomechanics but can also induce fatigue in the whole body or leg muscles (Tsushima et al., 2015). Furthermore, it is worth noting that only a minority of older adults engage in regular exercise activities (Sun et al., 2013). In this context, the stationary cycle ergometer emerges as a promising option for improving gait function, particularly gait velocity, when compared to other interventions such as walking. Given its accessibility, low-impact nature, and potential benefits for gait function, the stationary cycle ergometer represents a valuable tool for promoting physical activity and enhancing gait performance in older individuals.

Gait, its Phases, and Parameters

During the gait cycle of normal walking, a substantial portion of the cycle duration for a single limb is allocated to the stance phase, accounting for approximately 60 percent, while the swing phase occupies around 40 percent (Hebenstreit et al., 2015; Leach et al., 1984).

Spatial gait features are factors that can be noticed visually by studying the movement of the feet on the ground. These characteristics include step length (the distance between consecutive heel strikes of the same foot), stride length (the distance covered by both feet during a complete gait cycle), step width (the lateral separation between the feet), and progression angle (the angle formed by the line of progression and the direction of walking). Temporal features include variables that indicate time-related gait characteristics. The speed of walking is represented by velocity, step duration by the time it takes to complete one step, and cadence by the number of steps performed per unit of time. These temporal characteristics provide information about the time and rhythm of the gait cycle. Gait velocity is the product of cadence and step length (Houglam A & Bertoti B, 2011).

Spatial and Temporal Parameters Assessment Tools

Cerny (1983) provides one of the simplest techniques to assess the spatial and temporal parameters and this simply includes a timer, two felt tip marking pens with washable ink, and a premeasured 16-m walkaway marked with masking tape at four spots. As the subjects ambulate while being timed, the pens taped to the back of their shoes create imprints on the walkaway. The markers are then used to directly assess the spatial information required. Stride length is computed by averaging the middle three strides, which is the distance from the heel contact mark to the heel contact mark by the same foot. The step length measurement is the average of the middle three steps measured on the right side from the left contact pen mark to the right contact pen mark and on the left side from the right contact pen mark to the left contact pen mark. The step width is the distance perpendicular to the progression line from left to right and right to left. This measurement is obtained by averaging the middle three steps for each side (Cerny, 1983).

Another technique to assess spatial and temporal parameters is the use of a sensitized mat. The sensitized mat is made of a sequence of ribbed rubber mats, each with two gris embedded into the surface, one on top of the other. A control box provides power to both sides of the walkway and contains circuitry to detect signals from the walkway as well as two optical switches spaced at a known distance apart on the sidewalk. The subject walks along the walkway while wearing a shoe with self-adhesive conducting tape on the sole. When the tape comes into touch with the walkway, an electrical short circuit in the grid causes the control box to detect a signal. The signals are then stored and analyzed on a microcomputer (Bezner, 1996).

Other methods employ light-emitting diodes (LEDs) worn by the participant at specific bone landmarks. The individual is then shot ambulating on a sidewalk with a known distance indicated with LEDs using a 35-mm photography slide technique. The spatial properties of this film are then determined. Counting the number of flashes produced by a strobe-type light in the filming region determines the temporal features (Bezner, 1996).

Another developed method of investigating kinematic information is high-speed cinematography, which uses black and white film, often 16-mm film. The person is filmed walking with markers placed on specific bony landmarks. Once developed, the film is manually digitized, and the joint angles are computed using appropriate software programs. An automated video recording system captures a human walking with reflecting markers placed at certain anatomical points. The technology automatically tracks the markers as the recording of the subject walking through their typical gait pattern is played. Through the use of integrated software, the system is capable of detecting joint angles as well as many other gait metrics by tracking these markers (Bezner, 1996).

Spatial Parameters

The average stride length range was 1.06 to 1.25 m for females and 1.25 to 1.85 m for males of 18-40 years of age (Suner-Keklik et al., 2023). In a previous study (Correale et al., 2021) involving 40 healthy adults who walked on a 15-meter walkway at their normal self-selected speed. Stride length was measured using the inertial measurement unit Physilog5, and the results showed a mean stride length of 1.3 ± 0.1 meters (Correale et al., 2021). In another previous study (Gomez Bernal. et al., 2016a) involving 126 healthy adults, participants walked on a 10-meter walkway at their normal comfortable speed. Step length was measured using the OptoGait system, and the findings revealed a mean step length value of 135.85 centimeters (Gomez Bernal. et al., 2016b). Step width was 0.095 ± 0.018 m for young adults and 0.14 ± 0.034 m for older adults which was measured as distance in the medial-lateral direction between consecutive left and right heel strikes (Owings & Grabiner, 2004).

Temporal Parameters

The average cadence range for females were 98 to 138 steps/min and 91 to 135 steps/min for males (Suner-Keklik et al., 2023). Step time in their study was analyzed, and the results showed a mean step time of 0.5252 seconds (Gomez Bernal. et al., 2016b). In the previous study Correale et al. (2021), velocity was measured and found to have a value of 1.10 ± m/s. The evaluation of spatial and temporal aspects gives useful information on human gait and movement patterns.

Joint Kinematics During Walking

A rotation of the distal segment relative to the proximal segment is joint angle (Vaughan, 1999).The sagittal plane divides the body into the left and right halves, allowing us to analyze joint angles in forward and backward directions. In the sagittal plane, the primary joint angles of interest are hip flexion, hip extension, knee flexion, knee extension, ankle dorsiflexion, and ankle plantarflexion (Vaughan, 1999).

Hip

In the previous study (Kadaba et al., 1990) kinematic analysis was performed on a group of 40 normal, healthy adults. The results revealed changes in the hip flexion angle throughout the gait cycle. Specifically, at initial contact the hip flexion angle was measured at 40 degrees. This was followed by a transition to a peak hip extension angle of 5 degrees at pre-swing. Subsequently, at a later stage of the gait cycle, which is the terminal swing, the hip flexion angle reaches 40 degrees again (Kadaba et al., 1990).

In another previous study (Judge et al., 1996) the kinematic parameters of 32 young adults were observed. The findings revealed that at the initiation of the gait cycle (i.e., initial contact), there was a peak of 30 degrees of hip flexion. However, as the gait cycle progressed to 50% (i.e., terminal stance), a transition occurred, resulting in a peak of 10 degrees of hip extension. This was followed by 30 degrees of hip flexion at the terminal swing (Judge et al., 1996).

Knee

In (Kadaba et al., 1990) study, it was observed that the knee flexion angle exhibited distinct changes during the gait cycle. Specifically, during initial contact, the knee flexion angle was measured at 5 degrees. This was then followed by a transition to an extension angle of 0 degrees, indicating full extension of the knee joint. Subsequently, at a later stage of the gait cycle, the knee flexion angle reached a peak value of 60 degrees, illustrating a greater degree of flexion.

Judge et al. (1996) observed that the knee joint exhibited specific kinematic changes during the gait cycle. At the initial contact phase, the knee joint demonstrated 0 degrees of extension. However, as the gait cycle progressed to 70% of the gait cycle (i.e., initial swing), a peak flexion angle of 50 degrees at the knee joint was observed.

Ankle

Kadaba et al., (1990) showed that ankle joints had notable changes in the range of motion. At initial contact, there was a plantar flexion angle of 3-5 degrees. This angle then transitioned to a peak dorsiflexion angle of 10 degrees at the terminal stance. Subsequently, at pre-swing, the ankle exhibited a plantar flexion angle of peak value of 15 degrees.

Kitaoka et al. (2006) conducted a study on 20 normal subjects during level walking for gait analysis. The study revealed that the ankle-hind foot complex gradually dorsiflexes throughout the stance phase, attaining a maximum dorsiflexion angle of 6.5 ± 2.7 degrees in terminal stance. At the end of the stance phase, this dorsiflexion progressively transforms into a fast plantarflexion. By the end of the stance phase, the ankle-hind foot complex averages 11.8 ± 4.8 degrees of plantarflexion. The total range of motion in the sagittal plane during the stance phase averages 18.3 ± 4.5 degrees.

In summary, the hip, knee, and ankle joints display distinctive kinematic patterns during the gait cycle. The hip joint changes flexion and extension angles, with a peak flexion observed in the early stance phase and a transition to extension as the gait cycle progresses. The knee joint shows a transition from extension to peak flexion, indicating a significant degree of flexion during specific phases of the gait cycle. The ankle joint demonstrates a range of motion from plantar flexion to dorsiflexion, with specific angles observed at different stages of the gait cycle.

Joint Kinetics During Walking

During the stance phase of gait, the ankle, knee, and hip moments act as extensor moments to support the body and resist the collapse (Winter 1980). The ankle moment generates plantarflexion (negative) to maintain the body's center of mass over the foot and provide propulsion during the push-off phase of gait. The knee moment generates extension (positive) to maintain the body's stability and prevent the collapse of the lower limb. The hip moment generates extension (negative) to maintain the body's stability and prevent the collapse of the lower limb.

During the swing phase of gait, the ankle, knee, and hip moments have different actions. The ankle moment generates dorsiflexion to clear the foot from the ground and prepare for the next heel strike. The knee moment generates flexion to allow the leg to swing forward and prepare for the next heel strike. The hip moment generates flexion to allow the leg to swing forward and prepare for the next heel strike.

Hip

Monaco et al. (2009) conducted a study involving nine young subjects who underwent treadmill walking at five distinct speeds for three minutes each. The objective of the study was to investigate the intersegmental moments during different phases of the gait cycle. The results of the study revealed that during the early stance phase of the gait cycle, there was a hip extension moment (represented by a positive value) observed at the knee joint, with an average magnitude of 0.5 Nm/kg. Following the early stance phase, there was a subsequent hip flexion moment (represented by a negative value) which reached its maximum of 0.5 Nm/kg during the late stance phase, constituting approximately 50% of the entire gait cycle (Monaco et al., 2009).

Fukuchi et al. (2018)conducted a study involving 24 young participants who walked on a treadmill at comfortable speeds. The study aimed to investigate the kinetics of the hip joint during the gait cycle. The findings revealed distinct patterns of hip joint moments at different phases of the gait cycle. During the early stance phase, the hip joint exhibited a peak extension moment with a magnitude of 1.25 Nm/kg. Subsequently, at approximately 50% of the gait cycle, the hip joint experienced a peak flexion moment of 0.5 Nm/kg. Finally, toward the end of the gait cycle, there was a subsequent hip extension moment of 1 Nm/kg (Fukuchi et al., 2018).

Knee

Specific characteristics of the intersegmental moments at the knee joint during the gait cycle were demonstrated in previous work (Monaco et al., 2009). Their results indicated that the knee extension moment reached a peak value of approximately 0.4 Nm/kg during the early stance phase. Subsequently, during the mid-stance phase at approximately 50% of the gait cycle, there was a peak knee flexion moment also measuring around 0.4 Nm/kg and was then followed by a subsequent knee extension moment of approximately 0.4 Nm/kg.

Fukuchi et al., (2018) revealed that during the early stance phase, the knee joint demonstrated a peak flexion moment (represented by a negative value) with a magnitude of 0.5 Nm/kg. Following the early stance phase, there was a subsequent knee extension moment (represented by a positive value) with a magnitude of 0.25 Nm/kg. Lastly, there was another peak knee flexion moment observed with a magnitude of 0.5 Nm/kg.

Ankle

Previous study (Monaco et al., 2009) revealed that ankle plantarflexion reached its peak value of approximately 1 Nm/kg at approximately 50% of the gait cycle. Fukuchi et al., (2018) revealed that at approximately 50% of the gait cycle, the ankle joint exhibited a peak moment of ankle plantar flexion (represented by a positive value) with a magnitude of 1.5 Nm/kg.

Conclusion:

These findings emphasize the dynamic nature of joint moments during gait, as well as the roles of the hip, knee, and ankle in maintaining stability, producing propulsion, and facilitating the swing phase.

Cycling Cadence and Gait velocity

Stationary cycling ergometry has been employed as a method to improve motor functions across diverse populations. Modulating cadence during dynamic cycling has been shown to elicit an augmented afferent flow, thereby initiating central processing alterations believed to contribute to enhanced motor output. This mechanism involves the stimulation of cutaneous receptors, joint receptors, and proprioceptors, including muscle spindles and Golgi tendon organs, in the lower extremities (Ridgel & Ault, 2019). Such stimulation elicits a robust sensorimotor process and fosters neural efficiency, as demonstrated in studies involving healthy individuals who engaged in active pedaling and high cadence training (Jain et al., 2013; Ludyga et al., 2016). Recent research has suggested that cycling – especially at cadences greater than self-selected walking cadence – can improve gait velocity after the completion of the cycling exercise. Recent research studies have indicated that cycling, particularly at cadences higher than the self-selected walking cadence, may lead to improvements in gait velocity following the completion of the cycling exercise. These studies have been conducted to enhance motor function, particularly among older individuals within the population.

Salacinski et al., (2012) investigated the effects of a 12-week cycling intervention on gait velocity in individuals with mild-to-moderate knee osteoarthritis (OA). The participants, who had an average age of 57.7 ± 9.8 years, underwent the cycling program, and their gait velocity was measured before and after the intervention. The findings revealed a significant increase in gait velocity from 139.3 m/s to 147.1 m/s in the cycling group. In contrast, the control group did not experience any change in gait velocity.

Similarly, Ridgel et al., (2015) conducted a study involving 50 individuals with idiopathic Parkinson's Disease, aged between 59 and 79 years. The participants were divided into two groups: one group engaged in dynamic cycling at a cadence of 75-85 rpm for 30 minutes in three sessions, while the other group performed static cycling with a self-selected constant cadence. Motor function was assessed using the Time Up and Go Test before and after the cycling interventions. The results demonstrated a significant increase in motor function in the dynamic cycling group, as indicated by improved performance in the Time Up and Go Test compared to the static cycling group.

In another previous study (Tsushima et al., 2015) 20 sedentary individuals with an average age of 77.6 years were divided into two groups. One group performed cycling at varying cadences ranging from 45 to 65 rpm, while the other group maintained a constant cadence of 50 rpm. Each group cycled for 5 minutes, and gait velocity was measured before and after the cycling session. The findings demonstrated a significant increase in gait velocity from 0.88 m/s to 0.95 m/s in the varying cadence group, while the constant cadence group did not exhibit any change in gait velocity.

Previous studies have examined cycling cadences as a variable of interest. However, none of these studies have specifically investigated whether the manipulation of cycling workrate or cycling cadence can elicit changes in motor function, particularly gait velocity. Therefore, our laboratory conducted a study (Keating et al., 2024) to address this research gap. In this study, a group of 45 recreationally active young adults participated were divided into three groups: a control group with a workload of 1.0 W/kg and a cadence of 55 rpm, a fast group with a workload of 1.0 W/kg and a cadence of 75 rpm, and a hard group with a workload of 1.5 W/kg and a cadence of 55 rpm. Each group performed cycling for 15 minutes in a single session. The researchers measured gait velocity before and after the cycling session. The results demonstrated that only the fast group exhibited a significant increase in gait velocity, from 1.19 m/s to 1.29 m/s, following the cycling intervention. These findings indicate that cycling at a higher cadence, exceeding the normal cadence is correlated with an increase in post-cycling gait velocity. However, the question remains regarding the specific relationship or trend that exists between cycling cadence and gait velocity.

The decline in gait velocity is a notable consequence of the aging process, and it has a significant impact on balance, often resulting in falls among older individuals. However, there is potential for improving balance by enhancing gait velocity. Previous studies have explored the use of a stationary cycle ergometer as an intervention to enhance motor function and cardiovascular fitness in the elderly population. Notably, it has been observed that faster cycling speeds are associated with increased gait velocity following the cycling session.

To investigate this relationship further, a preliminary laboratory study was conducted. The study focused on examining gait velocity and cycling speed as the primary variables of interest. The results of the study demonstrated that gait velocity tends to increase after individuals engage in a cycling session. This finding suggests a potential positive impact of cycling on subsequent walking performance in terms of speed. By establishing a clearer understanding of the relationship between post-cycling gait velocity and cycling speed, the dosage relationship between these two factors can be obtained. This information can then be utilized to design targeted interventions aimed at improving balance in the elderly population. Such interventions may involve prescribing specific cycling protocols or exercises that can effectively enhance gait velocity and, consequently, enhance balance and reduce the risk of falls in older individuals.

CHAPTER III – METHODS

Participants

A random sample of 49 recreationally active young adults were recruited through class announcements and word of mouth to take part in a single lab visit. Prior to participation, all individuals provided informed consent, and the study procedures received approval from the Institutional Review Board at the University of Southern Mississippi. This study used a randomized crossover design utilizing within and between-group comparisons. A sample size of 42 was recommended by an a priori power analysis for a 3 × 2 [Group × Time] repeated measures analysis of variance (ANOVA) to obtain an alpha of 0.05 and a beta of 0.80 (Faul et al., 2007).

Inclusion Criteria

Inclusion criteria included being recreationally active for the last 3 months. In addition, participants were screened using the PAR-Q (Physical Activity Readiness Questionnaire) to ensure safety during exercise. To define the criteria of being recreationally active, we followed the ACSM (American College of Sports Medicine) Guidelines for Physical Activity of 150 minutes of moderate-intensity aerobic activity per week or muscle-strengthening activities on 2 or more days a week that consist of working all major muscle groups(American College of Sports Medicine, 2013).

Exclusion Criteria

Exclusion criteria included any lower extremity injuries within the last 6 months, any major lower extremity surgery, a history of cardiovascular problems, and a BMI (body mass index) greater than 40 kg/m^2. Additional exclusion criteria included any neurological disorders or assisted walking devices (i.e., prosthetic limbs, prophylactic braces).

Experimental Procedures

Anthropometric Measurements

Upon arrival at the laboratory, participants' height was measured with a stadiometer, and their weight was measured while they stood still on the force plate. Participants were randomly assigned to one of three groups in which they were asked to complete a single bout of cycling: Group 1, which cycled at a 10% increase in cycling cadence relative to gait cadence (TEN); Group 2, which cycled at a 20% increase in cycling cadence (TWENTY); and Group 3, which cycled at a 30% increase in cycling cadence (THIRTY). This study builds upon previous research (Tsushima et al., 2015)where an 18% increase in cycling cadence above the normal gait cadence was utilized. Additionally, the study conducted in our laboratory incorporated a 36% increase in cycling RPM above the normal cycling RPM (Keating et al., 2024).We aim to ascertain the trend in the relationship between an increase in cycling RPM and the associated increase in gait velocity by examining the three groups in conjunction with the findings from prior works (Keating et al., 2024; Tsushima et al., 2015).

Data Collection Procedures

Participants had 18 anatomic markers, and 8 segmental tracking markers, placed onto anatomical locations of interest. Bilateral placement of anatomical markers included the iliac crest, greater trochanter, medial and lateral femoral epicondyles, medial and lateral malleoli, distal end of the second toe, and the first and fifth metatarsal heads. Rigid thermoplastic shells were used to place segmental markers on the trunk, pelvis, thighs, shanks, and heels bilaterally. Before baseline testing, participants stood still on the force plate for a static trial and then had the anatomic markers removed. All participants first completed three Ten Meter Walk Tests (10MWT). Self-selected walking cadence was determined using the mean cadence recorded during three 10MWT trials. Following the baseline gait assessment, a single 15-minute bout of cycling was performed. Participants were instructed to cycle at a cadence according to their random assignment. After the 15-minute cycling bout, post-cycling gait parameters were recorded as participants performed two additional post-cycling 10MWT. All gait parameters (i.e., gait velocity, cadence, stride length, stride width, joint kinematics, and kinetics and vertical ground reaction forces were obtained when participants performed three 10MWT in a 6-camera motion capture volume equipped with 6 in-ground force platforms.

Instrumentation

A 6-camera Qualisys motion capture system was used to collect three-dimensional (3D) marker coordinate data of the lower extremity at a frequency of 240 Hz. Concurrently, GRF data was sampled at a frequency of 1200 Hz using 6 AMTI in-ground force plates. Anatomic reflective markers were placed in pairs on specific anatomical landmarks including the acromion process, iliac crest, greater trochanter, medial and lateral femoral epicondyles, medial and lateral malleoli, the distal end of the second toe, and the first and fifth metatarsal heads. Additionally, eight rigid thermoplastic segmental tracking clusters were attached to the trunk, pelvis, thighs, shanks, and heel on both sides.

Data Processing

Visual 3D biomechanical analysis suite (Version 6.0, C-Motion; Germantown, MD, USA) was used to calculate variables of interest from the exported kinematic and kinetic data. The spatiotemporal parameters in this study were defined as cadence, double-limb support time, stride length, and stride width. The stance phase of each step was specifically defined as the time between heel strike (the initial occurrence when the vertical GRF surpassed a predefined threshold of 10 N on the force platform) and toe-off (the first instance when the vertical GRF dropped below a predetermined threshold of 10N on the force platform) (Keating et al., 2024). Spatial and temporal variables of gait were computed by Visual3D by using 4 gait events (Right and Left Heel Strike and Toe-off). Gait cadence was calculated by first determining the duration of each step (e.g., the temporal difference between toe-off and heel strike). Then, cadence was determined as a quotient of 60 seconds and the right step time (HAS-Motion Product Documentation, n.d.). As such a zero-lag fourth-order Butterworth low-pass filter was used to filter data on kinematics and ground reaction forces at 6 Hz. To define angular kinematic and kinetic variable conventions, angular computations were done using a Cardan rotational sequence (X-Y-Z) based on the right-hand rule. Positive rotations include ankle dorsiflexion and inversion, knee extension and adduction, and hip flexion and adduction. Internal joint moments were computed and expressed in the joint coordinate system (Grood & Suntay, 1983). GRF was normalized to body weight, while moment and power variables were normalized to body mass. Peak joint angles and angular velocities were measured during the stance and swing stages of the right leg's stride. Peak GRF and joint moments were measured during the stance phase of one right foot. As participants performed all 10MWT within the motion capture volume, spatiotemporal characteristics were computed using data from both limbs.

The coefficient of variation (CV) was calculated as a method to ascertain meaningful change in post-cycling gait velocity. We computed CV as the quotient of the mean and standard deviation of the three pre-cycling 10MWT times and thus, the CV represents the variability in self-selected gait velocity for each individual (Brown et al., 2009). Using the difference of the CV pre-cycling mean of the 10MWT times as a lower bound, and the sum of the CV and the pre-cycling mean of the 10MWT times as an upper bound, we established a window of expected variability for each participant's self-selected pre-cycling gait velocity. Post-cycling 10MWT times were evaluated against this window of expected variability, and each person was coded dichotomously if their post-cycling 10MWT time did (coded "=1") or did not (coded "=0") fall below the lower bound of the window of expected variability.

Statistical Analysis

Our primary variables of interest were gait velocity and the coefficient of variation for each participant. Secondary variables included other spatiotemporal variables such as cadence, stride length, and stride width. Our tertiary explanatory variables were kinematics, kinetics, and GRF. Simple linear regression techniques were used to determine the relationship between increased cycling cadence and increased post-cycling gait velocity. For comparison back to previously published literature, data from the FAST group (Keating et al., 2024) was included (with permission) in the regression model. Because human gait is symmetrical, we looked at all features from the right limb. A one-way ANOVA was used to compare anthropometric variables between the three different groups. A 3 × 2 [Group × Time] repeated measures ANOVA was used to calculate pre- and post-cycling variables between the group. Post hoc pairwise t-tests with a Bonferroni correction were performed to determine the location of statistical significance in the event of significant main effect. Mann-Whitney U test was used to compare the gait velocities (pre-cycling, post-cycling, and raw change) between males and females. Statistical significance was established at $\alpha = 0.05$. To determine the effect size of the repeated ANOVA, partial eta squared (η_p^2) was computed. Effect sizes of 0.0099, 0.0588, and 0.1379 were considered small, medium and large respectively (Norouzian & Plonsky, 2018; Richardson, 2011). SPSS software (version 27, SPSS, Chicago, IL) was used to perform all statistical analyses.

CHAPTER IV – RESULTS

A total of 49 participants were initially recruited for the study. Data from one participant was excluded due to marker inconsistencies. One participant presented with exceptionally fast pre-cycling gait velocity (more than 3x the group mean), and their data was excluded. Three more participants (one from each group) were identified as outliers and excluded from our analysis as they demonstrated a post-cycling increase in gait velocity more than 3x greater than their group means. Finally, 2 participants voluntarily stopped the bout of cycling due to self-reported fatigue, and their data were excluded from our analysis. As a result, the data from 42 participants remained and was suitable for further analysis. We did not observe any statistically significant variation in demographics between groups (Table 1.1) in a two-way ANOVA.

We did not observe statistically significant interaction between Group and Time for post-cycling gait velocity ($F(2,78) = 0.324$, $p = 0.724$, $\eta_p^2 = 0.008$, Table 1.2) in a two-way ANOVA. A significant main effect of the group was found on gait velocity ($p = 0.002$, Table 1.2) suggesting that both pre- and post-cycling gait velocity were reduced in the THIRTY group compared to the TEN group ($p = .001$, Table 1.2). A significant main effect of time was found on post-cycling gait velocity ($p = .030$, Table 1.2), indicating that post-cycling gait velocity increased for all groups.

The relationship between increased cycling cadence and gait velocity was best described by a 2nd-order polynomial equation (Figure 1.1). Using this model, increased cycling cadence accounted for 33.6% of the variance in post-cycling gait velocity ($p < .001$).

21% of TEN, and 36% of TWENTY did not walk with a post-cycling gait velocity that fell outside of their window of expected variability (Figure 1.2). However, in the THIRTY 100% of the participants walked with a post-cycling gait velocity that was outside the window of expected variability (Figure 1.2).

Mann Whitney U test did not reveal any statistically significant variations in the gait velocities between males and females (($p > 0.005$), Table 1.6).

We did not observe any statistically significant interaction between Group and Time for double-limb support time (F (2,78) = 0.087, $p = 0.917$, $\eta_p^2 = 0.002$, Table 1.2) in a two-way ANOVA. A main effect of Group was observed for double limb support time (p = 0.003, Table 1.2) indicating that both pre- and pot-cycling double limb support time were reduced in TEN compared to TWENTY ($p = .003$) and THIRTY ($p = .028$) groups. We did not observe any statistically significant interaction between Group and Time for overall cadence (F (2,78) = 0.192, $p = 0.826$, $\eta_p^2 = 0.005$, Table 1.2) in a two-way ANOVA. A main effect of Group was observed on overall cadence ($p = 0.016$, Table 1.2) suggesting that both pre- and post-cycling overall cadence was increased in TEN compared to THIRTY ($p = .023$). There were no other statistically significant findings of any spatiotemporal variables.

We did not observe any statistically significant interaction between Group and Time for propulsive GRF (F (2,78) = 0.111, $p = 0.895$, $\eta_p^2 = 0.003$, Table 1.3) in a two-way ANOVA. A main effect of group was observed on propulsive GRF ($p = 0.02$), suggesting pre- and post-cycling propulsive GRF of THIRTY was higher compared to TEN ($p < .001$) and TWENTY ($p = .047$). We did not observe any statistically significant interaction between Group and Time for push-off vertical GRF (F (2, 78) = 0.125, $p =$

0.882, η_p^2 = 0.003, Table 1.3) in a two-way ANOVA. A main effect of Group was observed on push-off vertical GRF (p < .001) push-off GRF was increased for TWENTY compared to THIRTY (*p* < .001). We did not observe any statistically significant interaction between Group and Time for other GRF variables in a two-way ANOVA.

We did not observe any statistically significant interaction between the Group and Time for ankle kinematics (Table 1.4) in a two-way ANOVA.

We did not observe any statistically significant interaction between Group and Time for knee angle at heel strike (F (2, 78), 0.111, *p* = 0.895, η_p^2 = .003, Table 1.4) in a two-way ANOVA. A main effect of Group was observed for knee angle at heel strike (*p* < .001, Table 1.4) suggesting that knee angle at heel strike was varied in THIRTY compared to TEN (*p* < .001) and TWENTY (*p* < .001). We did not observe any statistically significant interaction between Group and Time for knee angle at toe-off (F (2, 78), = 0.520, *p* = 0.597, η_p^2 = 0.013, Table 1.4) in a two-way ANOVA. A main effect of Group was observed on knee angle at toe-off (p < .001, Table 1.4) indicating that TEN was different than TWENTY (*p* = .018) and THIRTY (*p* < .001), also TWENTY was different than THIRTY (*p* < .001). We did not observe any statistically significant interaction between Group and Time for peak knee flexion angle (F (2, 78), = 0.078, *p* = 0.925, η_p^2 = 0.002, Table 1.4) in a two-way ANOVA. The main effect of Group was observed on knee peak flexion angle (p = 0.016, Table 1.4) indicating peak knee flexion angle was different in TEN compared to TWENTY (*p* = .040) and THIRTY (*p* = .036). We did not observe any statistically significant interaction between Group and Group for peak knee extension angle, ankle angle at heel strike, ankle angle at toe-off, peak plantarflexion angle, and peak dorsiflexion angle in a two-way ANOVA. The main effect of time and cycling cadence was not observed as well.

We did not observe any statistically significant interaction between Group and Time for hip peak flexion angle (F (2, 78) = 0.045, $p = 0.956$, $\eta_p^2 = 0.001$, Table 1.4) in a two-way ANOVA. A main effect of Group was observed for peak hip flexion angle ($p < .001$, Table 1.4) suggesting that peak hip flexion angle was different in THIRTY compared to TEN ($p < .001$) and TWENTY ($p < .001$). We did not observe any statistically significant interaction between Group and Time for hip peak extension angle (F (2, 78) = 0.041, $p = 0.960$, $\eta_p^2 = 0.001$, Table 1.4) in a two-way ANOVA. A main effect of Group was observed on the peak hip extension angle ($p < .001$) suggesting that the peak hip extension angle in THIRTY was different compared to TEN ($p < .001$) and TWENTY ($p < .001$). We did not observe any statistically significant interaction between Group and Time for hip angle at heel strike and hip angle at toe-off in a two-way ANOVA.

We did not observe any statistically significant interaction between Group and Time for peak ankle, knee, or hip joint moments (Table 1.5) in a two-way ANOVA.

Table 1.1 Participant demographics information of TEN, TWENTY, and THIRTY and gait velocities for all groups, presented as mean ± s.d. p = p-value, η2 = eta squared.

	TEN	TWENTY	THIRTY	*p* (η^2)
Age	21.86 ± 5.25	22.57 ± 3.99	23.29 ± 3.85	.695 (.125)
Mass	62.35 ± 13.99	73.77 ± 16.42	76.53 ± 14.37	.059 (.330)
Height	1.69 ± 0.08	1.72 ± 0.09	1.75 ± 0.13	.350 (.197)
BMI	21.77 ± 4.54	24.9 ± 4.6	24.91 ± 2.76	.074 (.298)

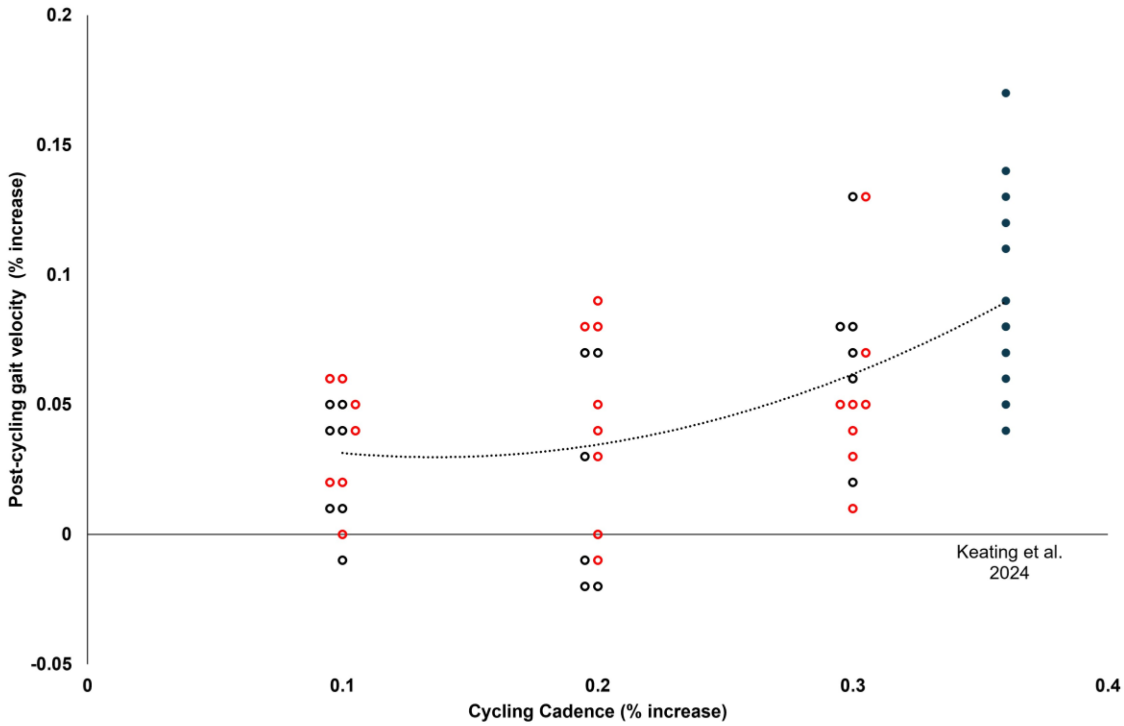

Figure 1.1 *Relationship between cycling cadence (% increase from self-selected gait cadence) and post-cycling gait velocity (% change from pre-cycling gait velocity) of Males (Red) and Females (Black), defined by the equation* $y = 1.1778x^2 - 0.317x + 0.0512$, $r^2 = .336$, $p < .001$. *Individual data from the FAST group of Keating et al. 2024 is included.*

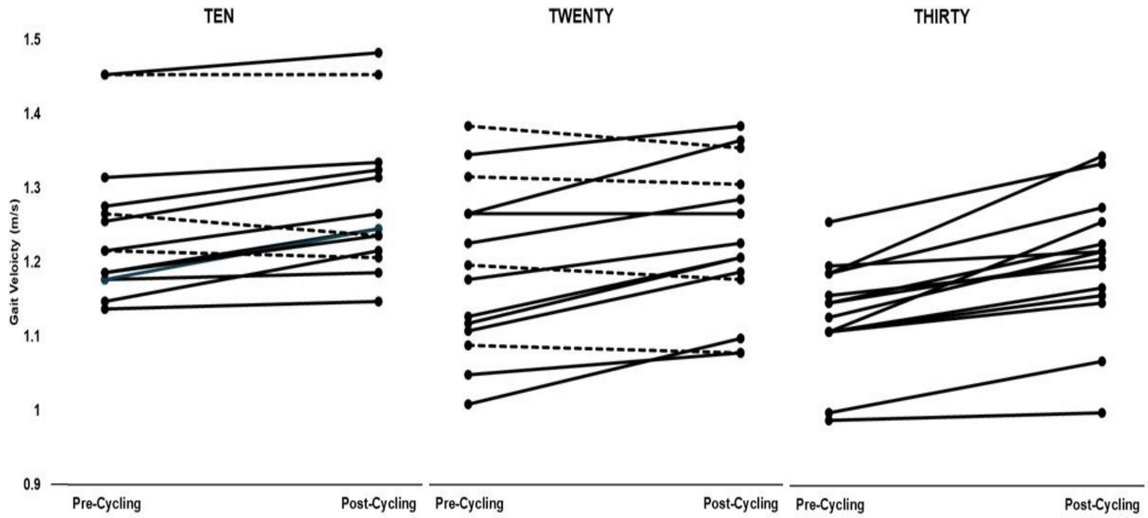

Figure 1.2 *Percentage of participants who exceeded (smooth line) and did not exceed (dotted line) coefficient of variation (CV) window*

Table 1.2 Spatiotemporal metrics of TEN, TWENTY, and THIRTY groups both pre- and post-cycling presented as mean ± s.d. p = p-value, ηp2 = partial eta squared. PRE = Pre-cycling. POST = Post-cycling. DLS = Double Limb Support. Bold indicates statistical significance.

	TEN		TWENTY		THIRTY		*p* (η_p^2)		
	PRE	POST	PRE	POST	PRE	POST	Group	Time	Interaction
DLS Time	0.18 ± 0.05*#	0.17 ± 0.05*#	0.23 ± 0.05	0.22 ± 0.05	0.22 ± 0.07	0.21 ± 0.07	**.003 (.142)**	.436 (.008)	.917 (.002)
Stride Width	0.21 ± 0.04	0.21 ± 0.03	0.22 ± 0.04	0.22 ± 0.04	0.21 ± 0.03	0.22 ± 0.03	.384 (.024)	.819 (.001)	.952 (.001)
Stride Length	1.32 ± 0.04	1.34 ± 0.04	1.32 ± 0.05	1.35 ± 0.05	1.27 ± 0.09	1.31 ± 0.07	.010 (.112)	.065 (.043)	.793 (.006)
Overall Cadence	114.47 ± 10.83	117.21 ± 12.34	108.45 ± 9.1	110.99 ± 9.13	106.04 ± 7.26	111.46 ± 8.81	**.016 (.101)**	.096 (.035)	.826 (.005)
Gait Velocity	1.25 ± 0.35	1.28 ± 0.10	1.19 ± 0.12	1.23 ± 0.1	1.13 ± 0.07	1.20 ± 0.09	**.002 (.153)**	**.030 (.059)**	.724 (.008)

* = significantly different from the 30% group at the same time point

= significantly different from the 20% group at the same time point

Table 1.3 Ground Reaction Force (GRF) during the stance phase of gait presented as mean ± s.d., normalized to body weight (BW), p = p-value, ηp2 = partial eta squared, LR = Loading response or first peak vertical GRF. PO = Push-off, or second peak vertical GRF. Bold indicates statistical significance.

	TEN		TWENTY		THIRTY		*p* (η_p^2)		
	PRE	POST	PRE	POST	PRE	POST	Group	Time	Interaction
Lateral GRF	0.012 ±0.016	0.017± 0.016	0.018 ± 0.015	0.02± 0.016	0.019 ± 0.011	0.022 ± 0.013	.332 (.028)	.303 (.014)	.865 (.004)
Medial GRF	0.133 ± 0.032	0.143 ± 0.038	-0.124 ± 0.028	-0.129 ± 0.034	-0.114 ± 0.019	0.126 ± 0.023	.074 (0065)	.164 (.025)	.916 (.002)
Propulsive GRF	0.212 ± 0.021*	0.217 ± 0.033*	0.199 ± 0.033*	0.211 ± 0.029*	0.179 ± 0.028#	0.192 ± 0.034#	**.002 (.152)**	.127 (.030)	.895 (.003)
Braking GRF	0.173 ± 0.033	0.174 ± 0.034	-0.196 ± 0.05	-0.173 ± 0.03	-0.158 ± 0.048	-0.158 ± 0.05	.065 (.068)	.422 (.008)	.488 (.018)
LR Vertical GRF	1.142 ± 0.112	1.179± 0.101	1.149 ± 0.109	1.121 ± 0.087	1.102 ± 0.08	1.12 ± 0.094	.167 (.045)	.675 (.002)	.444 (.021)
PO Vertical GRF	1.140 ± 0.074*	1.140 ± 0.074*	1.085 ± 0.043	1.116 ± 0.042	1.058 ± 0.049	1.078 ± 0.046	**<.001 (.196)**	.065 (.043)	.882 (.003)

* = significantly different from the 30% group at the same time point

= significantly different from the 20% group at the same time point

Table 1.4 Peak joint angles during one stride of the right leg presented as mean ± s.d., reported in degrees, p = p-value ηp 2= partial eta squared. HS = Heel strike, DF = Dorsiflexion, PF = Plantarflexion, TO = Toe-off. Bold indicates statistical significance.

	TEN		TWENTY		THIRTY		p (η_p^2)		
	PRE	POST	PRE	POST	PRE	POST	Group	Time	Interaction
Ankle HS	-1.13 ± 3.94	-0.07 ± 4.44	0.85 ± 3.84	1.12 ± 4.03	0.71 ± 2.34	2.51 ± 3.24	.077 (.064)	.199 (.021)	.741 (.008)
Dorsiflexion	10.3 ± 3.53	9.55 ± 4.04	11.47 ± 4.98	10.98 ± 3.95	8.75 ± 5.1	9.83 ± 6.31	.290 (.031)	.971 (.000)	.778 (.006)
Plantarflexion	-10. ± 2.31	-10.76 ± 2.68	-10.43 ± 3.18	-9.65 ± 3.31	-11.3 ± 4.98	-10.07 ± 5.38	.766 (.007)	.466 (.007)	.732 (.008)
Ankle TO	-5.47 ± 4.58	-6.02 ± 5.29	-6.05 ± 4.64	-6.72 ± 4.62	-7.31 ± 6.62	-7.44 ± 7.75	.564 (.014)	.720 (.002)	.983 (.000)
Knee HS	0.37 ± 4.66*	-0.58 ± 4.87*	-0.34 ± 4.78*	-0.13 ± 5.83*	-0.87 ± 5.44	-1.64 ± 6.69	**<.001 (.898)**	.961 (.000)	.895 (.003)
Knee Extension	2.6 ± 4.8	1.56 ± 6.2	0.76 ± 4.81	1.12 ± 8.09	0.46 ± 5.34	-0.003 ± 6.531	.519 (.017)	.776 (.001)	.911 (.002)
Knee Flexion	-33.49 ± 4.9#*	-33.49 ± 5.54#*	-38.95 ± 5.91	-37.67 ± 8.91	-38.37 ± 7.79	-38.42 ± 8.71	**.016 (.100)**	.793 (.001)	.925 (.002)
Knee TO	-33.07 ± 5.3#*	-32.69 ± 5.77#*	-39.01 ± 5.84*	-36.3 ± 8.57*	-38.35 ± 7.99	-37.8 ± 8.29	**<.001 (.876)**	0.558 (.004)	.597 (.013)
Hip HS	13.17 ± 15.65	12.1 ± 16.9	15.85 ± 16.33	16.68 ± 17.62	20.58 ± 18.46	21.3 ± 19.17	.207 (.404)	0.966 (.000)	.974 (.001)
Hip Flexion	12.75 ± 15.29*	11.69 ± 18.45*	15.55 ± 15.76*	17.31± 17.88*	20.83 ± 18.75	21.6 ± 19.004	**<.001 (.399)**	.906 (.000)	.956 (.001)
Hip Extension	-23.92 ± 18*	-24.9 ± 20.6*	-19.87 ± 14.7*	-18.13 ± 15.86*	-15.48 ± 20.61	-14.78 ± 18.48	**<.001 (.581)**	0.896 (.000)	.960 (.001)
Hip TO	-17.25 ± 18.01	-19.11 ± 20.3	-11.87 ± 15.17	11.84 ± 16.47	-7.68 ± 20.03	-8.27 ± 19.05	.115 (.054)	.840 (.001	.981 (.001)

* = significantly different from the 30% group at the same time point

= significantly different from the 20% group at the same time point

Table 1.5 Peak Joint moments during the stance phase of gait presented as mean ± s.d., reported in Nm/kg. p = p-value ηp2 = partial eta squared.

	TEN		TWENTY		THIRTY		p (η_p^2)		
	PRE	POST	PRE	POST	PRE	POST	Group	Time	Interaction
Ankle Peak DF	0.27 ± 0.1	0.27 ± 0.1	0.29 ± 0.11	0.24 ± 0.09	0.24 ± 0.06	0.23 ± 0.07	.068 (.066)	.141 (.028)	.857 (.004)
Ankle Peak PF	-1.41 ± 0.16	-1.44 ± 0.17	-1.38 ± 0.1	-1.44 ± 0.11	-1.33 ± 0.13	-1.36 ± 0.11	.242 (.036)	.498 (.006)	.558 (.575)
Knee Peak Extension	0.38 ± 0.23	0.4 ± 0.23	0.55 ± 0.22	0.43 ± 0.2	0.38 ± 0.22	0.37 ± 0.25	.057 (.071)	.335 (.012)	.992 (.000)
Knee Peak Flexion	-0.53 ± 0.16	-0.55 ± 0.17	-0.44 ± 0.1	-0.47 ± 0.13	-0.47 ± 0.1	-0.51 ± 0.11	.151 (.047)	.463 (.007)	.455 (.020)
Hip Peak Flexion	0.76 ± 0.27	0.81 ± 0.25	0.63 ± 0.19	0.70 ± 0.32	0.58 ± 0.22	0.65 ± 0.22	.143 (.049)	.151 (.026)	.671 (.010)
Hip Peak Extension	-0.95 ± 0.26	-1.09 ± 0.27	-0.86± 0.18	-0.92 ± 0.23	-0.95 ± 0.26	-0.99 ± 0.28	.061 (.079)	.275 (.015)	.989 (.000)

Table 1.6 Gait velocity (m/s) of Males and Females in each group presented as mean ± s.d. p = p-value.

	TEN			TWENTY			THIRTY		
	Pre	Post	Raw Change	Pre	Post	Raw Change	Pre	Post	Raw Change
Male	1.23 ± 0.06	1.25 ± 0.06	0.02 ± 0.03	1.18 ± 0.11	1.22 ± 0.11	0.04 ± 0.05	1.10 ± 0.07	1.16 ± 0.10	0.06 ± 0.04
Female	1.27 ± 0.13	1.31 ± 0.12	0.04 ± 0.03	1.21 ± 0.13	1.25 ± 0.10	0.04 ± 0.04	1.17 ± 0.05	1.26 ± 0.05	0.09 ± 0.04
p	0.426	0.161	0.278	0.345	0.249	0.171	0.116	0.115	0.400

CHAPTER V – DISCUSSION

The primary objective of our study was to investigate the minimum increment in cycling cadence needed to produce a statistically significant and clinically meaningful increase in post-cycling gait velocity. Our hypothesis, proposing that a gradual increase in cycling cadence would result in a nonlinear improvement in post-cycling gait velocity, was supported, as a 2^{nd}-order polynomial function that best described the increase in post-cycling gait velocity. These findings are consistent with previous studies (Keating et al., 2024; Tsushima et al., 2015)which also reported improvements in post-cycling gait velocity.

Our study revealed that achieving a meaningful increase in post-cycling gait velocity requires a minimum increment of thirty percent or more in cycling cadence, relative to gait cadence. In other words, a thirty percent or greater increase, as demonstrated in the study (Keating et al., 2024), which reported an increment in post-cycling gait velocity by using a thirty-six percent increment of cycling cadence, is necessary. Notably, all three groups in our current study exhibited statistically significant increases in post-cycling gait velocity of 2.4%, 3.4%, and 6.2% for the TEN, TWENTY, and THIRTY groups, respectively. Range of 0.05 m/s – 0.1 m/s could be considered clinically meaningful (Chui et al., 2012; Perera et al., 2006b). In our current study, post-cycling gait velocity for the TEN and TWENTY groups were 0.03 m/s and 0.04 m/s, respectively. On the other hand, the increment observed in the THIRTY group of 0.07 m/s falls within this range.

In addition, participant-specific CV calculations support a minimum increase of cycling cadence of 30% to facilitate a meaningful increase in gait velocity. Our results indicate that 21% of the participants in TEN and 36% of the participants in TWENTY did not walk with a post-cycling gait velocity that fell outside of their window of expected variability. However, in the THIRTY, 100% of the participants walked with a post-cycling gait velocity that was outside the window of expected variability. Moreover, the 2nd-order polynomial equation also revealed that there was a larger increase in post-cycling gait velocity in THIRTY compared to TEN and TWENTY. Collectively, this body of evidence suggests increasing cycling cadence by more than 30% of self-selected gait cadence is necessary to demonstrate meaningful change in post-cycling gait velocity.

Additionally, we hypothesized that there would be a non-linear increase in spatiotemporal parameters of gait across all experimental conditions. However, our hypothesis regarding the spatiotemporal parameters was not supported by the data. Specifically, no statistically significant differences were observed in the spatiotemporal parameters (double limb support, overall cadence, stride width, stride length) between pre- and post-cycling conditions. Keating et al., (2024) reported increased cadence with post-cycling gait velocity with no changes in stride length and stride width. In this current study, there was no change in overall cadence, stride length, or stride width post-cycling.

Our study found no statistically significant differences in the kinematic parameters between the pre- and post-cycling conditions. Additionally, there were no statistically significant variations in lower extremity kinetic variables. These results may be attributed to the relatively limited increases in cycling cadence that we employed in our study. The differences in cadence among our groups were only 10%, which may not have been substantial enough to induce significant changes in the kinematic and kinetic variables. Our TEN was 10%, TWENTY was 20%, and THIRTY was 30% above the self-selected gait cadence and these increments were small changes in cycling cadence which may not have substantially changed the task of walking to be reflected in kinematics or kinetics variables.

Increased gait velocity following high-cadence cycling may be attributed to a decrease in stance time and an increase in cadence (Thorsen et al., 2024). The gait mechanics behind these changes likely result from increased propulsive GRF, were increased joint angular velocity observed at the ankle, knee, and hip during the stance phase of gait (Thorsen et al., 2024). Contrary to these findings, this current study did not detect any significant changes in the spatiotemporal, GRF, kinematic, or kinetic variables. Given that our study involved a short bout of cycling, it is unlikely that the observed increase in gait velocity following cycling was due to an increase in strength or spatiotemporal change. Instead, we speculate that the acute increment in gait velocity may be attributed to neural drive, suggesting that neural mechanisms might play a role in this effect.

Peak propulsive GRF was determined by finding the minimum value of the anteroposterior GRF curve during each stance, with values from all consecutive stances averaged together of right limb. It is possible that this approach could have masked the consecutive peak GRF significance of each individual stride. However, the cumulative effect of increased GRF did play a part in the increased gait velocity post-cycling.

Mann-Whitney U test revealed no statistically significant variations in pre-cycling gait velocities and, post-cycling gait velocities between groups, and the raw changes between pre-cycling and post-cycling gait velocities when comparing males and females.

These results align with previous literature indicating that gait velocity tends to be similar among young healthy adults regardless of sex (Suner-Keklik et al., 2023).

Participants in the THIRTY group exhibited slower gait velocity in both the pre- and post-cycling 10MWT compared to the TEN and TWENTY groups. This difference may be attributed to the random sampling method used to recruit participants and mass variations between the groups as the average mass in THIRTY was higher compared to TEN and TWENTY. We assume similar improvements in post-cycling gait velocity would have been observed if the THIRTY presented with gait velocity similar to those in the TEN and TWENTY groups. The pattern of post-cycling gait velocity was still observed for the THRIY group even though the THRITY group had greater mass. It should be noted, however, that our groups did not differ statistically in mass or height.

Limitations

Several limitations should be acknowledged when interpreting the results of our study. Firstly, our research focused solely on a specific age group, specifically younger adults aged 18-39 years, recruited exclusively from our university. Consequently, the generalizability of our findings to the older adult population may be restricted. Secondly, the use of straps to secure reflective markers on participants' bodies posed an additional limitation. This approach may have introduced soft-tissue artifacts, potentially influenced the trajectories of the markers, and subsequently affected the accuracy of our measurements. Lastly, it is important to recognize that our study was conducted within controlled laboratory settings. Therefore, the extent to which our results can be generalized to the community-dwelling environment may be limited.

Conclusion

Within a population of young, healthy adults aged 18-39 years, we observed a significant and positive correlation between increased cycling cadence and post-cycling gait velocity. Our findings indicate that a minimum increment of 30% or above in cycling cadence is necessary to achieve a meaningful improvement in gait velocity. These results have potential implications for improving gait velocity in populations where reduction in gait velocity matters. Implementing interventions that focus on increasing cycling cadence may prove beneficial in enhancing gait velocity among older individuals.

APPENDIX A – Subject specific variables

Table A.1 Peak Lateral Ground reaction force (GRF) during stance phase of gait presented as mean ± s.d. normalized to body weight (BW)

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	0.01	0.021	0.009	0.023	0.006	0.013
	0.022	0.025	0.004	0.00	0.003	0.007
	0.034	0.032	0.017	0.006	0.031	0.013
	0.021	0.023	0.016	0.021	0.008	-0.008
	0.04	0.046	0.015	0.012	0.003	0.039
	0.003	-0.001	0.033	0.012	0.022	0.032
	0.016	-0.013	0.008	0.015	0.039	0.037
	0.008	0.006	0.016	0.034	0.018	0.02
	-0.026	-0.004	0.018	0.023	0.027	0.025
	0.004	0.019	0.011	-0.002	0.033	0.039
	0.006	0.018	0.011	0.029	0.016	0.014
	0.001	0.032	0.054	0.059	0.016	0.024
	0.024	0.032	0.004	0.013	0.019	0.027
	0.006	0.01	0.042	0.031	0.023	0.027
Mean	0.012	0.018	0.018	0.02	0.019	0.022
s.d.	0.016	0.016	0.015	0.016	0.011	0.013

Table A.2 Peak Medial GRF of each subject during stance phase presented mean ± s.d. normalized to body weight (BW)

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-0.098	-0.121	-0.104	-0.098	-0.121	-0.118
	-0.118	-0.132	-0.143	-0.142	-0.13	-0.129
	-0.109	-0.121	-0.125	-0.156	-0.094	-0.159
	-0.116	-0.13	-0.167	-0.18	-0.118	-0.154
	-0.135	-0.121	-0.16	-0.166	-0.119	-0.123
	-0.16	-0.172	-0.125	-0.131	-0.15	-0.161
	-0.121	-0.159	-0.135	-0.13	-0.119	-0.106
	-0.174	-0.168	-0.087	-0.091	-0.129	-0.122
	-0.183	-0.172	-0.106	-0.096	-0.092	-0.107
	-0.136	-0.132	-0.095	-0.119	-0.074	-0.08
	-0.12	-0.121	-0.122	-0.119	-0.123	-0.131
	-0.193	-0.243	-0.076	-0.075	-0.108	-0.102
	-0.089	-0.086	-0.159	-0.189	-0.109	-0.137
	-0.108	-0.122	-0.127	-0.115	-0.105	-0.129
Mean	-0.133	-0.143	-0.124	-0.129	-0.114	-0.126
s.d.	0.032	0.038	0.028	0.034	0.019	0.023

Table A.3 Peak Anterior GRF of each subject during stance phase presented as mean ± s.d. normalized to body weight (BW)

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	0.222	0.227	0.141	0.186	0.173	0.169
	0.222	0.226	0.162	0.195	0.254	0.278
	0.239	0.233	0.191	0.175	0.17	0.171
	0.232	0.235	0.168	0.171	0.17	0.178
	0.171	0.19	0.241	0.243	0.169	0.177
	0.188	0.207	0.182	0.188	0.173	0.18
	0.212	0.131	0.18	0.229	0.193	0.215
	0.227	0.232	0.174	0.178	0.158	0.166
	0.204	0.219	0.207	0.224	0.189	0.198
	0.2	0.245	0.212	0.227	0.138	0.159
	0.204	0.23	0.241	0.219	0.149	0.149
	0.246	0.272	0.242	0.262	0.179	0.2
	0.21	0.201	0.214	0.214	0.195	0.215
	0.188	0.197	0.233	0.244	0.198	0.228
Mean	0.212	0.218	0.199	0.211	0.179	0.192
s.d.	0.021	0.033	0.033	0.029	0.028	0.034

Table A.4 Peak Posterior GRF of each subject during stance phase of gait presented as mean ± s.d. normalized to body weight (BW)

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-0.155	-0.188	-0.144	-0.152	-0.104	-0.109
	-0.134	-0.114	-0.229	-0.173	-0.221	-0.233
	-0.193	-0.173	-0.18	-0.203	-0.169	-0.098
	-0.15	-0.142	-0.146	-0.122	-0.124	-0.149
	-0.209	-0.227	-0.288	-0.189	-0.183	-0.207
	-0.166	-0.189	-0.233	-0.19	-0.18	-0.179
	-0.216	-0.162	-0.198	-0.196	-0.145	-0.132
	-0.185	-0.208	-0.123	-0.098	-0.093	-0.108
	-0.234	-0.227	-0.192	-0.174	-0.154	-0.139
	-0.14	-0.171	-0.148	-0.174	-0.138	-0.131
	-0.159	-0.155	-0.168	-0.176	-0.118	-0.13
	-0.195	-0.192	-0.182	-0.187	-0.236	-0.2
	-0.163	-0.145	-0.243	-0.2	-0.236	-0.261
	-0.121	-0.137	-0.265	-0.185	-0.108	-0.134
Mean	-0.173	-0.174	-0.196	-0.173	-0.158	-0.158
s.d.	0.033	0.034	0.05	0.03	0.048	0.05

Table A.5 Peak Vertical Loading Response GRF of each subject during stance phase of gait presented as mean ± s.d. normalized to body weight (BW)

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	1.13	1.2	1.04	1.1	0.99	1.01
	1	1.05	1.21	1.15	1.21	1.22
	1.09	1.09	1.1	1.15	1.15	1.1
	1.04	1.05	1.1	1.06	1.03	1.09
	1.25	1.31	1.38	1.2	1.23	1.24
	1.18	1.23	1.28	1.22	1.15	1.21
	1.17	1.23	1.2	1.24	1.09	1.01
	1.21	1.27	1.08	1.04	1.01	1.02
	1.36	1.33	1.05	1	1.02	1.02
	1.21	1.25	0.99	0.94	1.07	1.09
	1.05	1.1	1.09	1.14	1.03	1.06
	1.28	1.24	1.17	1.17	1.2	1.25
	1.05	1.13	1.13	1.11	1.17	1.24
	0.98	1.03	1.27	1.18	1.08	1.13
Mean	1.14	1.18	1.15	1.12	1.1	1.12
s.d.	0.11	0.1	0.11	0.09	0.08	0.09

Table A.6 Peak Vertical Push-off GRF of each subject during stance phase of gait presented as mean ± s.d. normalized to body weight (BW)

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	1.21	1.22	1.05	1.11	1.1	1.06
	1.2	1.3	1.03	1.05	1.11	1.1
	1.22	1.19	1.03	1.08	1.13	1.11
	1.14	1.14	1.08	1.1	1.04	1.07
	1.09	1.1	1.07	1.14	1.03	1.02
	1.07	1.13	1.12	1.14	1.05	1.09
	1.09	1.03	1.11	1.18	1.04	1.09
	1.2	1.2	1.03	1.09	1.05	1.05
	1.04	1.08	1.09	1.11	1.08	1.09
	1.06	1.09	1.12	1.1	1.01	1.03
	1.03	1.08	1.16	1.09	1.02	1.03
	1.16	1.23	1.15	1.22	0.96	1.03
	1.13	1.09	1.1	1.11	1.13	1.17
	1.1	1.09	1.07	1.12	1.07	1.16
Mean	1.12	1.14	1.09	1.12	1.06	1.08
s.d.	0.07	0.08	0.04	0.04	0.05	0.05

Table A.7 Peak Ankle Plantarflexion Angle (degrees) of each subject during one stride of the right leg presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-17.26	-14.52	-44.49	-43.39	-25.35	-20.85
	-19.20	-16.95	-33.99	-28.86	-62.09	-49.56
	-25.03	-40.95	-23.55	-16.91	-36.56	-37.81
	-20.89	-19.80	-27.08	-23.06	-7.78	-3.78
	-53.01	-57.27	-20.47	-13.16	-22.86	-27.69
	-17.85	-14.06	-27.32	-36.87	-36.17	-35.09
	-13.29	-18.35	-27.19	-26.08	-0.86	-3.96
	-22.55	-22.67	-25.36	-30.18	0.60	9.89
	-32.09	-33.93	-19.99	-15.14	-6.06	-6.31
	-56.37	-63.85	-12.25	-9.55	-1.45	-9.54
	-42.00	-37.26	-25.50	-25.80	-14.13	-11.13
	-1.76	9.31	10.09	11.83	17.74	12.78
	-24.35	-23.72	4.99	8.16	2.54	1.26
	10.73	5.47	-6.02	-4.84	-24.35	-25.16
Mean	-23.92	-24.90	-19.87	-18.13	-15.48	-14.78
s.d.	18.00	20.59	14.70	15.86	20.61	18.48

Table A.8 Peak Ankle Dorsiflexion Angle (degrees) of each subject during one stride of the right leg presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-17.26	-14.52	-44.49	-43.39	-25.35	-20.85
	-19.20	-16.95	-33.99	-28.86	-62.09	-49.56
	-25.03	-40.95	-23.55	-16.91	-36.56	-37.81
	-20.89	-19.80	-27.08	-23.06	-7.78	-3.78
	-53.01	-57.27	-20.47	-13.16	-22.86	-27.69
	-17.85	-14.06	-27.32	-36.87	-36.17	-35.09
	-13.29	-18.35	-27.19	-26.08	-0.86	-3.96
	-22.55	-22.67	-25.36	-30.18	0.60	9.89
	-32.09	-33.93	-19.99	-15.14	-6.06	-6.31
	-56.37	-63.85	-12.25	-9.55	-1.45	-9.54
	-42.00	-37.26	-25.50	-25.80	-14.13	-11.13
	-1.76	9.31	10.09	11.83	17.74	12.78
	-24.35	-23.72	4.99	8.16	2.54	1.26
	10.73	5.47	-6.02	-4.84	-24.35	-25.16
Mean	-23.92	-24.90	-19.87	-18.13	-15.48	-14.78
s.d.	18.00	20.59	14.70	15.86	20.61	18.48

Table A.9 Ankle Angle (degrees) at Heel Strike of each subject during one stride of the right leg presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-9.00	-6.18	3.64	2.49	2.23	1.86
	0.76	3.71	-5.67	-4.57	-2.70	-4.20
	1.55	3.04	-2.46	-0.28	4.14	3.54
	2.39	3.18	5.45	10.06	-2.38	1.20
	-1.38	-2.73	-3.72	-4.71	-0.39	2.09
	-0.87	0.61	0.12	0.12	4.31	5.99
	0.19	3.82	-2.61	-1.12	2.36	0.80
	-2.43	3.06	4.33	1.89	2.77	5.19
	-5.19	-3.39	6.11	5.48	-0.13	3.97
	0.99	0.34	0.55	0.34	-1.35	3.76
	0.96	3.17	3.55	5.48	2.15	1.56
	-8.91	-11.30	1.01	1.31	0.91	9.42
	2.34	1.89	4.62	1.92	-1.99	0.51
	2.72	-0.15	-3.02	-2.76	-0.02	-0.54
Mean	-1.13	-0.07	0.85	1.12	0.71	2.51
s.d.	3.94	4.44	3.84	4.03	2.34	3.24

Table A.10 Ankle Angle (degrees) at Toe-off of each subject during one stride of the right leg presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-5.69	-6.44	1.34	-0.65	-10.01	-11.24
	-3.43	0.29	-8.75	-9.58	-13.93	-16.89
	-7.79	-7.49	-7.99	-6.56	-4.95	-6.52
	-6.51	-6.96	3.10	3.65	-12.76	-14.31
	5.58	4.51	-8.79	-10.66	1.58	0.97
	-9.41	-7.58	-7.55	-5.93	-0.61	-2.45
	-3.80	-4.95	-5.35	-7.80	-11.42	-9.82
	-0.36	1.31	-0.01	-1.91	-9.10	-11.52
	-9.15	-9.49	-9.47	-10.14	-10.80	-11.31
	-2.56	-6.43	-9.03	-8.65	4.13	6.71
	-9.17	-11.04	-7.00	-7.75	-0.74	1.61
	-4.86	-6.53	-8.10	-8.15	-5.27	-1.63
	-6.40	-6.83	-3.82	-5.24	-9.05	-6.96
	-13.12	-16.73	-13.34	-14.67	-19.41	-20.83
Mean	-5.48	-6.03	-6.05	-6.72	-7.31	-7.44
s.d.	4.58	5.29	4.64	4.62	6.62	7.75

Table A.11 Peak Knee Flexion Angle (degrees) of each subject during one stride of the right leg presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-33.06	-36.48	-35.73	-33.69	-32.49	-34.07
	-24.22	-27.46	-34.25	-36.53	-19.92	-22.09
	-33.85	-35.41	-42.96	-47.19	-31.94	-25.60
	-35.99	-34.40	-30.34	-30.66	-42.83	-44.78
	-29.42	-28.72	-33.30	-32.04	-46.01	-47.94
	-33.01	-36.44	-35.22	-17.71	-31.05	-30.76
	-32.46	-21.15	-39.82	-39.58	-43.00	-42.46
	-33.06	-33.30	-42.75	-37.17	-43.60	-42.99
	-31.41	-31.43	-37.41	-35.22	-38.87	-38.67
	-31.25	-30.85	-39.64	-36.99	-42.54	-43.28
	-30.68	-35.02	-41.06	-44.83	-42.61	-43.36
	-35.57	-33.96	-43.77	-43.86	-49.95	-53.28
	-39.31	-40.75	-53.96	-56.17	-38.64	-35.96
	-45.56	-43.47	-35.15	-35.79	-33.74	-32.63
Mean	-33.49	-33.49	-38.95	-37.67	-38.37	-38.42
s.d.	4.90	5.54	5.91	8.91	7.79	8.71

Table A.12 Peak Knee Extension Angle (degrees) of each subject during one stride of the right leg presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-1.56	-4.24	4.51	4.89	6.39	9.80
	13.85	13.02	3.00	3.35	6.44	6.53
	1.80	-0.14	2.85	-1.57	1.17	5.35
	7.43	6.53	10.35	7.76	2.16	-4.66
	7.35	6.55	-2.23	0.09	-1.01	1.53
	0.94	-2.00	0.42	17.75	4.69	4.91
	3.66	11.22	-1.91	3.37	-1.54	0.73
	6.34	3.01	-4.88	-0.64	4.03	-0.51
	-3.30	-1.18	0.94	4.14	2.07	0.21
	3.31	3.73	5.26	2.87	2.38	-0.37
	-0.90	-2.29	1.64	-3.99	-3.56	-5.64
	0.04	1.31	-5.87	-7.26	-14.77	-17.48
	-3.19	-5.20	-7.20	-18.40	-1.63	0.40
	0.58	-8.49	3.84	3.35	-0.43	-0.86
Mean	2.60	1.56	0.77	1.12	0.46	0.00
s.d.	4.80	6.20	4.81	8.09	5.34	6.53

Table A.13 Knee Angle (degrees) at Heel Strike of each subject during one stride of the right leg presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-5.08	-6.51	1.62	1.55	6.43	8.31
	12.06	10.36	0.16	1.32	5.47	5.33
	0.89	-1.72	3.52	1.51	-1.95	2.86
	7.07	5.93	7.10	4.80	2.38	-1.86
	1.48	0.31	-1.32	-0.93	-0.03	0.14
	0.73	-1.02	0.39	17.93	0.75	0.00
	2.92	4.83	-1.44	3.62	-2.31	-0.11
	-0.57	-3.07	-2.07	1.05	1.25	-0.49
	-3.35	-1.52	0.50	4.85	2.07	0.21
	0.92	1.86	4.28	3.54	2.38	-0.48
	-2.60	-4.77	-0.87	-3.56	-5.54	-7.83
	-2.17	-2.12	-7.46	-8.16	-15.42	-19.15
	-4.51	-4.70	-11.93	-16.40	-3.52	-4.85
	-2.61	-6.02	2.82	3.06	-4.10	-3.33
Mean	0.37	-0.58	-0.34	1.01	-0.87	-1.52
s.d.	4.66	4.87	4.78	7.57	5.44	6.45

Table A.14 Knee Angle (degrees) at Toe-off of each subject during one stride of the right limb presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-32.81	-34.59	-33.61	-30.85	-32.28	-33.81
	-23.46	-28.90	-34.55	-35.93	-18.50	-22.09
	-33.85	-35.41	-43.55	-45.35	-33.38	-25.50
	-36.62	-35.96	-30.12	-27.71	-42.66	-41.12
	-28.73	-27.36	-33.54	-32.96	-43.46	-44.77
	-35.75	-35.36	-34.90	-16.21	-31.05	-30.76
	-29.35	-17.98	-42.10	-36.13	-43.09	-40.99
	-29.10	-33.75	-43.08	-37.84	-46.21	-43.06
	-29.85	-30.04	-36.65	-32.70	-38.87	-38.67
	-32.00	-31.36	-38.85	-38.28	-42.54	-43.28
	-31.46	-33.61	-44.91	-43.42	-42.61	-43.36
	-35.57	-33.96	-44.20	-44.25	-49.95	-53.28
	-39.56	-35.61	-50.88	-51.15	-38.64	-35.96
	-44.94	-43.84	-35.28	-35.48	-33.74	-32.63
Mean	-33.08	-32.70	-39.02	-36.30	-38.36	-37.81
s.d.	5.30	5.77	5.84	8.57	7.99	8.29

Table A.15 Peak Hip Extension Angle (degrees) of each subject during one stride presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-17.26	-14.52	-44.49	-43.39	-25.35	-20.85
	-19.20	-16.95	-33.99	-28.86	-62.09	-49.56
	-25.03	-40.95	-23.55	-16.91	-36.56	-37.81
	-20.89	-19.80	-27.08	-23.06	-7.78	-3.78
	-53.01	-57.27	-20.47	-13.16	-22.86	-27.69
	-17.85	-14.06	-27.32	-36.87	-36.17	-35.09
	-13.29	-18.35	-27.19	-26.08	-0.86	-3.96
	-22.55	-22.67	-25.36	-30.18	0.60	9.89
	-32.09	-33.93	-19.99	-15.14	-6.06	-6.31
	-56.37	-63.85	-12.25	-9.55	-1.45	-9.54
	-42.00	-37.26	-25.50	-25.80	-14.13	-11.13
	-1.76	9.31	10.09	11.83	17.74	12.78
	-24.35	-23.72	4.99	8.16	2.54	1.26
	10.73	5.47	-6.02	-4.84	-24.35	-25.16
Mean	-23.92	-24.90	-19.87	-18.13	-15.48	-14.78
s.d.	18.00	20.59	14.70	15.86	20.61	18.48

Table A.16 Peak Hip Flexion Angle (degrees) of each subject during one stride of the right limb presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	23.31	29.26	-14.25	-7.12	7.45	8.07
	12.02	12.38	-2.07	4.67	-12.92	-10.42
	19.59	-0.19	7.81	11.46	4.68	3.68
	9.91	9.33	13.42	15.79	23.50	32.84
	-13.45	-14.87	24.19	26.22	8.75	7.53
	20.58	21.34	12.55	-2.25	1.72	3.14
	20.11	23.37	8.24	5.68	32.34	31.34
	16.51	16.65	6.96	2.08	30.81	36.18
	-2.08	-1.74	14.72	21.07	28.49	29.71
	-13.90	-23.83	17.37	20.78	26.29	19.50
	2.47	0.26	13.65	9.70	21.59	24.35
	35.04	40.62	47.19	50.62	60.05	59.96
	12.86	15.05	39.72	50.11	44.72	44.92
	35.60	35.96	28.26	33.51	14.09	11.60
Mean	12.76	11.69	15.55	17.31	20.83	21.60
s.d.	15.29	18.45	15.76	17.88	18.75	19.00

Table A.17 Hip Angle (degrees) at Heel Strike of each subject during one stride of the right limb presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	24.69	28.17	-14.07	-8.72	7.39	7.88
	10.52	11.74	-0.95	4.07	-15.79	-12.67
	19.55	-0.19	7.80	10.08	8.01	3.51
	9.24	10.11	12.06	15.84	23.98	30.66
	-12.79	-12.50	21.95	24.57	8.78	8.31
	19.68	21.16	10.28	-2.10	1.63	3.00
	22.80	22.20	8.77	8.86	32.47	31.04
	17.21	16.33	6.22	1.65	31.89	37.94
	0.60	0.48	15.44	19.04	28.47	29.71
	-15.26	-20.17	17.93	19.31	25.12	19.26
	2.25	4.54	14.36	8.83	21.26	24.33
	35.01	40.62	48.76	49.56	56.82	59.58
	13.17	13.77	41.36	49.02	44.13	44.13
	37.66	33.13	31.92	33.49	13.98	11.58
Mean	13.17	12.10	15.85	16.68	20.58	21.30
s.d.	15.65	16.90	16.33	17.62	18.46	19.17

Table A.18 Hip Angle (degrees) at Toe-off of each subject during one stride of right leg presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-11.73	-8.64	-43.07	-39.00	-17.21	-15.03
	-14.58	-11.74	-24.81	-23.26	-49.00	-45.42
	-18.29	-35.38	-10.64	-8.86	-26.83	-31.06
	-13.07	-13.01	-17.98	-17.61	-1.46	1.50
	-47.35	-51.97	-13.11	-9.51	-18.75	-20.70
	-8.85	-8.87	-19.03	-31.60	-30.76	-29.71
	-9.56	-16.35	-17.26	-21.02	7.06	3.98
	-17.65	-15.68	-18.71	-22.05	11.65	17.41
	-28.32	-28.64	-13.62	-11.65	-0.22	0.71
	-46.15	-54.97	-6.70	-4.43	7.26	-0.13
	-34.15	-32.14	-12.44	-14.65	-3.94	-1.27
	8.02	16.44	19.59	20.12	25.49	19.22
	-17.83	-17.02	10.12	15.48	8.07	4.64
	18.00	10.40	1.49	2.31	-18.89	-19.90
Mean	-17.25	-19.11	-11.87	-11.84	-7.68	-8.27
s.d.	18.01	20.30	15.17	16.47	20.03	19.05

Table A.19 Peak Ankle Plantarflexion Moment (Nm/kg) of each subject during stance phase of gait presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-1.67	-1.73	-1.42	-1.58	-1.52	-1.45
	-1.65	-1.79	-1.31	-1.49	-1.41	-1.37
	-1.33	-1.31	-1.48	-1.56	-1.56	-1.56
	-1.43	-1.37	-1.35	-1.44	-1.21	-1.28
	-1.17	-1.37	-1.26	-1.32	-1.28	-1.26
	-1.25	-1.31	-1.27	-1.29	-1.23	-1.26
	-1.27	-1.18	-1.26	-1.43	-1.25	-1.30
	-1.44	-1.52	-1.32	-1.35	-1.21	-1.23
	-1.44	-1.41	-1.34	-1.38	-1.36	-1.39
	-1.27	-1.32	-1.33	-1.34	-1.34	-1.46
	-1.26	-1.32	-1.50	-1.44	-1.55	-1.57
	-1.55	-1.62	-1.60	-1.67	-1.26	-1.34
	-1.54	-1.50	-1.39	-1.40	-1.27	-1.33
	-1.50	-1.46	-1.44	-1.50	-1.22	-1.29
Mean	-1.41	-1.44	-1.38	-1.44	-1.33	-1.36
s.d.	0.16	0.17	0.10	0.11	0.13	0.11

Table A.20 Peak Ankle Dorsiflexion Moment (Nm/kg) of each subject during stance phase of gait presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	0.2	0.3	0.2	0.1	0.2	0.2
	0.3	0.3	0.3	0.3	0.2	0.2
	0.4	0.3	0.1	0.1	0.2	0.1
	0.3	0.3	0.3	0.2	0.1	0.2
	0.5	0.4	0.6	0.5	0.3	0.4
	0.3	0.3	0.4	0.4	0.2	0.2
	0.3	0.4	0.4	0.3	0.2	0.2
	0.3	0.4	0.3	0.2	0.2	0.2
	0.2	0.3	0.2	0.2	0.2	0.3
	0.2	0.3	0.2	0.2	0.2	0.2
	0.2	0.3	0.3	0.2	0.2	0.2
	0.1	0.0	0.2	0.2	0.4	0.3
	0.2	0.2	0.3	0.2	0.3	0.3
	0.2	0.2	0.3	0.3	0.3	0.3
Mean	0.3	0.3	0.3	0.2	0.2	0.2
s.d.	0.1	0.1	0.1	0.1	0.1	0.1

Table A.21 Peak Knee Flexion Moment (Nm/kg) of each subject during stance phase of gait presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-0.48	-0.42	-0.49	-0.59	-0.48	-0.50
	-0.93	-0.86	-0.39	-0.49	-0.62	-0.61
	-0.41	-0.39	-0.41	-0.22	-0.52	-0.50
	-0.41	-0.39	-0.46	-0.44	-0.35	-0.29
	-0.49	-0.64	-0.47	-0.61	-0.50	-0.60
	-0.36	-0.33	-0.49	-0.37	-0.44	-0.43
	-0.53	-0.68	-0.49	-0.61	-0.45	-0.49
	-0.61	-0.62	-0.31	-0.34	-0.41	-0.41
	-0.58	-0.60	-0.34	-0.41	-0.45	-0.47
	-0.75	-0.59	-0.46	-0.45	-0.63	-0.65
	-0.33	-0.41	-0.50	-0.63	-0.52	-0.61
	-0.45	-0.62	-0.47	-0.49	-0.32	-0.40
	-0.63	-0.81	-0.26	-0.29	-0.36	-0.48
	-0.47	-0.36	-0.67	-0.63	-0.60	-0.66
Mean	-0.53	-0.55	-0.44	-0.47	-0.48	-0.51
s.d.	0.16	0.17	0.10	0.13	0.10	0.11

Table A.22 Peak Knee Extension Moment (Nm /kg) of each subject during stance phase of gait presented as mean ± s.d)

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	0.52	0.64	0.43	0.59	0.07	0.06
	-0.06	-0.06	0.98	0.57	0.46	0.37
	0.21	0.15	0.47	0.47	0.36	0.19
	0.08	0.07	0.58	0.36	0.23	0.34
	0.74	0.70	0.67	0.29	0.52	0.59
	0.34	0.42	0.61	0.38	0.57	0.55
	0.46	0.42	0.59	0.47	0.41	0.16
	0.49	0.50	0.62	0.45	0.12	0.10
	0.63	0.52	0.24	0.19	0.20	0.20
	0.61	0.67	0.21	0.16	0.39	0.51
	0.52	0.50	0.33	0.08	0.43	0.38
	0.26	0.35	0.58	0.59	0.87	0.89
	0.41	0.57	0.91	0.83	0.57	0.72
	0.11	0.20	0.43	0.53	0.18	0.18
Mean	0.38	0.40	0.55	0.43	0.38	0.37
s.d.	0.23	0.23	0.22	0.20	0.21	0.25

Table A.23 Peak Hip Extension Moment (Nm/kg) of each subject during stance phase of gait presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	-1.16	-1.14	-0.66	-1.05	-0.60	-0.65
	-0.85	-1.00	-0.68	-0.68	-0.90	-0.64
	-0.95	-0.86	-0.63	-0.56	-0.85	-0.93
	-0.89	-0.88	-0.85	-0.78	-0.68	-0.61
	-0.77	-1.12	-1.15	-1.35	-1.02	-1.16
	-0.77	-0.81	-1.11	-0.74	-0.83	-0.82
	-1.03	-1.48	-1.04	-1.25	-0.92	-0.96
	-0.72	-0.90	-0.65	-0.67	-0.88	-0.87
	-0.69	-1.17	-0.71	-0.85	-0.85	-0.91
	-1.52	-1.29	-0.92	-0.91	-1.10	-1.23
	-0.67	-0.82	-1.03	-1.01	-1.10	-1.25
	-1.04	-1.35	-1.03	-1.16	-1.58	-1.44
	-1.37	-1.64	-0.77	-0.89	-0.72	-0.89
	-0.83	-0.82	-0.84	-0.91	-1.30	-1.45
Mean	-0.95	-1.09	-0.86	-0.92	-0.95	-0.99
s.d.	0.26	0.27	0.18	0.23	0.26	0.28

Table A.24 Peak Hip Flexion Moment (Nm/kg) of each subject during stance phase of gait presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	0.76	0.79	0.73	1.02	0.88	0.82
	0.71	0.90	0.73	0.80	0.94	0.74
	0.79	0.74	0.64	0.46	0.76	1.04
	0.67	0.61	0.95	0.81	0.60	0.66
	1.08	1.07	0.71	0.69	0.69	0.83
	0.70	0.76	0.81	1.36	0.84	0.94
	0.64	1.06	0.93	1.12	0.58	0.69
	0.56	0.52	0.54	0.80	0.28	0.23
	0.35	0.44	0.46	0.65	0.54	0.69
	1.20	1.27	0.61	0.63	0.33	0.49
	0.75	0.70	0.60	0.32	0.52	0.51
	1.00	0.95	0.43	0.40	0.24	0.38
	1.17	1.05	0.31	0.22	0.40	0.46
	0.28	0.47	0.42	0.47	0.60	0.63
Mean	0.76	0.81	0.63	0.70	0.59	0.65
s.d.	0.28	0.25	0.19	0.32	0.22	0.22

Table A.25 Peak Limb Support Time (s) of each subject during stance phase of gait presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	0.16	0.16	0.27	0.26	0.29	0.29
	0.21	0.21	0.23	0.22	0.21	0.19
	0.09	0.09	0.24	0.25	0.23	0.24
	0.20	0.20	0.32	0.32	0.25	0.23
	0.18	0.17	0.14	0.16	0.21	0.20
	0.22	0.18	0.19	0.19	0.22	0.20
	0.21	0.20	0.23	0.20	0.24	0.22
	0.19	0.17	0.29	0.27	0.29	0.26
	0.16	0.14	0.25	0.25	0.25	0.23
	0.18	0.18	0.17	0.17	0.33	0.33
	0.25	0.23	0.21	0.20	0.12	0.11
	0.06	0.06	0.21	0.22	0.11	1.11
	0.17	0.17	0.25	0.24	0.26	0.12
	0.25	0.23	0.20	0.19	0.11	0.10
Mean	0.18	0.17	0.23	0.22	0.22	0.27
s.d.	0.05	0.05	0.05	0.04	0.07	0.25

Table A.26 Stride Width (m) of each subject presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	0.17	0.17	0.18	0.22	0.25	0.24
	0.20	0.21	0.29	0.23	0.23	0.22
	0.16	0.17	0.26	0.29	0.22	0.25
	0.22	0.22	0.26	0.27	0.24	0.26
	0.21	0.20	0.20	0.19	0.22	0.23
	0.22	0.21	0.22	0.23	0.24	0.23
	0.20	0.23	0.24	0.22	0.21	0.21
	0.21	0.18	0.17	0.19	0.21	0.22
	0.21	0.22	0.25	0.22	0.17	0.18
	0.20	0.22	0.17	0.17	0.18	0.18
	0.20	0.21	0.19	0.20	0.24	0.24
	0.30	0.31	0.18	0.16	0.24	0.20
	0.14	0.18	0.29	0.30	0.18	0.20
	0.23	0.20	0.20	0.20	0.17	0.18
Mean	0.21	0.21	0.22	0.22	0.21	0.22
s.d.	0.04	0.03	0.04	0.04	0.03	0.03

Table A.27 Stride Length (m) of each subject presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	1.31	1.33	1.39	1.43	1.31	1.33
	1.40	1.41	1.24	1.32	1.37	1.37
	1.31	1.34	1.32	1.32	1.29	1.29
	1.30	1.28	1.33	1.34	1.24	1.29
	1.35	1.37	1.35	1.34	1.33	1.39
	1.27	1.28	1.23	1.26	1.23	1.29
	1.34	1.35	1.31	1.39	1.29	1.32
	1.28	1.33	1.29	1.31	1.24	1.26
	1.36	1.38	1.28	1.33	1.37	1.36
	1.32	1.36	1.37	1.40	1.17	1.42
	1.34	1.38	1.37	1.35	1.02	1.27
	1.26	1.27	1.34	1.34	1.37	1.11
	1.35	1.29	1.34	1.33	1.26	1.32
	1.34	1.35	1.39	1.41	1.30	1.30
Mean	1.32	1.34	1.33	1.35	1.27	1.31
s.d.	0.04	0.04	0.05	0.05	0.09	0.07

Table A.28 Overall Cadence (steps/min) of each subject presented as mean ± s.d. normalized to body weight (BW)

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	108.21	108.66	96.86	101.29	92.80	93.44
	98.80	101.34	107.31	114.24	104.04	103.32
	121.74	122.29	110.36	107.64	104.85	112.14
	111.77	112.38	94.04	92.81	110.09	114.03
	108.18	109.70	122.61	125.74	115.46	121.56
	111.06	117.47	113.04	110.25	111.42	113.64
	117.98	117.23	114.99	121.59	112.61	119.75
	113.64	115.95	96.81	103.24	101.99	104.42
	110.55	112.65	105.31	110.24	104.91	108.04
	115.08	119.77	118.40	119.76	95.41	98.30
	103.93	105.36	115.30	118.43	110.37	117.54
	140.33	149.20	118.25	117.40	97.34	116.63
	131.70	135.71	100.75	102.87	107.13	114.85
	109.61	113.30	104.24	108.32	116.08	122.72
Mean	114.47	117.22	108.45	110.99	106.04	111.46
s.d.	10.83	12.34	9.10	9.13	7.26	8.81

Table A.29 Gait Velocity (m/s) of each subject presented as mean ± s.d.

	TEN Pre	TEN Post	TWENTY Pre	TWENTY Post	THIRTY Pre	THIRTY Post
	1.18	1.19	1.13	1.21	0.99	1
	1.14	1.15	1.11	1.19	1.11	1.15
	1.28	1.33	1.2	1.18	1.11	1.16
	1.22	1.21	1.05	1.08	1.13	1.22
	1.19	1.24	1.39	1.36	1.19	1.35
	1.19	1.25	1.09	1.08	1.16	1.2
	1.27	1.24	1.27	1.37	1.19	1.28
	1.22	1.27	1.01	1.1	1	1.07
	1.32	1.34	1.12	1.21	1.2	1.22
	1.26	1.32	1.35	1.39	1.11	1.17
	1.15	1.22	1.27	1.27	1.15	1.21
	1.46	1.49	1.32	1.31	1.15	1.23
	1.46	1.46	1.18	1.23	1.11	1.26
	1.18	1.25	1.23	1.29	1.26	1.34
Mean	1.25	1.28	1.19	1.23	1.13	1.2
s.d.	0.1	0.1	0.12	0.1	0.07	0.09

APPENDIX B – IRB Approval Letter

Office of Research Integrity

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

118 COLLEGE DRIVE #5116 • HATTIESBURG, MS | 601.266.6756 | WWW.USM.EDU/ORI

NOTICE OF INSTITUTIONAL REVIEW BOARD ACTION

The project below has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services regulations (45 CFR Part 46), and University Policy to ensure:

- The risks to subjects are minimized and reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered involving risks to subjects must be reported immediately. Problems should be reported to ORI using the Incident form available in InfoEd.
- The period of approval is twelve months. If a project will exceed twelve months, a request should be submitted to ORI using the Renewal form available in InfoEd prior to the expiration date.

PROTOCOL NUMBER:	23-1033
PROJECT TITLE:	Effects of increased cycling cadence on post-cycling gait velocity
SCHOOL/PROGRAM	College of Education & Human Sciences
RESEARCHERS:	PI: Nitu Lama Investigators: Thorsen, Tanner Austin~Lama, Nitu~
IRB COMMITTEE ACTION:	Approved
CATEGORY:	Expedited Category
PERIOD OF APPROVAL:	25-Jan-2024 to 24-Jan-2025

Donald Sacco, Ph.D.
Institutional Review Board Chairperson

APPENDIX C – Health History Questionnaire

Health History Questionnaire

YES	NO	
☐	☐	1. Has your doctor ever said that you have a heart condition and that you should only do activity recommended by a doctor?
☐	☐	2. Do you feel pain in your chest when you do physical activity?
☐	☐	3. In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4. Do you lose your balance because of dizziness, or do you ever lose consciousness?
☐	☐	5. Do you have a bone or joint problem (For example, back, knee, or hip) that could be made worse by a change in your physical activity?
☐	☐	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7. Do you know of any other reason why you should not do physical activity?
☐	☐	8. Have you had any lower extremity injuries within the last 6 months?
☐	☐	9. Have you ever had a lower extremity surgery?
☐	☐	10. Do you currently have any neurological disorders or use assisted walking devices (i.e., prosthetic limb, prophylactic braces)?

If you answered NO honestly to all questions, you can be reasonably sure that you can:

- Start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- Take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If you reading is over 144/94, talk with your doctor before you start becoming much more physically active.
-

If you answered YES to one or more questions, talk with your doctor by phone or in person BEFORE you start becoming more physically active or BEFORE you have a fitness appraisal.

- You may be able to do any activity you want – as long as you start slowly and build up gradually. Or, you may need to restrict activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in a follow his/her advice.
- Find out which community programs are safe and helpful for you.

Name (print):______________________________ Date ___/___/______

Signature:_________________________________

APPENDIX D – Informed Consent Form

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

The School of Kinesiology & Nutrition

STANDARD (SIGNED) INFORMED CONSENT

Today's date:

PROJECT INFORMATION		
Project Title: Effects of Increasing Cycling Cadence on Post-Cycling Gait Velocity: An Experimental Study		
Protocol Number: 23-1033		
Principal Investigator:	Phone:	Email:
Nitu Lama	601-266-6503	nitu.lama@usm.edu
College: Education and Human Sciences		**School and Program:** School of Kinesiology and Nutrition

RESEARCH DESCRIPTION

1. **Purpose:**
As people get older, their ability to walk can decline. Scientists have found that certain factors, like the speed of walking, the number of steps taken per minute, and balance, tend to decrease with age. To help improve these factors, researchers have used stationary bikes to train older adults. Studies have shown that cycling can increase the number of steps taken per minute, which indirectly improves walking speed. Previous research from our laboratory has shown that cycling at higher speeds than walking can make people walk faster, but we don't know exactly how much faster cycling needs to be to improve walking speed. Therefore, the goal of our research is to examine how increasing the speed of cycling affects how fast people walk afterward. By understanding this relationship better, we hope to find ways to help older adults improve their walking abilities and maintain their independence.

2. **Description of Study**
You will do a single tesing session lasting about an hour. When you arrive at the lab, you will be given information about the study and asked to fill out a questionnaire about your health history. This questionnaire is important to identify any participants who may have had cardiovascular problems or injuries in the past. If you indicate any current or previous cardiovascular, metabolic, or neurological diseases, you will be asked to get a medical release from their doctor before taking part in the study.

After obtaining informed consent, you will be given instructions for the tests you will undergo and will be randomly assigned to one of three cycling groups. Adhesive reflective markers will be placed on specific body locations to track movement during the tests.

You will be asked to perform three Ten Meter Walk Tests (10MWT). Then, you will complete a single 15-minute cycling session. You will be instructed to cycle at a specific cadence according to their assigned group (10%, 20%, 30%) at a moderate exercise intensity. After this single cycling session, you will perform three more 10MWT. This will be done using motion capture cameras and force platforms.

3. **Benefits**

You will likely receive no direct benefit from taking part in this research study.

4. **Risks**

Due to the nature of the exercise that is employed in the study, the risk for musculature injury is present. The level of exercising required in this study may increase the risk of a cardiovascular event or sudden death. However, screening tools that determine physical activity readiness will greatly reduce any chance of this type of event. Discomforts associated with moderate to vigorous intensity exercise may result from the single cycling session.

Trained, non-physician exercise specialists certified in CPR, basic life support, and exercise testing will supervise participants undergoing testing. All participants will be instructed to report any unexpected problems or adverse events they may encounter during the course of the study to study personnel.

Additionally, the inclusion criteria of being physical active for the past three months and the completion of the health history questionnaire, along with the submaximal nature of the exercise we believe reduces the risk of musculature injury. The following will be in place to help mitigate the consequences of an adverse cardiovascular event during exercise: the researcher on site is certified in CPR, an automated external defibrillator (AED) is located outside the laboratory, and 911 will be called. I will be encouraged to rest any time I feel tired. If I feel uncomfortable and do not want to continue, I need only let one of the researchers know. It is suggested that you wear appropriate clothes to perform cycling exercise in. These include shorts, t-shirt, and athletic shoes. You are also encouraged to bring water to drink during the cycling exercise. If a participant does not bring water to drink, the researchers will instruct participants that the nearest water fountain is immediately outside of the laboratory.

5. **Confidentiality**

Every effort will be made to maintain the confidentiality of the study records.
Only members of the research team will be allowed to inspect sections of my research records related to this study. If the findings from the study are published, I will not be identified by name. My identity will remain confidential unless disclosure is required by law. My Protected Health Information such as name, address, date of birth, etc. is stored in a separate database at University Southern Mississippi.

6. **Alternative Procedures**

No alternatives are available if I choose not to participate in this study.

7. **Participant Assurance:**
   This project and this consent form have been reviewed by USM's Institutional Review Board, which ensures that research projects involving human subjects follow federal regulations. Any questions or concerns about rights as a research participant should be directed to:

   Chair of the Institutional Review Board
   The University of Southern Mississippi
   118 College Dr. #5125
   Hattiesburg, MS 39406-0001
   601-266-5997

REFERENCES

Abellan Van Kan, G., Rolland, Y., Andrieu, S., Bauer, J., Beauchet, O., Bonnefoy, M., Cesari, M., Donini, L., Gillette-guyonnet, S., Inzitari, M., Nourhashemi, F., Onder, G., Ritz, P., Salva, A., Visser, M., Vellas, B., & Abellan van Kan, G. (2009). GAIT SPEED AT USUAL PACE AS A PREDICTOR OF ADVERSE OUTCOMES IN COMMUNITY-DWELLING OLDER PEOPLE AN INTERNATIONAL ACADEMY ON NUTRITION AND AGING (IANA) TASK FORCE. In *The Journal of Nutrition* (Vol. 13, Issue 10).

Abu Samah, Z., Mohd Nordin, N. A., Shahar, S., & Singh, D. K. A. (2016). Can gait speed test be used as a falls risk screening tool in community dwelling older adults? A review. In *Polish Annals of Medicine* (Vol. 23, Issue 1, pp. 61–67). Urban and Partner. https://doi.org/10.1016/j.poamed.2015.04.007

Alfaro-Acha, A., Al Snih, S., Raji, M. A., Markides, K. S., & Ottenbacher, K. J. (2007). Does 8-foot walk time predict cognitive decline in older Mexicans Americans? *Journal of the American Geriatrics Society*, *55*(2), 245–251. https://doi.org/10.1111/j.1532-5415.2007.01039.x

Ambrose, A. F., Paul, G., & Hausdorff, J. M. (2013). Risk factors for falls among older adults: A review of the literature. In *Maturitas* (Vol. 75, Issue 1, pp. 51–61). https://doi.org/10.1016/j.maturitas.2013.02.009

American College of Sports Medicine. (2013). *ACSM's guidelines for exercise testing and prescription* (9th edition). Lippincott williams & wilkins.

Bezner, S. A. (1996). *The development of a gait evaluation tool*. Texas Woman's University.

Brown, C. N., Padua, D. A., Marshall, S. W., & Guskiewicz, K. M. (2009). Variability of motion in individuals with mechanical or functional ankle instability during a stop jump maneuver. *Clinical Biomechanics*, *24*(9), 762–768. https://doi.org/10.1016/j.clinbiomech.2009.07.001

Cerny, K. (1983). *A Clinical Method of Quantitative Gait Analysis Suggestion from the Field* (Vol. 63, Issue 7).

Christensen, L. O. D., Johannsen, P., Sinkjaer, T., Petersen, N., Pyndt, H. S., & Nielsen, J. B. (2000). Cerebral activation during bicycle movements in man. *Experimental Brain Research*, *135*(1), 66–72. https://doi.org/10.1007/s002210000493

Chui, K., Hood, E., & Klima, D. (2012). Meaningful change in walking speed. In *Topics in Geriatric Rehabilitation* (Vol. 28, Issue 2, pp. 97–103). https://doi.org/10.1097/TGR.0b013e3182510195

Correale, L., Febbi, M., Pellino, V. C., Marin, L., & Vandoni, M. (2021). Comparison of an inertial measurement unit system and baropodometric platform for measuring spatiotemporal parameters and walking speed in healthy adults. *Motor Control*, *25*(1), 89–99. https://doi.org/10.1123/MC.2020-0060

El-Khoury, F., Cassou, B., Latouche, A., Aegerter, P., Charles, M. A., & Dargent-Molina, P. (2015). Effectiveness of two year balance training programme on prevention of fall induced injuries in at risk women aged 75-85 living in community: Ossébo randomised controlled trial. *BMJ (Online)*, *351*. https://doi.org/10.1136/bmj.h3830

Espy, D. D., Yang, F., Bhatt, T., & Pai, Y. C. (2010). Independent influence of gait speed and step length on stability and fall risk. *Gait and Posture*, *32*(3), 378–382. https://doi.org/10.1016/j.gaitpost.2010.06.013

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). *Statistics textbooks in the*.

Florence, C. S., Bergen, G., Atherly, A., Burns, E., Stevens, J., & Drake, C. (2018). Medical Costs of Fatal and Nonfatal Falls in Older Adults. *Journal of the American Geriatrics Society*, *66*(4), 693–698. https://doi.org/10.1111/jgs.15304

Fukuchi, C. A., Fukuchi, R. K., & Duarte, M. (2018). A public dataset of overground and treadmill walking kinematics and kinetics in healthy individuals. *PeerJ*, *2018*(4). https://doi.org/10.7717/peerj.4640

Gillespie, L. D., Robertson, M. C., Gillespie, W. J., Sherrington, C., Gates, S., Clemson, L. M., & Lamb, S. E. (2012). Interventions for preventing falls in older people living in the community. In *Cochrane Database of Systematic Reviews* (Vol. 2012, Issue 9). John Wiley and Sons Ltd. https://doi.org/10.1002/14651858.CD007146.pub3

Gomez Bernal., A., Becerro-de-Bengoa-Vallejo, R., & Losa-Iglesias, M. E. (2016a). Reliability of the OptoGait portable photoelectric cell system for the quantification of spatial-temporal parameters of gait in young adults. *Gait and Posture, 50,* 196–200. https://doi.org/10.1016/j.gaitpost.2016.08.035

Gomez Bernal., A., Becerro-de-Bengoa-Vallejo, R., & Losa-Iglesias, M. E. (2016b). Reliability of the OptoGait portable photoelectric cell system for the quantification of spatial-temporal parameters of gait in young adults. *Gait and Posture, 50,* 196–200. https://doi.org/10.1016/j.gaitpost.2016.08.035

Grood, E. S., & Suntay, W. J. (1983). *A Joint Coordinate System for the Clinical Description of Three-Dimensional Motions: Application to the Knee 1*. http://asmedigitalcollection.asme.org/biomechanical/article-pdf/105/2/136/5599866/136_1.pdf?casa_token=rNwXu2KZr34AAAAA:WBi0FOjZUDH-RoNeA-1qXpPUTdDcyrxc1lGzDsKixH8HEgI8qYIkrI5W6Zj7WuP-lpvJlA

HAS-Motion Product Documentation. (n.d.). *Metric Compute Temporal Distance - Software Product Documentation*. Retrieved June 14, 2024, from https://wiki.has-motion.com/Metric_Compute_Temporal_Distance

Hebenstreit, F., Leibold, A., Krinner, S., Welsch, G., Lochmann, M., & Eskofier, B. M. (2015). Effect of walking speed on gait sub phase durations. *Human Movement Science*, *43*, 118–124. https://doi.org/10.1016/j.humov.2015.07.009

Houglam A, P., & Bertoti B, D. (2011). *Brunnstrom's Clinical Kinesiology* (Sixth). F.A. Davis Company.

Iwamoto, J., Suzuki, H., Tanaka, K., Kumakubo, T., Hirabayashi, H., Miyazaki, Y., Sato, Y., Takeda, T., & Matsumoto, H. (2009). Preventative effect of exercise against falls in the elderly: A randomized controlled trial. *Osteoporosis International*, *20*(7), 1233–1240. https://doi.org/10.1007/s00198-008-0794-9

Jain, S., Gourab, K., Schindler-Ivens, S., & Schmit, B. D. (2013). EEG during pedaling: Evidence for cortical control of locomotor tasks. *Clinical Neurophysiology*, *124*(2), 379–390. https://doi.org/10.1016/j.clinph.2012.08.021

Judge, J. O., Davis, R. B., & Ounpuu, S. (1996). Step Length Reductions in Advanced Age The Role of Ankle and Hip Kinetics. In *Journal of Gerontology: MEDICAL*

SCIENCES (Vol. 51, Issue 6). https://academic.oup.com/biomedgerontology/article/51A/6/M303/593071

Kadaba, M. P., Ramakrishnan, H. K., & Wootten, M. E. (1990). Measurement of lower extremity kinematics during level walking. *Journal of Orthopaedic Research*, *8*(3), 383–392. https://doi.org/10.1002/jor.1100080310

Kasović, M., Štefan, L., & Štefan, A. (2021). Normative data for gait speed and height norm speed in ≥ 60-year-old men and women. *Clinical Interventions in Aging*, *16*, 225–230. https://doi.org/10.2147/CIA.S290071

Keating, C. J., Hester, R. J., & Thorsen, T. A. (2024). High cadence cycling not high work rate, increases gait velocity post-exercise. *Sports Biomechanics*. https://doi.org/10.1080/14763141.2024.2315245

Kitaoka, H. B., Crevoisier, X. M., Hansen, D., Katajarvi, B., Harbst, K., & Kaufman, K. R. (2006). *Foot and Ankle Kinematics and Ground Reaction Forces During Ambulation*.

Leach, D. H., Ormrod, K., & Clayton, H. M. (1984). Standardised terminology for the description and analysis of equine locomotion. In *EQUINE VETERINARY JOURNAL Equine vet. J* (Issue 6).

Lee, K. (2021). Virtual reality gait training to promote balance and gait among older people: A randomized clinical trial. *Geriatrics (Switzerland), 6*(1), 1–11. https://doi.org/10.3390/geriatrics6010001

Legters, K. (2002). *Fear of Falling*. https://academic.oup.com/ptj/article/82/3/264/2837020

Ludyga, S., Gronwald, T., & Hottenrott, K. (2016). Effects of high vs. low cadence training on cyclists' brain cortical activity during exercise. *Journal of Science and Medicine in Sport*, *19*(4), 342–347. https://doi.org/10.1016/j.jsams.2015.04.003

McCrum, C., Gerards, M. H. G., Karamanidis, K., Zijlstra, W., & Meijer, K. (2017). A systematic review of gait perturbation paradigms for improving reactive stepping responses and falls risk among healthy older adults. In *European Review of Aging and Physical Activity* (Vol. 14, Issue 1). Springer Verlag. https://doi.org/10.1186/s11556-017-0173-7

Middleton, A., Fritz, S. L., & Lusardi, M. (2015). Walking speed: The functional vital sign. *Journal of Aging and Physical Activity*, *23*(2), 314–322. https://doi.org/10.1123/japa.2013-0236

Mollinedo Cardalda, I., López, A., & Cancela Carral, J. M. (2019). The effects of different types of physical exercise on physical and cognitive function in frail institutionalized older adults with mild to moderate cognitive impairment. A randomized controlled trial. *Archives of Gerontology and Geriatrics*, *83*, 223–230. https://doi.org/10.1016/j.archger.2019.05.003

Monaco, V., Rinaldi, L. A., Macrì, G., & Micera, S. (2009). During walking elders increase efforts at proximal joints and keep low kinetics at the ankle. *Clinical Biomechanics*, *24*(6), 493–498. https://doi.org/10.1016/j.clinbiomech.2009.04.004

Norouzian, R., & Plonsky, L. (2018). Eta- and partial eta-squared in L2 research: A cautionary review and guide to more appropriate usage. In *Second Language Research* (Vol. 34, Issue 2, pp. 257–271). SAGE Publications Ltd. https://doi.org/10.1177/0267658316684904

Owings, T. M., & Grabiner, M. D. (2004). Variability of step kinematics in young and older adults. *Gait and Posture*, *20*(1), 26–29. https://doi.org/10.1016/S0966-6362(03)00088-2

Peel, N. M., Kuys, S. S., & Klein, K. (2013). Gait speed as a measure in geriatric assessment in clinical settings: A systematic review. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences*, *68*(1), 39–46. https://doi.org/10.1093/gerona/gls174

Perera, S., Mody, S. H., Woodman, R. C., & Studenski, S. A. (2006a). Meaningful change and responsiveness in common physical performance measures in older adults. *Journal of the American Geriatrics Society*, *54*(5), 743–749. https://doi.org/10.1111/j.1532-5415.2006.00701.x

Perera, S., Mody, S. H., Woodman, R. C., & Studenski, S. A. (2006b). Meaningful change and responsiveness in common physical performance measures in older adults. *Journal of the American Geriatrics Society*, *54*(5), 743–749. https://doi.org/10.1111/j.1532-5415.2006.00701.x

Raasch, C. C., & Zajac, F. E. (1999). *Locomotor Strategy for Pedaling: Muscle Groups and Biomechanical Functions*.

Richardson, J. T. E. (2011). Eta squared and partial eta squared as measures of effect size in educational research. In *Educational Research Review* (Vol. 6, Issue 2, pp. 135–147). https://doi.org/10.1016/j.edurev.2010.12.001

Ridgel, A. L., & Ault, D. L. (2019). High-cadence cycling promotes sustained improvement in bradykinesia, rigidity, and mobility in individuals with mild-moderate Parkinson's disease. *Parkinson's Disease*, *2019*. https://doi.org/10.1155/2019/4076862

Ridgel, A. L., Phillips, R. S., Walter, B. L., Discenzo, F. M., & Loparo, K. A. (2015). Dynamic high-cadence cycling improves motor symptoms in Parkinson's disease. *Frontiers in Neurology*, *6*(SEP). https://doi.org/10.3389/fneur.2015.00194

Sadigh, S., Reimers, A., Andersson, R., & Laflamme, L. (2004). FALLS AND FALL-RELATED INJURIES AMONG THE ELDERLY: A SURVEY OF RESIDENTIAL-CARE FACILITIES IN A SWEDISH MUNICIPALITY. In *Journal of Community Health* (Vol. 29, Issue 2).

Salacinski, A. J., Kelly Krohn, Sco, F. L., Megan, L. H., Kathryn Ireland, & Gregory Marchei. (2012). The effects of group cycling on gait and pain-related disability in individuals with mild-to-moderate knee osteoarthritis: A randomized controlled trial. *Journal of Orthopaedic and Sports Physical Therapy*, *42*(12), 985–995. https://doi.org/10.2519/jospt.2012.3813

Schrack, J. A., Althoff, K. N., Jacobson, L. P., Erlandson, K. M., Jamieson, B. D., Koletar, S. L., Phair, J., Ferrucci, L., Brown, T. T., Margolick, J. B., Bream, J. H., Crain, B., Dobs, A., Johnson-Hill, L., Leng, S., Munro, C., Plankey, M. W., Post, W., Sacktor, N., … Surkan, P. (2015). Accelerated longitudinal gait speed decline in HIV-infected older men. *Journal of Acquired Immune Deficiency Syndromes*, *70*(4), 370–376. https://doi.org/10.1097/QAI.0000000000000731

Shankar, A., McMunn, A., Demakakos, P., Hamer, M., & Steptoe, A. (2017). Social isolation and loneliness: Prospective associations with functional status in older adults. *Health Psychology*, *36*(2), 179–187. https://doi.org/10.1037/hea0000437

Sherrington, C., Tiedemann, A., Fairhall, N., Close, J. C. T., & Lord, S. R. (2011). Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. In *New South Wales public health bulletin* (Vol. 22, Issues 3–4, pp. 78–83). https://doi.org/10.1071/nb10056

Shin, S.-S., & yoo, W.-G. (2015). *Effects of gait velocity and center of mass acceleration during turning gait in old-old elderly women*.

Sterling, D. A., O'connor, J. A., & Bonadies, J. (2001). Geriatric Falls: Injury Severity Is High and Disproportionate to Mechanism The Journal of TRAUMA Injury, Infection, and Critical Care. In *J Trauma* (Vol. 50).

Sun, F., Norman, I. J., & While, A. E. (2013). *Physical activity in older people: a systematic review*. http://www.biomedcentral.com/1471-2458/13/449

Suner-Keklik, S., ÇOBANOĞLU, G., ECEMİŞ, Z. B., & ATALAY GÜZEL, N. (2023). Gender Differences in Gait Parameters of Healthy Adult Individuals. *Journal of Basic and Clinical Health Sciences*, *7*(1), 277–283. https://doi.org/10.30621/jbachs.1097400

Terroso, M., Rosa, N., Torres Marques, A., & Simoes, R. (2014). Physical consequences of falls in the elderly: A literature review from 1995 to 2010. In *European Review of Aging and Physical Activity* (Vol. 11, Issue 1, pp. 51–59). Springer Verlag. https://doi.org/10.1007/s11556-013-0134-8

Thorsen, T. A., Hester, R., & Keating, C. J. (2024). *Changes in Lower Extremity Gait Biomechanics Following High-Cadence Cycling*. *11*. https://doi.org/10.3390/xxxxx

Tinetti, M. E., Franklin Williams, T., Mayewski, R., & York, N. (1986). *Fall Risk Index for Elderly Patients Based on Number of Chronic Disabilities*.

Tsushima, A., Ochi, A., & Takaishi, T. (2015). Immediate effects of varying cadence in bicycle ergometry on characteristics of gait and lower extremity motor activity in frail older adults. *Aging Clinical and Experimental Research*, *27*(1), 43–51. https://doi.org/10.1007/s40520-014-0245-8

Vaughan, C. L. (1999). *GaitCD*. [Kiboho Publishers].

Zethraeus, N., Strömberg, L., Jönsson, B., Svensson, O., & Öhlén, G. (1997). The cost of a hip fracture. Estimates for 1,709 patients in Sweden. *Acta Orthopaedica Scandinavica*, *68*(1), 13–17. https://doi.org/10.3109/17453679709003968