The Impact of a Bariatric Simulation Suit on Functional Mobility in Adults Without Obesity

by

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Abstract

Background: Functional mobility is an important factor associated with quality of life. However, it is often compromised in individuals with obesity due to changes in body function and structures. With excessive adipose tissue accumulation, some individuals have a shifted center of mass, restricted range of motion, limited relative muscle force, restricted field of vision, and altered kinesthetic feedback that can lead to poor balance. As a result, gait pattern and stride frequency are often altered in order to maintain balance and support body weight. These alterations can increase difficulties in performing functional tasks. A non-weight matched bariatric simulation suit is used for healthcare professionals to understand the functional movements of individuals with obesity. To date, there is no research that has compared the impact of a non-weight matched bariatric simulation suit on functional mobility adults with obesity.

Objectives: The primary objective was to explore the impact of a bariatric simulation suit on functional mobility in adults without obesity :1) if the bariatric simulation suit alters the movement patterns of individuals without obesity; 2) if so, does it simulate the movement patterns of individuals with obesity? A secondary objective was to capture the participant experiences wearing the bariatric simulation suit.

Methods: Ten students in health care professional training programs, age 18-40 years old with BMI$\leq$25kg/m^2 were recruited for the intervention group. Eight participants, age 18-40 years old with a BMI$\geq$30kg/m^2 were recruited for the control group.

Procedures: The study included four functional tasks: walking for 5 meters, stair climbing, Timed Up and Go, and crossing obstacles. Three-dimensional kinematic data were collected with the whole-body plug-in-gait model of OptiTrack eSyn 2 with twenty-four infrared cameras. After performing the functional tasks, participants were asked to complete a semi-structured interview to reflect on the perceived difficulties of the tasks. Participants in the intervention group were asked to complete the tasks twice, with and without a bariatric simulation suit distributed by COBI Rehab, in a randomized order.

Result: The bariatric simulation suit altered the gait pattern and increased the time to complete the TUG of participants without obesity during walking, stair climbing, and obstacle crossing. The bariatric simulation suit significantly decreased walking speed ($p=0.021$), step length ($p<0.01$), step height($p<0.01$), and increased step width ($p<0.01$) during walking. For stair climbing, the bariatric simulation suit increased the step width($p<0.01$) of participants without obesity. The bariatric simulation suit decreased the walking speed ($p=0.01$), increased step width ($p<0.01$) and double support time ($p=0.04$) during obstacle crossing. In addition, wearing the bariatric simulation suit also increased the total time ($p=0.021$) to complete the TUG test. Participants without obesity also found that it was more challenging to complete the tasks with the bariatric simulation suit.

Conclusion: The bariatric simulation suit altered the functional movements of individuals without obesity. Participants without obesity also found the tasks were more challenging to complete with the bariatric simulation suit. Using three-dimensional motion capture system is an effective way to measure body movements in this type of research. This pilot study did not provide confirmation that the bariatric simulation suit was effective in representing the typical gait of people with obesity but did provide establish a protocol for a definitive future study.

Preface

This thesis is an original work by Yilina Liubaoerjijin. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "The Impact of a Bariatric Simulation Suit on Functional Mobility in Adults Without Obesity", No. Pro00081525, May 31, 2018.

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Chapter 1: Introduction

1.1 Problem Statement

Twenty-seven percent of adults in Canada have obesity based on the 2016 and 2017 Canadian Health Measures Survey. The World Health Organization (WHO) defines obesity as a body mass index (BMI) greater than 30kg/m^2 and a condition with excessive body fat accumulation to an extent that health may be compromised (WHO, 2016). Excess body weight is a risk factor for a variety of chronic conditions including cardiovascular disease, type 2 diabetes, and metabolic syndrome (Hramiak, Leiter, & Paul, 2007). In addition, the excessive fat accumulation leads to anthropometric alterations, which causes functional disabilities (Corbeil, Simoneau, Rancourt, Tremblay, & Teasdale, 2001; Pataky, Armand, Muller-Pinger, Golay, & Allet, 2013).

A critical review by Phelan et al. (2015) shows that healthcare providers hold strong negative attitudes and stereotypes about people with obesity and these attitudes may reduce the quality of care they provide. A consequence of these negative attitudes are experiences or expectations for poor treatment, which may cause stress and avoidance of care, mistrust of healthcare providers and poor adherence among patients with obesity (Phelan et al., 2015). To improve the quality of care and patients' adherence to medical treatments and interventions, many strategies have been proposed to educate health care providers. One of the potential strategies to improve empathy is perspective-taking exercises, where the health care providers can experience the living condition of individuals with obesity (Phelan et al., 2015). Simulated experiences using a bariatric simulation suit is one potential strategy by which to create a better understanding of what it is like to live with obesity (XXL Rehab, 2011; Kim and Jones, 2010) and thereby promote respect and empathy from health care professionals (XXL Rehab, 2011).

One of the important aspects of living with obesity is restricted mobility (Forhan & Gill, 2013). Mobility is defined as the ability to walk, climb stairs, transfer body weight and generate moderate walking speed; mobility is important for many activities that are necessary for independent life, and is an important outcome for quality of life (Guralnik, Ferrucci, Balfour, Volpato, & Di Iorio, 2001; Cesari, 2009). Although many studies have published and revealed that individuals with obesity are experiencing restricted mobility(Corbeil et al., 2001; Forhan & Gill, 2013; Lai, Leung, Li, Zhang, 2008; Fabris de Souza et al., 2005), a front-line experience may provide health care providers and researchers in depth understanding of the daily challenges faced by individuals with obesity.

A bariatric simulation suit (Figure 1) distributed by COBI Rehab, formerly known as XXL Rehab, is marketed for use as an educational tool to promote better understanding and learning of the abilities of a bariatric patient (XXL Rehab, 2011). In the description of the product, it is specified that it provides an opportunity for people to “obtain a wide view of the mobility patterns, the restricted movement of the body” (XXL Rehab, 2011) as those experienced by individuals with obesity. Currently, no study has compared the mobility patterns created by this simulation suit to the movement pattern of individuals living with obesity.

Figure 1. Bariatric simulation suit by COBI Rehab

1.2 Study Objective

The primary study objective of the study is to explore the impact of a bariatric simulation suit on functional mobility in adults without obesity. Functional mobility is defined as the spatiotemporal gait characteristics (gait patterns) during stair climbing, obstacle crossing, walking on even ground and the total time to complete the tasks of moving from sitting to standing to walking and sitting down. Specifically, I was interested in finding 1) if the bariatric simulation suit alters the movement patterns of individuals without obesity; 2) if so, does it simulate the movement patterns of individuals with obesity?

A secondary objective was to capture the participant experiences wearing the bariatric simulation suit. Specifically, I was interested in the participants perception of their functional mobility performance while wearing the suit during the tasks.

1.3 Hypothesis

Hypothesis 1:

H_0: The bariatric simulation suit does not alter the functional mobility of individuals without obesity.

H_1: The bariatric simulation suit alters the functional mobility of individuals without obesity.

Hypothesis 2:

H_0: The bariatric simulation suit does not simulate the functional mobility of individuals with obesity.

H_1: The bariatric simulation suit simulates the functional mobility of individuals with obesity.

Hypothesis 3:

H_0: The bariatric simulation suit does not alter the perceived difficulties of the functional tasks of individuals without obesity.

H_1: The bariatric simulation suit increases the perceived difficulties of the functional tasks of individuals without obesity.

CHAPTER 2. LITERATURE REVIEW

This chapter gives an overview of functional challenge of individuals with obesity. Including structural alteration, functional alteration, and functional mobility of individuals with obesity. Then current studies of bariatric simulation suit are also discussed.

2.1 Body structure and functional alteration of individuals with obesity

Balance and stability.

Obesity is associated with reduced postural control and stability. A study undertaken by Mitchell, Lord, Harvey and Close (2014) found that individuals with obesity had a 31% higher risk of falling. The factors associated with the increased risk of falling may include abdominal fat, limited range of motion, altered kinesthetic feedback, and limited muscle force. The following section will discuss the impact of each factor on balance and stability.

Abdominal fat.

The presence of excessive abdominal fat or a panniculus alters the center of mass and increases the risk of falling in individuals with obesity (Corbeil, Simoneau, Rancourt, Tremblay, & Teasdale, 2001). Based on a humanoid model, the distribution of body fat in the abdominal area shifts the center of mass anteriorly, which places the line of gravity closer to the boundary for the body's base of support (Corbeil et al., 2001). This means that weight is carried toward the front of the feet and this may lead to anterior-posterior (AP) instability during static and dynamic balance (Corbeil et al., 2001; Forhan & Gill, 2013). The movement of the panniculus may also contribute to instability while walking. The frequent movements of the panniculus during walking may cause constant shifting of the center of mass not only in the AP direction but in the medial-lateral (ML) direction as well. The shift of the center of mass in the ML direction may cause ML instability during static and dynamic balance. As a result, perturbation in ML direction can increase the risk of falling.

Range of motion.

The range of motion in individuals with obesity also impacts balance and postural control. Several studies have found that individuals with obesity are expected to have reduced joint range of motion as the adipose tissue around body joints are likely to interfere and restrict inter-segmental rotations (Escalante et al., 1999a; 1999b; Chaffin et al., 2006; Gilleard and Smith, 2007). When compared to individuals without obesity, people with obesity experienced decreased range of motion in shoulder extension (-22.0% of mean difference (MD)) and adduction (-38.9% MD), lumbar spine extension (-21.7% MD) and lateral flexion (-7.6% MD), and knee flexion (-11.1%, -12.3% MD) (Park, Ramachandran, Weisman, and Jung, 2010). The range of motion in the hip and knee may be critical to maintain and recover balance from large perturbations (Wojcik, Thelen, Schultz, Ashton-Miller & Alexander, 2001). Therefore, restricted range of motion of individuals with obesity may reduce their ability to recover from the large perturbations.

Kinesthetic feedback.

A study done by Hue et al. (2007) found a strong correlation between increased body weight and decreased postural stability. One of the potential explanations of the strong correlation between balance stability and body weight is increased body weight desensitizes foot mechanoreceptors and cutaneous sensation for balance control (Hue et al., 2007). Several studies showed an increase in plantar contact areas and pressure level in the heel, midfoot and metatarsal areas (Birtane &Tuna, 2004; Fabris S et al., 2006; Gravante, Russo, Pomara & Ridola, 2003; Hills, Bar-Or, McDonald & Hennig, 2001). This may suggest that the increased contact area and elevated pressure interposes with the function of the mechanoreceptors that is necessary to inform the body's response to oscillation due to an elevation in body weight (Del Porto, Pechak, Smith & Reed-Jones, 2012; Hue et al., 2007).

Muscle force.

When compared to healthy individuals without obesity, individuals with obesity have lower relative muscle strength and muscle mass (Maffiuletti et al., 2007). Which may indicate that during tasks that require generating muscular force, individuals with obesity are less likely to generate the adequate amount of force over a prolonged period of time due to lower relative muscle strength. In addition, the study done by Corbeil et al. (2001) based on a humanoid model stated that the alterations to the center of mass increase the ankle torque needed to stabilize the body; meaning that muscles associated with the ankle joint must exert greater amount of force to maintain the balance of the body and to counteract the perturbation. However, the values of the minimal ankle torque needed may exceed the maximum ankle muscular torque that a person can produce (Corbeil et al., 2001). As a result, any alteration of land surface or perturbation may increase the likelihood of falling while walking.

2.2 Functional mobility of individuals with obesity

Walking.

Individuals with obesity utilize more metabolic energy than their lean counterparts when walking at the same speed (Browning and Kram, 2005). One potential cause for the high energy expenditure is the support required for maintaining stability in individuals with obesity; this support increases energy cost for walking (Browning and Kram, 2005). To compensate for the shifted center of mass and instability, individuals with obesity can develop altered gait patterns with decreased speed, shorter strides, and increased step width (Pataky, Armand, Muller-Pinger, Golay, & Allet, 2013; Ko, Stenholm, and Ferrucci, 2010); these changes in gait pattern may increase the energy used for walking and contribute to increased fatigue (Browning and Kram, 2005; Donelan, Kram, and Kuo, 2001; Russell, Braun, and Hamill, 2010).

Studies have found that as body weight decreases, the energy cost for walking of an individual with obesity decreases (Peyrot et al., 2011; Doucet, Imbeault, St-Pierre, Almeras, Mauriege, Despres, et al., 2003). The underlying mechanisms of the decrease in energy cost of walking is likely due to the reduced metabolic rate related to maintaining balance and supporting body weight during walking (Peyrot et al., 2011).

Stair walking.

Stair walking performance was also found to differ between individuals living with obesity compared to individuals without obesity. A study done by Apovian et al. (2002) found that older women living with obesity require longer time to climb the stairs when compared to older women without obesity. A study by Strutzenberger, Richter, Schneider, Mündermann, and Schwameder (2010) also found that the lower limb joints of children with obesity experience greater movements during stair ascending and descending. These differences in joint movements may cause joint overloading and increase the risk of knee and hip osteoarthritis (Strutzenberger et al., 2010).

Obstacle crossing.

A study done by Bronislava (2015) found that when crossing obstacles with different heights, adults with obesity had slower velocity, lower cadences, shorter steps, larger step width, and longer single and double limb support time than adults without obesity. These findings may suggest a greater time spent for motor planning between the steps when crossing obstacles. For degrees of sway, adults with obesity had a higher degree of ML sway and AP sway than adults without obesity. This can be detrimental to individuals with obesity because higher degrees of sways in both directions make it more taxing and challenging to maintain balance during a dynamic task such as walking with obstacles involved (Bronislava, 2015).

2.3 Bariatric Simulation suit

Simulation suits are designed to simulate the functional impairments experienced by individuals with disabilities. Simulation suits are currently available for aging simulations (Groza, Sebesi &Mandru, 2017) and bariatric simulations (Kim and Joines, 2010). Simulation suits could potentially be a strong tool in providing information to researchers and developers of products that target individuals living with obesity. Medical personnel working with people with obesity could also be users of a simulation suit with the purpose of better understanding the needs of the patients they take care of. The proposed benefits would be to provide more appropriate service delivery approaches and develop empathy.

A study by Kim and Joines (2010) explored the impact of a weighted bariatric simulation suit on adults' physiological response and subjective perception of the functional tasks compared to adults with obesity. They found that similar physiological responses (heart rates) were produced during the functional tasks between participants with and without obesity. However, individuals without obesity reported having more difficulty performing the functional tasks when compared to individuals with obesity. In their study, the mobility patterns during the performance of functional tasks were not measured. In addition, the bariatric simulation suit used had only focused on the structural alteration of the torso and upper extremities.

2.4 Summary of Literature Review

The above review briefly introduced the structural and functional alteration of individuals with obesity. With excessive adipose tissue accumulation, some individuals with obesity have a shifted center of mass, restricted range of motion, limited relative muscle force, and altered kinesthetic feedback that can lead to poor balance. As a result, gait pattern and stride frequency are often altered in order to maintain balance and support body weight. These alterations significantly increase the difficulties to perform functional tasks. Although many studies have published and revealed that individuals with obesity are experiencing restricted mobility, a simulated experience may provide health care providers and researchers an in-depth understanding of the daily challenges faced by individuals with obesity. Current study of weighted bariatric simulation suit on adults' physiological response and subjective perception of found that similar physiological responses (heart rates) were produced during the functional tasks (Kim and Joines, 2010). The mobility patterns during the performance of functional tasks were never measured in this study.

CHAPTER 3 METHODS

This chapter discusses the research methods in this study, including study design, sampling, recruitment method, inclusion and exclusion criteria, data collection, procedures of the study and data analysis. Details about how the study was carried out and the justification for this research are provided in the following sections.

3.1 Study Design

A non-randomized controlled study design was conducted between the intervention group and the control group. Repeated-measures were used to compare two test conditions in the intervention group. The advantage of conducting a repeated-measures design is that there is no risk that the individuals in one test condition are substantially different from the individuals in another in the intervention group. The repeated-measures design also requires fewer participants for the intervention group. However, the disadvantage of this design is that there might be an order effect, where the participants' performance in the first test influences the participants' performance in the second test. To minimize the presence of order effect in one condition only, a randomized crossover trial was conducted for the intervention group, so the participants were randomly assigned to different test orders. Randomization was determined a priori. The researcher randomly assigned the ten participants without obesity into the "suit first" condition or "without suit first" condition by a computer based random number generator (Research Randomizer, 2018). The computer based random generator generated 10 sets of numbers (1-10), each set of numbers represents one participant based on their order of participation. Then another number is randomly assigned to each set, either 1 or 2. The number 1 represents the Suit first condition and the number 2 represents the without suit first condition. Five sets of numbers were randomly assigned with the number 1 and other five sets of numbers were randomly assigned with the number 2. This way we had five participants in each condition. The intervention group completed all of the functional tasks under both conditions on the same day. A 10 minute or self-determined resting (washout) period was provided before the participants repeat the functional tasks with or without the bariatric simulation suit in the intervention group.

3.2 Sampling

The sampling technique for this study was convenience-sampling technique; a non-probability sampling that is accessible, efficient and suitable for pilot studies (Emerson, 2015).

Sample size.

This study is a pilot study because this is the first study to look at the impact of a bariatric simulation suit on functional mobility in adults without obesity and we need to test the feasibility of the methods. Our outcome of interest is the movement patterns of functional mobility created by the bariatric simulation suit. Nineteen participants were recruited, ten in the intervention group and nine in the control group.

3.3 Recruitment

Nine adults (4 female and 5 male) with obesity, and ten adults (9 female and 1 male) students from the health care professionals were recruited through posters and through social media. There were two recruitment methods:

1) Posters (Appendix A) of the study was posted in the University of Alberta for participant recruitment.
2) The study was advertised through social media (Facebook and Twitter accounts of the Bariatric Care and Rehabilitation Research Group, The Faculty of Rehabilitation Medicine and the Canadian Obesity Network), invited individuals with obesity and students without obesity in a health care or related training programs (e.g., Physical therapy, occupational therapy, nursing, kinesiology) between the ages of 18-40 years and without walking impairment. Individuals who are interested in the study were instructed to contact the researcher for more information.

3.4 Inclusion and exclusion Criteria

Inclusion criteria.

Individuals were eligible to participate in this study if they met the following criteria:

Intervention group:

1) BMI$\leq$25kg/m^2

2) Between18-40 years old

3) Able to walk a minimum of 10 minutes at a self-selected speed without a mobility aid.

4) Have normal or corrected to normal vision.

5) Participants must be students from the health professional programs (OT (occupation therapist), Nursing, PT (physical therapist) and, kinesiology students). The simulation suit are used for educational purpose in the health professional programs therefore, we recruited in this population.

6) Participants must be able to speak, read and write in English. Both males and females were eligible to participate.

Control group:

1) BMI$\geq$30kg/m^2;

2) Between18-40 years old

3) Able to walk a minimum of 10 minutes at a self-selected speed without a mobility aid

4) Have normal or corrected to normal vision.

5) Participants must be able to speak, read and write in English.

Exclusion Criteria.

1) This study requires stair climbing and stepping over obstacles and is focused on changes in independent, functional mobility. Therefore, individuals diagnosed with a musculoskeletal disorder that impairs mobility, diabetes, neuropathy, neuromuscular disorder including amyotrophic lateral sclerosis, multiple sclerosis, myasthenia gravis and spinal muscular atrophy.
2) Have sustained a recent lower extremity injury that impairs mobility.
3) Require a mobility device including a wheelchair, walker, crutches, cane, etc.

3.5 Bariatric Simulation Suit

The bariatric simulation suit weighs 6.5 kilogram and is made with form fitting foam. It is a one size fits all suit. However, the researchers were able to adjust fitting based on participants' body size by adjusting the straps attached on the suit. Although a pair of jeans and a t-shirt were provided, during the functional activities the exterior clothes were not worn due to difficulties of marker attachment.

3.6 Procedure

Participants were recruited through the recruitment approaches described earlier in the proposal. The researcher pre-screened (Appendix B & Appendix D) all individuals who expressed an interest in the study to determine their eligibility. For those who met eligibility criteria to participate in the study, an in-person meeting was arranged through email or by telephone. Meetings took place in the private meeting room in Rehabilitation Robotics lab, University of Alberta. During the meeting, the researcher introduced the study in detail and obtained informed, written consent. Sociodemographic and anthropometric data (Appendix H) were collected by the researcher. Then the participants were asked to perform the functional tasks either with or without the simulation suit first based on the number assigned to their order of participation.

Functional tasks.

Three-dimensional kinematic data were collected with the whole-body plug-in-gait model of OptiTrack eSync 2 (Appendix E) with twenty-four infrared cameras (Prime 17W) (Appendix E). Based on a study by Lerner, Board and Browning (2014), Forty-three reflective markers were placed over the following anatomical landmarks identified via palpation: 7th cervical vertebrae, acromion processes, right scapular inferior angle, sternoclavicular notch, xyphoid process, 10th thoracic vertebrae, posterior–superior iliac spines, anterior-superior iliac spines (ASIS), iliac crests (IC), medial and lateral epicondyles of the femurs, medial and lateral malleoli, calcanei, first metatarsal heads, second metatarsal heads, and proximal and distal heads of the 5th metatarsals. Marker clusters were adhered to the thighs, shanks, and sacrum to aid in three-dimensional tracking (Lerner, Board & Browning, 2014). Marker clusters (Figure 2) are three or four noncollinear markers affixed to a rigid plate which is made by the thermoplastic plates. The plates were molded based on their body structures for each participant and each experimental condition prior to the functional tasks. The individual reflective makers were attached to the body parts with double sided body tapes. The marker clusters attached on to the body parts by Velcro attachment on to the fabric wraps wrapped around the body parts. For the “with suit” condition, study personnel palpated the anatomical landmark underneath the suit and attach the markers on to the appropriate position on the suit. The reflective markers were positioned bilaterally capture motion with x- (anterior/posterior), y- (medial/ lateral), and z- (up/down) coordinates from the anterior and posterior portions of the head, the shoulders (acromion process) the anterior and posterior superior iliac spines, the lateral thighs, the knee joints, each tibia, the ankle joints, the heels and the big toes. Joint angles created with the x, y, and z coordinates from the motion data were read into the Motive program, which produced a point-light display of participants as they walk.

Figure 2. Marker Clusters

Walking.

Participants were asked to perform two 5 m straight walking trials (Figure 3) within the lab which enabled assessment of the spatiotemporal parameters of gait. A 5-sec stand still period of time was recorded before and after each walking trial. Parameters such as cadence, double support, limp, swing time, stride speed, and stride length in the AP and ML directions were obtained for each gait cycle. Trials ended when participants reached the stop line at the end of the walking path.

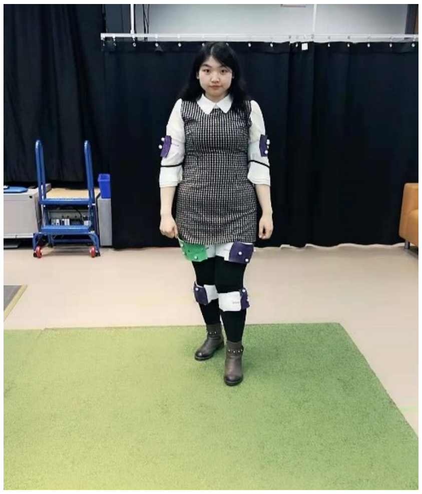

Figure 3. Start of walking trial without simulation suit

Stair climbing.

The staircase used for this study had bilateral handrails and included three steps on either side of a landing platform (Figure 4). The dimensions of each step were 19.5 cm, 20cm and 25.5(riser) and 28cm(tread). All participants were asked to ascend the stair on one side, walk across the platform and descend the stairs on the opposite side, placing only one foot on each step with a self-selected speed. No specific instructions for arm position were given. For each participant, testing consists of two stair walking trials for each condition. Participants took a self-determined period of rest between stair climbing trials to avoid fatigue.

Figure 4. Experimental Staircase

Timed-Up-and-Go (TUG) Test.

Participants were asked to perform two TUG tests (Timed Up and Go, 2018). Each test involved rising from a sitting position from a chair with armrests (Figure 5), walk three meters straight ahead, turn around, walk back to the chair, and sit down. Participants were instructed to move at their comfortable pace. Average time to complete the task for all trials were computed per participant.

Figure 5. Set up for TUG trial

Obstacles.

Following an auditory go signal, participants crossed obstacles at a self-selected walking pace on a 5 metre long path. There were three conditions: low obstacles, medium obstacles, high obstacles. During low, medium, and high obstacle conditions, participants were crossing obstacles that are created with an 81-cm-long wooden dowel inserted into two 25-cm-high wooden towers at 4 cm (low obstacle), 11 cm (medium obstacle), and 16 cm (high obstacle) (Figure 6). Each height reflects obstacles that would be encountered in everyday life: a door threshold (4 cm), a small step (11 cm), and a tall step (16 cm). Trials ended when participants reached the stop line at the end of the walking path. Averages for all trials were computed per participants for further analysis.

Figure 6. Five-metre-long path with obstacles

Participant experience.

Participants completed a questionnaire (Appendix F) after each functional task. The questionnaire consisted of two parts. Part 1 is a questionnaire used in the study done by Kim and Joines, 2010, which included statements about each task (walking, TUG test, stair walking and obstacle crossing). The statements focus on general ease of performance and being out of breath (Kim and Joines, 2010). Participants reported their strength of agreement to each statement using a 6-point scale (1: strongly disagree, 6: strongly agree) (Kim and Joines, 2010). Part 2 consisted of assessing level of fatigue for each task. Participants used the 20-point Borg RPE scale (Appendix G) to rate perceived effort for each portion of the task.

After completing the functional mobility tasks, participants were asked to participate in a face-to-face interview with the researcher for the purpose of describing what it was like to complete the functional tasks while wearing the simulation suit or living with obesity. Participants were asked to answer a set of questions from the questionnaires about their experience of the functional mobility tasks, their perception of weight and their experience about the simulation suit. The researcher then directly asked participants to answer two key questions: 1. What is like to move around with obesity/ bariatric suit? 2. Did anything surprise you while you were performing the tasks? So, participants had the opportunity to discuss their experience and perceptions in depth.

After 10-minutes of rest, or participants self-determined rest breaks, the participants in the intervention group were asked to change into or remove the simulation suit to repeat the same procedure.

3.7 Data Collection

1. Sociodemographic data: This includes age, sex, general medical history and comorbid conditions.
2. Anthropometric data: Anthropometric data were measured using the Canadian Society for Exercise Physiology (CSEP) protocols (CSEP, 2013). The participants were asked to wear clothing that was form fitting including a short-sleeved shirt, shorts at or above the knee with shoes removed while taking their measurements.

- Weight (kg): A scale was placed on the smooth, level section of the floor. Participants were ensured to have removed footwear (socks are kept on) and were dressed in light clothing. Participants were asked to stand on the scale with both feet and keep still for a few seconds until the study personnel finish recording the weight.
- Height (cm): Participants were asked to stand with back, buttocks and heels against a stadiometer. Their feet were kept as close together as possible and flat on the floor with shoes removed. Then the participants were asked to take and hold a deep breath. The measurement of standing height was recorded at the end of the participant's deep inward breath.
- BMI: Body mass index was calculated once the weight and height data were collected using the formula BMI = kg/m2 where kg is a person's weight in kilograms and m2 is their height in meters squared.
- Waist circumference (cm): Participants were positioned with feet shoulder width apart and arms crossed over the chest in a relaxed manner. The waist circumference measurement was taken at the top of the iliac crest. The measuring tape was positioned in a horizontal plane around the abdomen. At the end of a normal expiration, the measurement was taken to the nearest 0.5cm.
- Hip circumference (cm): Participants were positioned with feet shoulder width apart and arms crossed over the chest in a relaxed manner. The hip circumference measurement was taken at widest portion of the buttocks, with the tape parallel to the floor. At the end of a normal expiration, the measurement was taken to the nearest 0.5cm.

Study personnel collected the sociodemographic and anthropometric data using standardized case report forms (paper copies were retained and securely stored) (Appendix H) and transfer the data into the electronic database, RedCap, using a secure desktop computer in the research office. Patient identifying information were kept separate from the paper copies and electronic files, identified only by a study number.

3. Spatiotemporal parameters

Information about gait speed, step height, step length, step width, % double support time, stance phase duration (% gait cycle), the proportion of participants who had neck and trunk flexion were collected with the 3D motion capture system (OptiTrack eSync 2). A difference of angle between sacrum and neck/head larger than 30 degree at the sagittal plane is considered the presence of neck or trunk flexion. Time to complete each task was also collected with the 3D motion capture system. Spatiotemporal parameters were calculated using the custom MATLAB program (Appendix I).

Following data collection, the data were transferred to a computer and analyzed by our research staff at the Rehabilitation Robotic lab using the Motive (Appendix E) optical motion capture software and MATLAB (Appendix I).

4. Subjective Assessments

Participants were asked to answer a set of questions from the questionnaires about their experience of the functional mobility tasks, their perception of weight and their experience about the simulation suit.

- Perceived level of fatigue: the Borg RPE scale was used to assess participants' perceived level of fatigue of each functional task. The Borg RPE scale is a numerical scale that ranges from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion." After completion of each task, the participants were asked to choose a number from the Borg scale to describes their level of exertion during the functional task.
- Perceived ease and frustration: a questionnaire from the study by Kim and Joines, 2012 was used to assess the level of perceived ease and frustration. The questionnaire has two statements. The statements focus on general ease of performance and being out of breath (Kim and Joines, 2010). Participants reported their strength of agreement to a statement using a 6-point scale, where 1 means " strongly disagree l" and 6 means " strongly agree."

The researcher then directly asked participants to answer two key questions (1. What is like to move around with obesity/ bariatric suit? 2.Did anything surprise you while you were performing the tasks?) on these topics, so participants had the opportunity to discuss their experience and perceptions in depth. The interview answers were recorded using a digital voice recorder. They were transcribed verbatim by the researcher. The data were transferred to an electronic database, RedCap, using a secure desk-top computer in room 1-46 Corbett Hall, University of Alberta. Patient information were kept separate from the paper copies and electronic files, identified only by a study number

3.8 Data Analysis

Analysis was conducted using IBM SPSS Statistics (version 23; IBM) software. Descriptive statistics were used to describe sociodemographic and anthropometric data. The primary research question in this study was to determine if wearing the bariatric simulation suit impacts the functional mobility in adults without obesity. Therefore, the following data analyses were conducted: the differences in spatiotemporal parameters, as well as subjective assessments of effort and comfort during task performance with and without wearing the suit for each participant in the intervention group were analyzed with a paired t-test. The difference in spatiotemporal parameters, and subjective assessments of effort and comfort during task performance between the intervention group and the control group were analyzed with an unpaired t-test. If non-parametric testing was required when data is not normally distributed or the homogeneity of variance is violated, Mann-Whitney test was used for comparisons between groups, and Wilcoxon Signed-Rank Test were used for comparing within groups. Normal distribution of the data is determined by Shapiro-Wilk test and the homogeneity of variance is determined by Levene's Test. The difference in proportion of participants had neck/trunk flexions between groups and conditions were analyzed with Chi Square. The statistical significance was set at a p-value ≤ 0.05. Data were expressed as mean ± standard deviation (SD).

3.9 Summary of Methods

A non-randomized controlled study design was conducted between the intervention group and the control group. Further, A repeated-measures design was used to compare two test conditions in the intervention group. A group of ten individuals with obesity were recruited for the control group and a group of ten students in health care professional training programs without obesity who were in the same age were recruited for the intervention group. Recruitment sources included universities and social media. The tests and practice sessions were taken place in the Rehabilitation Robotic lab, University of Alberta. The study includes four functional tasks: walking for 5 meters, stair walking, Timed Up and Go and, crossing obstacles. Three-dimensional kinematic data were collected with the whole-body plug-in-gait model of OptiTrack eSyn 2 with twenty-four infrared cameras. After performing the functional tasks, participants were asked to participate in a semi-structured interview to reflect on the perceived difficulties of the tasks. Participants in the intervention group were asked to complete the tasks twice, with and without a bariatric simulation suit, in a randomized order.

CHAPTER 4. RESULTS

This chapter presents the results of this study, including the participants' demographics, findings from both 3D motion capture system and self-reported measurement tools. Descriptive data are presented in the format of mean ± standard deviation in the tables.

4.1 Participants Involvement

The recruitment of the intervention group and the control group occurred in September 2018 and October 2018, respectively. At the end of November 2018, a total of 21 people who were interested in the study had contacted the principal investigator. Nine individuals living with obesity and ten health sciences students without obesity met the inclusion criteria and participated the study. In the control group, one participant had altered gait pattern due to knee injury. Therefore, this participant's data was excluded from the analysis. Accordingly, there were eight participants in the control group and ten in the intervention group.

4.2 Participants' Demographics

As Table 1 shows, of the ten participants in the intervention group, there were nine females and one male. The mean age of the intervention group was 24.2 years old. The mean height was 167.1cm and the mean BMI was 22.6kg/m^2. These students were from the programs of Kinesiology, Occupational therapy and Physical therapy.

Of the eight participants in the control group, four participants were female and four participants were as male. The mean age of the intervention group was 27.3 years. The mean height and BMI of the control group are 168.4cm and 33.4kg/m^2. The statistical analysis indicated no significant differences in age or height between the two groups（age: $p=0.1$; height: $p=0.7$).

Table 1. Participant demographics

	Control	Intervention	p value
Number of participants	8 (4 male, 4 female)	10 (1 male, 9 female)	
Age (years)	27.3 (4.43)	24.2 (3.36)	0.116
BMI (kg/m^2)	33.4 (2.46)	22.6 (1.45)	<0.001
Weight (kg)	95.1 (12.34)	63.1 (3.88)	<0.001
Height (cm)	168.4 (9.70)	167.1 (9.72)	0.736
Waist Circumference (cm)	96.6 (7.66)	71.9 (2.26)	<0.001
Hip Circumference(cm) (SD)	115 (6.00)	98.1 (3.43)	<0.001
Waist Hip Ratio	0.84 (0.0767)	0.73 (0.0327)	0.001

Continuous variables presented as mean (standard deviation)

4.3 Walking Pattern

Table 2 summarized the walking data from the 3D motion capture system for the intervention group and the control group. Six variables are presented in the table, including the average walking speed, % of double support time, step length, step width, step height, and gait cycle time. Although there were only eight participants in the control group and ten participants in the intervention group, the results of the normality test and homogeneity test showed that the data are normally distributed and have equal variance.

There were significant differences between the "with suit" condition and "without suit" condition in the walking speed ($p=0.01$), step length ($p<0.01$), step width ($p<0.01$) and step height ($p <0.01$) in the intervention group. To be more specific, compared with "without suit" condition, participants in the intervention group had slower walking speed (1.17±0.36m/s vs. 1.05±0.09 m/s), shorter step length (0.57±0.04m/s vs. 0.51±0.04m/s), greater step width (0.16±0.05m/s vs. 0.23±0.04m/s), and shorter step height(0.24±0.01m/s vs. 0.22±0.02m/s) when wearing the bariatric simulation suit.

When each condition ("with suit" and "without suit") were compared to the control group, only gait cycle time shown significant differences (control vs. without suit: 1.20±0.06s vs. 1.06±0.08s, $p=0.02$; control vs. suit: 1.20±0.06s vs. 1.09±0.07, $p=0.02$). There was no significant difference in other variables.

Table 2. Summary of results for components of walking pattern

Walking	Control	Intervention		p value		
		With Suit	Without Suit	Control vs. With Suit	Control VS. Without Suit	With Suit vs. Without Suit
	Mean (SD)	Mean (SD)	Mean (SD)			
Speed(m/s)	1.04 (0.09)	1.05 (0.09)	1.17 (0.36)	0.926	0.22	0.013
Double Support (%)	18.16 (3.39)	17.87 (1.86)	17.71 (3.60)	0.818	0.792	0.89
Step Length(m)	0.55 (0.05)	0.51 (0.04)	0.57 (0.04)	0.055	0.331	<0.001
Step Width(m)	0.21 (0.08)	0.23 (0.04)	0.16 (0.05)	0.543	0.133	<0.001
Step Height(m)	0.24 (0.01)	0.22 (0.02)	0.24 (0.01)	0.187	0.285	0.001
Stance Phase (%)	63.88 (4.67)	64.60 (3.66)	65.59 (3.79)	0.719	0.403	0.302

4.4 Stair Climbing

Table 3 summarizes the stair climbing data from the 3D motion capture system for the intervention group and the control group. Five variables are presented in the table, including the average walking speed, % of double support time, step width, step height, and stance phase. The results of the normality test and homogeneity test showed that the data are normally distributed and have equal variance.

Within the intervention group there were significant differences between the “with suit” condition and the “without suit” condition in step width ($p<0.01$). There was no significant difference in other variables.

Participants in the control group had significantly longer double support time (without suit vs. control: 47.27±10.76 vs. 55.02±10.53, $p=0.03$; with suit vs. control: 49.53±9.84 vs. 55.02±10.53, $p<0.05$). There was no significant difference in stair walking speed, step width, step height and stance phase between groups.

Table 3. Summary of results for components of stair walking

Stairs	**Control**	**Intervention**		**p value**		
		With Suit	**Without Suit**	**Control vs. With Suit**	**Control vs. Without Suit**	**With Suit vs. Without Suit**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**			
Speed(m/s)	0.68 (0.21)	0.69 (0.12)	0.77 (0.14)	0.966	0.338	0.205
Double Support (%)	55.02 (10.53)	49.53 (9.84)	47.27 (10.76)	0.047	0.030	0.675
Step Width(m)	0.22 (0.07)	0.25 (0.06)	0.19 (0.04)	0.088	0.219	0.002
Step Height(m)	0.61 (0.08)	0.64 (0.05)	0.66 (0.06)	0.1	0.126	0.242
Stance Phase (%)	69.51 (8.15)	70.45 (3.42)	69.21 (7.21)	0.742	0.935	0.604

4.5 Obstacle Crossing

Table 4 summarizes the obstacle crossing data from the 3D motion capture system for the intervention group and the control group. Six variables are presented in the table, including the average walking speed, % of double support time, step length, step width, step height, and % of stance phase time. The results of the normality test and homogeneity test showed that the data are normally distributed and have equal variance.

There was significant difference between the "with suit" condition and the "without suit" condition in the walking speed ($p=0.01$), step width ($p<0.01$) and double support time ($p=0.04$) in the intervention group. To be more specific, compared to the "without suit" condition, participants had significantly slower walking speed (1.00±0.12 m/s vs. 0.88±0.10m/s), shorter step width (0.16±0.04m/s vs. 0.24±0.06m/s), and longer double support time (17.14±2.98m/s vs. 18.97±3.38m/s) when in the "with suit" condition. There was no significant difference in other variables included in the stair-climbing task.

When each condition (with suit and without suit) was compared to the control group there was no significant difference in the stair-climbing variables.

Table 4. Summary of results for components of obstacle crossing

Obstacles	Control	Intervention		p value		
		With Suit	Without Suit	Control vs. With Suit	Control vs. Without Suit	With Suit vs. Without Suit
	Mean (SD)	Mean (SD)	Mean (SD)			
Speed(m/s)	0.89 (0.12)	0.88 (0.10)	1.00 (0.12)	0.859	0.089	0.010
Step Length (m)	0.55 (0.07)	0.50 (0.06)	0.55 (0.08)	0.105	0.830	0.093
Step Width(m)	0.21 (0.07)	0.24 (0.06)	0.16 (0.04)	0.386	0.061	<0.001
Step Height(m)	0.36 (0.03)	0.33 (0.03)	0.35 (0.03)	0.069	0.570	0.088
Double Support %	17.06 (2.11)	18.97 (3.38)	17.14 (2.98)	0.182	0.069	0.044
Stance Phase %	64.18 (2.05)	64.64 (2.34)	63.61 (2.05)	0.657	0.131	0.258

4.6 Timed Up and GO (TUG)

The TUG test results in the "without suit" condition and control group were normally distributed (p>0.05) but the TUG results for "with suit" condition were not (p<0.05). Therefore, a Wilcoxon signed-rank test was used to analyse the data within the intervention group, a Mann Whitney test was used to analyse the data between" with suit" condition and the control group, and an unpaired t test was used to analyse the data between "without suit" condition and the control group.

The statistical analysis result showed within the intervention group that there were significant differences between "with suit" condition and "without suit" condition in the time to complete the TUG test (z=-2.31, p=0.02). Compared with "without suit" condition when wearing the bariatric simulation suit, participants in the intervention group had significantly longer time to complete TUG test (median for without suit condition: 9.07s; median for with suit condition: 10.02s).

The unpaired t test showed that compare to the “without suit” condition the participants in the control group had significantly longer time to complete timed up and go test (TUG) (No suit vs. Control: 9.16±0.99s vs. 10.93±1.42s, $p<0.01$). A Mann Whitney test showed that there was no difference between total time to complete the TUG test when participants were wearing the bariatric suit compared to the control group ($z=-0.98$, $p=0.36$).

Table 5. Summary of the Timed Up and GO (TUG) test results

TUG	**Control**	**Intervention**		**p value**		
		With Suit	**Without Suit**	**Control vs. With Suit**	**Control vs. Without Suit**	**With Suit vs. Without Suit**
	Median (Range)	**Median (Range)**	**Median (Range)**			
Time(s)	11.03 (3.91)	10.02 (4.11)	9.07 (3.01)	0.360	0.007	0.021

4.7 Neck Flexion or Trunk Flexion

Total numbers of participants who had neck flexions and trunk flexions per task were also measured during the functional tasks. The proportion of participants who had neck flexion and trunk flexion in each group and condition were measured during each activity. The results of proportion of neck flexion were listed in table 6. The study used Chi Square to analyse the data within intervention group, and between groups.

The Chi Square showed that compared to “without suit” condition, when wearing the bariatric simulation suit, a significantly greater numbers of participants in the intervention group had neck flexions or trunk flexions during obstacle crossing (Chi square=5.05, $p=0.03$). When compared to control group, a significantly less numbers of participants in “without suit” condition had neck or trunk flexions during walking only (Chi square=4.50, P=0.03). There was no significant difference in other conditions within the intervention group and between groups.

Table 6. Proportion of participants had neck flexion or trunk flexion

Proportion of participants had neck flexion or trunk flexion	**Control**	**Intervention**		**p value**		
		With Suit	**Without Suit**	**Control vs. With Suit**	**Control vs. Without Suit**	**With Suit vs. Without Suit**
	%	**%**	**%**			
Walking	37.5	10	0	0.163	0.034	0.305
Stair	75	40	40	0.138	0.138	1.000
Obstacles	50	70	20	0.387	0.18	0.025

4.8 Subjective Assessment

After the functional tasks, each participant was asked to sit in a quiet room in the Rehabilitation Robotics lab to complete the interview. Ten participants from the intervention group and eight participants from the control group completed the subjective assessment.

4.8.1 Fatigue Index.

This study used the Borg RPE scale to assess participants' perceived level of fatigue of each functional task. The results are presented in Table 7.

The results from the Wilcoxon signed-rank test and Sign test indicated that compared to "without suit" condition, when wearing the bariatric simulation suit participants in the intervention group perceived significantly more effort in all tasks (Walking: p=0.02; Stairs: p=0.01; Obstacles: p=0.01; TUG: p<0.01).

When compared with the control group, the Mann Whitney test showed that wearing the bariatric simulation suit, participants in the intervention group also perceived significantly more effort in all tasks (Walking: U=29, p=0.01; Stairs: U=7.5, p<0.01; Obstacles: U=9, p<0.01; TUG: U=2, p<0.01). There is no difference in perceived fatigue between the without suit condition and the control group.

Table 7. Borg Scale result

Fatigue Index	**Control**	**Intervention**		**p value**		
		With Suit	**Without Suit**	**Control vs. With Suit**	**Control vs. Without Suit**	**With Suit vs. Without Suit**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**			
Walking	6.3 (0.5)	8.9 (2.6)	6.2 (0.4)	0.012	0.897	0.016
Stairs	7.1 (1.6)	11.0 (2.1)	6.6 (0.5)	0.002	1.000	0.005
Obstacles	7.1 (1.9)	10.6 (2.2)	6.5 (0.7)	0.004	0.829	0.005
TUG*	6.6 (0.9)	10.6 (2.2)	6.7 (1.1)	<0.001	0.965	0.004

*TUG: Timed Up and GO

4.8.2 Perceived ease and frustration.

The results of Perceived ease and frustration of each functional task showed in Table 8 and Table 9. Two statements were asked after each task. The statements focus on general ease of performance and being out of breath (Kim and Joines, 2010). Participants reported their strength of agreement to a statement using a 6-point scale, where 1 means " strongly disagree l" and 6 means " strongly agree."

The results from the Wilcoxon signed-rank test and Sign test indicated that compared to “with suit” condition, participants in the intervention group perceived that it is easier and less frustrated to perform all functional tasks without the bariatric simulation suit (Ease: Walking: p=0.004; Stairs: p=0.01; Obstacles: p<0.01; TUG: p<0.01. Frustration: Walking: p=0.01; Stairs: p<0.01; Obstacles: p=0.01; TUG: p<0.01).

The Mann Whitney test showed that participants in the control group also perceived that is easier and less frustration to perform the tasks when compared to intervention group in the "with suit" condition. (Ease: Walking: U=4, p<0.01; Stairs: U=7, p<0.01; Obstacles: U=6, p<0.01; TUG: U=4, p<0.01. Frustration: Walking: U=8, p<0.01; Stairs: U=0, p<0.01; Obstacles: U=4, p=0.01; TUG: U=0, p<0.01). There is no difference in perceived ease and frustration between without suit condition and control group.

Table 8. Perceived Ease

Q1: ease of completion	**Control**	**Intervention**		**p value**		
		With Suit	**Without Suit**	**Control vs. With Suit**	**Control vs. Without Suit**	**With Suit vs. Without Suit**
	Median (Range)	**Median (Range)**	**Median (Range)**			
Walking	6 (0)	5 (3)	6 (0)	0.001	1.000	0.004
Stairs	6 (1)	4 (4)	6 (0)	0.002	0.408	0.007
Obstacles	6 (1)	4 (4)	6 (0)	0.001	0.696	0.004
TUG*	6 (0)	4 (4)	6 (0)	0.001	1.000	0.004

*TUG: Timed Up and GO

Table 9. Perceived Frustration

Q2: Level of frustration	Control	Intervention		p value		
		With Suit	Without Suit	Control vs. With Suit	Control vs. Without Suit	With Suit vs. With out Suit
	Median (Range)	Median (Range)	Median (Range)			
Walking	1 (0)	2 (3)	1 (0)	0.003	1.000	0.008
Stairs	1 (0)	3.5 (2)	1 (1)	<0.001	0.762	0.004
Obstacles	1 (0)	3 (4)	1 (1)	0.001	0.762	0.006
TUG*	1 (0)	2 (2)	1 (0)	<0.001	1.000	0.002

*TUG: Timed Up and GO

4.8.3 Interview questions.

Two open-ended questions were asked after participants provided responses to the questionnaire items. Two participants from the control group decided to write down their answers on the questionnaire sheet. The average time for the participants to complete this section is 62 seconds. Data were interpreted within the context of the researcher's views as a rehabilitation science student with experience working with people who have obesity. Findings from the open-ended questions were reported as common themes and key words about their experience and perceptions.

The first question asked by the researcher is "What is it like to move around while wearing the bariatric simulation suit/ Obesity?" Nine participants in the intervention group reported that the cushions on the bariatric simulation suit restricted their limb movements. For examples, participants stated that it was "weird [to do the tasks] with the extra cushion" (participant number I02), "difficult to stand up and sitting down" (participant I05), " restricted, hard to get the leg up" (participant I06) and "[hard] to keep straight in hips and knee" (participant I09).

The participants in the control reported that they did not notice any challenge or difficulties when performing the tasks.

The second question asked by the researcher is "Did anything surprise you while you were performing the tasks?" A common theme was found in the intervention group: the bariatric simulation suit led to restricted visual field. Five participants from the intervention group reported that the bariatric simulation suit restricted their visual field during the functional tasks. Specifically, participants stated that they "couldn't see their feet" (participant I07 and I10), "looked at the floor a lot more" (participant I04), and "hard to make a judgement" (participant I07). Participants in the control reported that they did not experience any surprises during the functional tasks.

4.9 Summary of Results

Ten students from the healthcare programs enrolled in the intervention group and eight individuals with obesity enrolled in the control group. The bariatric simulation suit significantly altered the gait pattern and trunk/neck flexion of participants without obesity during walking, stair climbing, and obstacle crossing. The bariatric simulation suit significantly decreased walking speed, step length, step height, and increased step width during walking. For stair climbing, the bariatric simulation suit increased the step width of participants without obesity. The bariatric simulation suit decreased the walking speed, increased step width and double support time during obstacle crossing. In addition, wearing the bariatric simulation suit also increased the total time to complete the TUG test. However, only some of the alterations with regard to functional movement while wearing the bariatric simulation suit were similar to the movements observed with participants in the control group. Participants from the intervention group also found that it was more challenging to complete the tasks with bariatric suit while individuals in the control group reported no challenges.

CHAPTER 5 DISCUSSION

The following chapter discusses the key findings generated from the results of the study, including implications of the spatiotemporal measurements, the self-reported information, and potential biases of this study. As a pilot study on the impact of a bariatric simulation suit on functional mobility in adults without obesity this chapter also addresses the limitations of the study and makes recommendations for further research.

5.1 Challenges of Recruitment

Based on the original plan, the study required the 10 participants in each group to have matched age, sex and height. However, we were not able to match the characteristics between groups and recruit enough participants for the control group by the end of the study. The recruitment posters and social media were used to reach out large population. However, there was limited number of requests to participate in the study and therefore we were unable to recruit enough participants to have matched controls. Due to time restraints on equipment rentals for the study and funding it was decided by the research team to forgo matched controls. Since we were not able to match the characteristics between groups, we were therefore not able to conclude whether the simulation suit simulates movements in persons who have a body size similar to that created by the simulation suit. The challenges during the study process also provided useful information and recommendations for future studies.

5.2 Experimental Challenges

We used reflective motion capture markers in our study to capture kinematic information. It was difficult to attach the marker clusters on the participants and the bariatric simulation suit, so we tried different methods and found that placing the markers on to the modifiable thermoplastic plates and molding them according to the body shape of the participants and the bariatric simulation suit were effective. To reduce the vibration of the marker clusters during the functional tasks we found that attaching the plates on to the fabric wraps with Velcro was effective to keep the marker clusters in place. Another challenge we found with the 3D motion capture system was non-identifiable source of flickering in the background which can interfere with the marker data we captured. After several attempts, we found that calibrating the system less than 30 minutes prior to the experimental trials reduced the problems of flickering.

5.3 Bariatric Suit and Walking

The results from the walking task showed that the bariatric simulation suit decreased the walking speed, step length, step height, and increased step width of adults without obesity. Although in our study, these differences were not found when comparing the control group (obesity) to the intervention group without the suit, they are very similar to the findings of gait pattern of individuals with obesity in other studies(Ko, et al., 2010; Lai, Leung, Li, Zhang, 2008; Fabris de Souza et al., 2005). Multiple studies have shown that compared to individuals with a normal BMI, individuals with obesity have slower walking speed, shorter and wider steps, and increased stance phase and double support phase during walking (Ko, et al., 2010; Lai, Leung, Li, Zhang, 2008; Fabris de Souza et al., 2005). One possible explanation for the discrepancy is that the BMI of most participants in the control group was at the lower end of the obesity range. Therefore, the physical alterations might not be significant enough to lead to gait alterations during walking.

5.4 Bariatric Suit and Stair walking

The results from the stair walking task showed an increased step width while wearing the bariatric simulation suit. The extra cushioning of the suit in between the legs separated the participants' legs further apart and forced them to have wider steps. The difference in step width were not found between participants with obesity and participants with normal BMI. As mentioned in the walking section, the BMI of most participants in the control group were at the lower end (obesity class 1) of the BMI classification chart and I propose that their body structures are not significantly altered due to excessive weight and fat. Therefore, the tissues in between the legs may not be significant enough to cause wider steps. Surprisingly, longer double support time is only found in control group. This finding may indicate that the double support is largely influenced by body weight.

5.5 Bariatric Suit and Obstacle crossing

Results show that while wearing the bariatric simulation suit obstacle crossing speed decreased, step width and double support time increased. This finding is consistent with the study conducted by Bronislava (2015). They found that when crossing obstacles with different heights, adults with obesity had slower velocity, lower cadences, shorter steps, larger step width, and longer single and double limb support time than adults without obesity. As in other activities, the difference is only found between the "with suit condition and the "without suit" condition. There is no significant difference between control group and intervention group. It may be due to the effect of the instantaneous change and the body may not have adapted to the change and required greater movement to cope with it. Whereas for individuals with obesity, the structural alteration is gradual, and the body has developed different mechanisms, over time, to cope with the alterations.

5.6 Bariatric Suit and Timed Up and Go

The total time for the participants to complete the TUG test was collected. The total time to complete the task was increased when participants were the bariatric simulation suit. We also found that the control group had significant longer total time to complete the task when comparing to the "without suit" condition. This suggested that the suit added difficulty to perform the tasks such as standing up, walking and sitting down. This result is similar to the study done by Merder-Coşkun et al., 2017 on children and adolescents with obesity. Because the "with suit' condition had similar result as the control group in total time to complete the TUG, it can be suggested that the physical impairments during functional task such as standing and sitting down are due to structural alterations to the body. In addition, as the TUG test is used to measure the static balance and dynamic balance, longer time may indicate mobility impairments (Bischoff et al., 2003). Therefore, the bariatric suit may have functionally impaired the individuals without obesity.

5.7 Neck or Trunk flexion

This study also recorded and analyzed the data from measurement of neck or trunk flexions, which was used as an indirect way to indicate that extra movements are needed for participants to obtain the visual information for guidance during the functional tasks. Results show that the "with suit" condition increased the number of participants who had head/trunk flexion only in obstacle crossing task. This may suggest head or trunk flexion were needed to provide information about the ground when the environment or the tasks is difficult. Interestingly, similar findings are not found in the stair climbing tasks. This may be because the hand railing was attached to the stairs, and the additional support may decrease the need for additional information for foot placement using a visual field. Greater numbers of individuals with obesity had head/trunk flexion only during walking when compared to individuals without obesity in normal condition. This may suggest different mechanisms may be developed by the participants with obesity: Instead of depending on the visual information for balance and support individuals with obesity may rely on other mechanisms for support such as kinesthetic feedbacks. This may also attribute to the fact that the BMI of most participants in the control group were at the lower end (obesity class 1) of the BMI classification chart and may not have a large amount of abdominal fat accumulation that blocked the field of view. The spatiotemporal findings showed that compared to the intervention group (in both conditions) participants in the control group had longer double support time during stair walking. This may suggest, in different conditions, people with obesity use different mechanisms to perform the functional tasks.

5.8 Participant reported Outcome

Participants from the intervention group found that the tasks were more challenging to complete with the bariatric simulation suit. However, participants with obesity did not find that the tasks were challenging at all. This finding is similar to the study done by Kim and Joines (2010), where they found that individuals without obesity reported that they feel tired after completing the tasks while wearing a weighted simulation suit and the obesity group were relatively not tired. In their study, they proposed the difference may be attributed to the instant change in weight for individuals without obesity and gradual accommodation for individuals with obesity. Similar mechanism may also contribute to the findings in our study. Although, the bariatric simulation suit in this study was not weighted, there were instant structural alterations to the body that appeared to increase the level of difficulties while completing the functional tasks. Whereas in the control group, participants who have obesity were accustomed to the physical compensations associated with their body size and shape.

Furthermore, most participants in the intervention group reported that the bariatric simulation suit restricted their visual field and limited their limb movements. These findings are confirmed by the information captured in 3D motion capture system. During obstacle crossing, in the intervention group, more participants without obesity had neck/trunk flexion while wearing the bariatric simulation suit. This may suggest that the visual information about the ground is limited when wearing the bariatric simulation suit, participants needed to bend their head or trunk forward to accurately locate the obstacles on the ground to determine how to step over them. In addition, the bariatric simulation suit increased the step width in all activities. This may suggest that the extra cushion between the limbs restricted their limbs to move as they normally do. Interestingly, the control group did not report any difficulties or challenges related to obesity. This may also attribute to fact that the individuals with obesity were accustomed to the physical compensations associated with their body size and shape.

5.9 Effectiveness of Bariatric Simulation Suit

This study is the first to demonstrate the impact of a non-weighted bariatric suit on functional mobility in individuals without obesity. The result of this study showed that the gait pattern of individuals without obesity was altered while wearing the bariatric simulation suit. Although not all alterations were similar to the gait pattern of individuals with obesity in the control group, the alterations were similar to the findings in other studies (Ko et al., 2010; Lai, Leung, Li, Zhang, 2008; Fabris de Souza et al., 2005). This may attribute to the BMI level of the control group being at the lower end of the obesity classification (i.e. obesity class I). As result, the participants with obesity may not have much physical structure alterations compare to the groups with obesity in other studies. When compared with the studies that have obesity group with a higher BMI (i.e. obesity class II or III), the numbers of spatiotemporal parameters that were altered in the 'with suit" condition were less than the participants with obesity in other studies. This may because the unchanged spatiotemporal parameters in our study are affected by the weight not physical structural alterations.

This study is the first study using a bariatric simulation suit that included information about head position with respect to visual fields during the functional tasks. As discussed above the neck and truck flexion used to determine visual field were different between the "with suit" condition and the control group. Due to the limitation of the sample in this study, we cannot conclude if the discrepancy is due to the physical structure alterations or weight related factors.

Results from the brief interview found that participants without obesity after experiencing the instant change of body shape and size noticed the difficulties of performing the functional tasks. Individuals in the study with obesity did not experience a sudden change of body size and shape and may have developed functional mechanisms over time to participate in functional tasks in the context of their current body structure. As result, participants without obesity did not report any difficulties with the performance of the functional tasks.

5.10 Limitations

This study had a number of limitations. Firstly, we were not able to match the characteristics between groups. Therefore, this pilot study was not sufficient to conclude whether the simulation suit simulates movements in persons who have a body size similar to that created by the simulation suit and the results should be interpreted with caution. However, the study shows statistically significant differences in bariatric suit wearing condition and without suit condition of individuals without obesity in functional mobility. These results indicated the potential application of the bariatric simulation suit as an effective educational tool among health care settings.

A second limitation is that most of the participants within the intervention group were female. This may have affected the study results. However, according to the study by Frimenko, Whitehead, and Bruening (2014) gait patterns are more affected by a persons' height and leg length, not by sex. In our study the there is no significant difference in height between groups. Therefore, it is unlikely that the gait pattern differences between groups were affected by sex.

Thirdly, although the functional tasks performed during the experiment are standardized tests for functional mobility that are used routinely in research to assess function, those tasks are short and brief. Therefore, they may have affected the gait patterns, neck/trunk flexions and the interview answers. Those tasks may not be physically demanding enough to represent the daily activities and may not able to show the difference between groups and conditions in some parameters over a longer period of time.

Fourth, in this study we chose to use BMI to classify obesity. As BMI does not take muscle mass into consideration, some participants might have been classified as living with obesity but may be classified as normal in other systems. This may have affected the results of the control group. It may also partially explain the phenomenon of having few gait pattern alterations in the control group.

Lastly, the cameras we used for the 3D motion capture system are mounted on the ceiling. This arrangement may have affected the precision of the location of the markers on the lower limbs due to extra light reflections captured by the 3D motion capture system. With cameras mounted on the ceiling, extra noise caused by light reflecting off the shiny floor surface were captured by the system as unidentifiable markers. These may be accidentally identified as data markers along the movement path of the participants by the system. To reduce the light noise captured by the 3D motion capture system, a non-reflective floor surface and light blocking curtains were installed. We also could not incorporate force plates into the experiments. Therefore, we could not capture dynamic information about center of mass and dynamic measures of ground foot reaction forces.

5.11 Suggestions for Future Studies

Future studies should consider recruiting from wider age range to achieve a larger sample size. Although we tried to recruit through the Obesity Canada Public Engagement Committee (OC-PEC), there was little or no response. Perhaps not enough young people (18-40 years old) are members of the OC-PEC. Recruit from a wider age range may allow the researcher to carefully match participants with their gender, age and height. Moreover, participants should be classified based on their obesity level. This may allow researchers to find the best classes that the bariatric simulation suit represented.

Future studies should also consider setting up the motion capturing cameras at ground level to achieve better resolutions. In addition, incorporating force plates may also be beneficial for capturing dynamic information of center of mass and dynamic measure of ground foot reaction forces.

Future research should analysis the information of joint angle for future work to gather more accurate information about how the bariatric simulation suit affected the range of motion of individuals without obesity. The upper limb movements should also be analyzed to further understand the mechanisms used during the functional activities. Moreover, the duration and complexity of the functional tasks may be modified more representative of the daily tasks. Future studies should also try to add an eye tracker device into the study to directly gather the information about visual allocation of the participants during the tasks.

The center of mass of the participants in each group were not measured in this study. Therefore, we were not able to conclude if the balance and stability were affected by the bariatric simulation suit. Future studies should consider measuring the distribution of the center of mass for each group. This will allow researchers to find if the bariatric simulation suit impacts the balance and stability of individuals without obesity by altering the center of mass. It will further provide information if the altered gait pattern in bariatric suit condition are due to compensation of poor balance and instability.

Using the bariatric simulation suit as an educational tool with students and health care professionals is relatively new (Kim and Joines, 2010). To help build more evidence for the use of the bariatric simulation suit as an educational tool, future research would benefit from the addition of qualitative methodology to evaluate participants' experience of wearing the bariatric simulation suit. In addition, as the bariatric simulation suit is commonly used in healthcare programs to educate future healthcare providers, students from more programs are needed to further explore how does the bariatric simulation suit impacted their view on obesity and evaluating the effectiveness of the bariatric simulation suit as an educational tool.

CHAPTER 6 CONCLUSION

The main purpose of this study was to test how a bariatric simulation suit affected the functional mobility of individuals without obesity. The results indicate that the bariatric simulation suit alters the functional movements of individuals without obesity. Although, this pilot study did not provide confirmation that the bariatric simulation suit was effective in representing the typical gait of people with obesity but did provide establish a protocol for a definitive future study.

The study also evaluated individuals' experience about wearing the bariatric simulation suit during functional tasks. The results showed that these participants found the tasks were more challenging to complete with the bariatric simulation suit. It confirms that the bariatric simulation suit alters the perception of obesity.

Although the study design did not allow us to determine whether the simulation suit simulates movements in persons who have a body size similar to that created by the simulation suit, this study demonstrated that the simulation suit alters the functional mobility of individuals without obesity. The possible reasons may relate to the alteration of physical structure and decrease of range of motion. To help build stronger evidence for the bariatric simulation suit, future studies need to have matched samples with classified obesity groups. Representative functional tasks and qualitative interviews may also helpful to better illustrate the mechanism of the bariatric simulation suit.

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Appendices

Appendix A Recruitment Posters

Recruitment Poster for the intervention group

Participants Needed For a Gait Study Using a Bariatric Simulation Suit

We are looking for volunteers:

- **With a body mass index between 18-25 kg/m^2**
  Click following link or scan the QR code for BMI calculation:
  https://bit.ly/2jW8Pxy
- **18-40 years old**
- **Occupation Therapy, Physical Therapy, Kinesiology or nursing students**

As a participant in this study, you would be asked to:

- **Perform straight walking trials (10 meters) two times**
- **Stair walking**
- **Timed up and Go** (rise from a chair, walk three meters, walk back to the chair, and sit down)
- **Complete questionnaires**
- **Repeat the same procedure with and without the simulation suit**

Your participation would involve *one* session,
which is approximately *1-1.5 hours*.

For more information about this study, or to volunteer for this study, please contact:
***Yilina Liubaoerjijin, Rehabilitation Medicine* at 780-492-9020 or email:**
liubaoer@ualberta.ca

Recruitment Poster for control group

Participants Needed for a Gait Analysis Study

We are looking for volunteers:

- **with a body mass index (BMI) ≥30kg/m^2**
  Click on the following link or scan the QR code for BMI calculation:
  https://bit.ly/2jW8Pxy
- **18-40 years old**

As a participant in this study, you would be asked to:

- **Perform straight walking trials (10 meters) two times**
- **Stair walking**
- **Timed up and Go** (rise from a chair, walk three meters, walk back to the chair, and sit down)
- **Complete questionnaires**

Your participation would involve *one* session,
which is approximately *1 hour*.

For more information about this study, or to volunteer for this study, please contact:
Yilina Liubaoerjijin, Rehabilitation Medicine **at 780-492-9020 or email:**
liubaoer@ualberta.ca

Appendix B Pre-Screening form to assess the eligibility

This is to be completed before participating the study. It is important that you disclose ALL of the relevant medical conditions so that we/I may determine whether you are eligible to participate in this study.

Age:

Sex:

Height:

Weight:

BMI:

Visual impairments ☐

musculoskeletal disorder that impairs mobility ☐

diabetes ☐

neuropathy ☐

neuromuscular disorders:

amyotrophic lateral sclerosis ☐

multiple sclerosis ☐

myasthenia gravis ☐

spinal muscular atrophy ☐

Sustained a recent lower extremity injury that impairs mobility ☐

Osteoarthritis ☐

Gouts ☐

Sustained a recent lower extremity injury that impairs mobility ☐

require a mobility device

wheelchair ☐

walker ☐

crutches ☐

cane ☐

Appendix C Information Sheet and Consent Form

Research Study
The Impact of a Bariatric Simulation Suit on Functional Mobility in Adults With a Body Mass Index Classified as "Normal"

Participant Information Sheet and Consent Form for intervention group

Principal Investigator:

Dr. Mary Forhan
Department of Occupational Therapy
University of Alberta, Edmonton AB T6G 2G4
Email: forhan@ualberta.ca
Phone: 780-492-0300

Background and Purpose:
The University of Alberta is using a commercially available bariatric simulation suit as a teaching tool for use with students registered in clinical training programs including nursing, occupational therapy, physical therapy and kinesiology. The manufacturer of the simulation suit claims that wearing the simulation suit results in a better understanding of what it is like for individuals to move about who have a body mass index (BMI) of $\geq 30kg/m^2$. However, the extent to which the simulation suit truly simulates moving about to that of individuals with a BMI of $\geq 30kg/m^2$ has yet to be examined.

Purpose:
The purpose of this study is to test the bariatric simulation suit with regard to its ability to produce the similar movement patterns as individuals with a body mass index (BMI) of $\geq 30kg/m^2$. The findings of this study will provide information on the effectiveness of a bariatric simulation suit in helping students in health care professionals to understand daily challenges that some individuals with obesity may experience.

Procedures:
If you choose to join in this research study, you will be asked to sign a consent form to participate. For the study, you will be asked to answer some questions about your sociodemographic and anthropometric data, medical history, weight history, and level of fear of falling. Then, you will be asked to complete the functional tasks listed below while wearing 3D motion capture sensors and an eye tracking glasses (Tobii pro glasses 2). After the functional tasks you will be asked to participate in a face- to-face interview about the perception of weight and overall comment about the tasks will be collected.

Activities	Description
Descriptive Stats & Questionnaires	Sociodemographic (ethnicity, age, date of birth, and sex) and anthropometric data (weight, height, BMI, waist circumference, hip circumference and waist to hip ratio), medical history, weight history, EQ5-D (A quality of life measure), Fear of Falling Avoidance Behavior Questionnaire

Functional tasks	**Complete the functional tasks listed below while wearing 3D motion capture sensors and an eye tracking glasses (Tobii pro glasses 2)**	
	Walking trials	Two 10 metre straight walking trials at a self-selected speed. Rate perceived effort using task evaluation form and Borg scale
	Stair walking	Participants need to ascend and descend a maximum of six steps on a staircase three times, placing only one foot on each step at a self-selected speed. Rate perceived effort using task evaluation form and Borg scale
	Timed up and Go	Participants need to rise from a chair with armrests, walk three meters, turn around, walk back to the chair, and sit down at the comfortable pace. Participants need to perform the task twice. Rate perceived effort using task evaluation form and Borg scale
	Obstacle crossing	Participants need to cross three obstacles created with wooden dowels that reflect the height of a door threshold (4 cm), a small step (11 cm), and a tall step (16 cm), at a self-selected pace on a 10 metre long path. Participants will be asked to perform this task three times. Rate perceived effort using task evaluation form and Borg scale
	Participants will be asked to repeat all of the same procedures as above with and without wearing the bariatric simulation suit.	
Interview	Participants will be asked to answer a set of questions about their experience of the functional mobility tasks, their perception of weight and their experience about the simulation suit. Two key questions that the researcher will ask directly to the participants and the answers will be recorded using a digital voice recorder. It will be transcribed verbatim by the researcher. The data will be transferred to an electronic database, RedCap, using a secure desk-top computer in room 1-46 Corbett Hall, University of Alberta. Patient information will be kept separate from the paper copies and electronic files, identified only by a study number.	
Total time: 1.5 hr		

Potential Benefits:
By participating in this study, you will be able to find out some information about your walking speed, gait patterns, and your visual perception while moving about.

Potential Risks:
You will be walking, standing, climbing and descending the stairs, rising and sitting down both with and without the simulation suit. Therefore, you could have a trip or fall while performing tasks in the study. You will be monitored at all times by study staff to minimize this risk. There is also a small risk that you may feel fatigued from the functional tasks. You will be able to decide

how fast to walk or exert yourself during each task, so you can rest or pace yourself during the testing to prevent overexertion.

Stopping the Tests:
You may stop any of the tests at any time without any jeopardy to you.

Confidentiality
Confidentiality will be respected and no information that discloses your identity will be released or published. Your data will be saved in a database using an identification number known only to the research team.

After the study is done, we will still need to securely store your data that was collected as part of the study. At the University of Alberta, we keep data stored for a minimum of 5 years after the end of the study.
If you leave the study, we will not collect new information about you, but we may need to keep the data that we have already collected.

Costs:
There are no costs to you to participate in this study. Participants who require parking on campus to attend the session will be given a code to use at the parking meters on campus to cover the cost of parking.

Voluntary Participation:
Participation in this study is voluntary. If you choose to participate in this study, you can withdraw from the study at any time. You do not have to give a reason for withdrawing from the study.

Please contact the individual identified below if you have any questions or concerns:
Principle Investigator: Dr. Mary Forhan **Phone:** 780-492-0300

The plan for this study has been reviewed for its adherence to ethical guidelines and approved by the Health Research Ethics Board at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the Research Ethics Office at (780)492-2615.

Research Study
The Impact of a Bariatric Simulation Suit on Functional Mobility in Adults With a Body Mass Index Classified as "Normal"

Participant Information Sheet and Consent Form for control group

Principal Investigator:

Dr. Mary Forhan
Department of Occupational Therapy
University of Alberta, Edmonton AB T6G 2G4
Email: forhan@ualberta.ca
Phone: 780-492-0300

Background and Purpose:
The University of Alberta is using a commercially available bariatric simulation suit as a teaching tool for use with students registered in clinical training programs including nursing, occupational therapy, physical therapy and kinesiology. The manufacturer of the simulation suit claims that wearing the simulation suit results in a better understanding of what it is like for individuals to move about who have a body mass index (BMI) of $\geq$ 30kg/m^2. However, the extent to which the simulation suit truly simulates moving about to that of individuals with a BMI of $\geq$ 30kg/m^2 has yet to be examined.

Purpose:
The purpose of this study is to test the bariatric simulation suit with regard to its ability to produce the similar movement patterns as individuals with a body mass index (BMI) of $\geq$ 30kg/m^2. The findings of this study will provide information on the effectiveness of a bariatric simulation suit in helping students in health care professionals to understand daily challenges that some individuals with obesity may experience.

Procedures:
If you choose to join in this research study, you will be asked to sign a consent form to participate. For the study, you will be asked to answer some questions about your sociodemographic and anthropometric data, medical history, weight history, and level of fear of falling. Then, you will be asked to complete the functional tasks listed below while wearing 3D motion capture sensors and an eye tracking glasses (Tobii pro glasses 2). After the functional tasks you will be asked to participate in a face- to-face interview about the perception of weight and overall comment about the tasks will be collected.

Activities	**Description**
Descriptive Stats & Questionnaires	Sociodemographic (ethnicity, age, date of birth, and sex) and anthropometric data (weight, height, BMI, waist circumference, hip circumference and waist to hip ratio), medical history, weight history, EQ5-D (A quality of life measure), Fear of Falling Avoidance Behavior Questionnaire
Functional tasks	**Complete the functional tasks listed below while wearing 3D motion capture sensors and an eye tracking glasses (Tobii pro glasses 2)**

	Walking trials	Two 10 metre straight walking trials at a self-selected speed. Rate perceived effort using task evaluation form and Borg scale
	Stair walking	Participants need to ascend and descend a maximum of six steps on a staircase three times, placing only one foot on each step at a self-selected speed. Rate perceived effort using task evaluation form and Borg scale
	Timed up and Go	Participants need to rise from a chair with armrests, walk three meters, turn around, walk back to the chair, and sit down at the comfortable pace. Participants need to perform the task twice. Rate perceived effort using task evaluation form and Borg scale
	Obstacle crossing	Participants need to cross three obstacles created with wooden dowels that reflect the height of a door threshold (4 cm), a small step (11 cm), and a tall step (16 cm), at a self-selected pace on a 10 metre long path. Participants will be asked to perform this task three times. Rate perceived effort using task evaluation form and Borg scale
Interview	Participants will be asked to answer a set of questions about their experience of the functional mobility tasks and their perception of weight. Two key questions that the researcher will ask directly to the participants and the answers will be recorded using a digital voice recorder. It will be transcribed verbatim by the researcher. The data will be transferred to an electronic database, RedCap, using a secure desk-top computer in room 1-46 Corbett Hall, University of Alberta. Patient information will be kept separate from the paper copies and electronic files, identified only by a study number.	
Total time: 1 hr		

Potential Benefits:
By participating in this study, you will be able to find out some information about your walking speed, gait patterns, and your visual perception while moving about.

Potential Risks:
You will be walking, standing, climbing and descending the stairs, rising and sitting down both with and without the simulation suit. Therefore, you could have a trip or fall while performing tasks in the study. You will be monitored at all times by study staff to minimize this risk. There is also a small risk that you may feel fatigued from the functional tasks. You will be able to decide how fast to walk or exert yourself during each task, so you can rest or pace yourself during the testing to prevent overexertion.

Stopping the Tests:
You may stop any of the tests at any time without any jeopardy to you.

Confidentiality
Confidentiality will be respected and no information that discloses your identity will be released or published. Your data will be saved in a database using an identification number known only to the research team.

After the study is done, we will still need to securely store your data that was collected as part of the study. At the University of Alberta, we keep data stored for a minimum of 5 years after the end of the study.
If you leave the study, we will not collect new information about you, but we may need to keep the data that we have already collected.

Costs:
There are no costs to you to participate in this study. Participants who require parking on campus to attend the session will be given a code to use at the parking meters on campus to cover the cost of parking.

Voluntary Participation:
Participation in this study is voluntary. If you choose to participate in this study, you can withdraw from the study at any time. You do not have to give a reason for withdrawing from the study.

Please contact the individual identified below if you have any questions or concerns:
Principle Investigator: Dr. Mary Forhan **Phone:** 780-492-0300

The plan for this study has been reviewed for its adherence to ethical guidelines and approved by the Health Research Ethics Board at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the Research Ethics Office at (780)492-2615.

Research Study
The Impact of a Bariatric Simulation Suit on Functional Mobility in Adults Without Obesity

Consent Form

Principal Investigator:
Dr. Mary Forhan
Department of Occupational Therapy
University of Alberta, Edmonton AB T6G 2G4
Email: forhan@ualberta.ca
Phone: 780-492-0300

	Yes	No
Do you understand that you have been asked to be in a research study?		
Have you read and received a copy of the attached information sheet?		
Do you understand the benefits and risks involved in taking part in this research study?		
Have you had an opportunity to ask questions and discuss this study?		
Do you understand that you are free to leave the study at any time, without having to give a reason and without affecting your future health care?		
Has the issue of confidentiality been explained to you?		
Do you understand who will have access to the information your provide?		
Who explained this study to you? ________________________________		
I agree to participate in this study: *Signature of Research Participant*___________________________ *Printed Name*___________________________ *Contact phone/email* ___________________________ *Date(DD/MM/YYYY)*___________________________		

THE INFORMATION SHEET MUST BE ATTACHED TO THIS CONSENT FORM AND A COPY GIVEN TO THE STUDY PARTICIPANT

Appendix D. Fear of Falling Avoidance Behavior Questionnaire (Landers, Durand, Powell, Dibble & Young, 2011)

Please answer the following questions that are related to your balance. For each statement, please check one box to say how the fear of falling has or has not affected you. If you do not currently do the activities in question, try and imagine how your fear of falling would affect your participation in these activities. If you normally use a walking aid to do these activities or hold onto someone, rate how your fear of falling would affect you as if you were not using these supports. If you have questions about answering any of these statements, please ask the questionnaire administrator.

	Please check **one box** for each question				
Due to my fear of falling, I avoid…	**Completely disagree**	**Disagree**	**Unsure**	**Agree**	**Completely agree**
1. Walking					
2. Lifting and carrying objects (e.g., cup, child)					
3. Going up and downstairs					
4. Walking on different surfaces (e.g., grass, uneven ground)					
5. Walking in crowded places					
6. Walking in dimly lit, unfamiliar places					
7. Leaving home					
8. Getting in and out of a chair					
9. Showering and/or bathing					
10. Exercise					
11. Preparing meals (e.g., planning, cooking, serving)					
12. Doing housework (e.g., cleaning, washing clothes)					

Please make sure you have checked one box for each question. Thank you!

For Office Use Only:

Total:

Appendix E Motion Capture System

The System

OptiTrack eSync 2.

Sample rate of 10 Hz - 50 kHz.

Cameras

Prime 17W

Sample rate of 360 Frames per Second (FPS).

Resolution: 1.7 MP.

Field of view: 70 degrees.

12.6cm x 12.6 cm.

Number of cameras: 8-12.

Markerset

Software

Motive (Optical motion capture software).

Calibration

Continuous; uses tracking data during collection to self heal calibration over time.

Ignores spurious noise (ie. from temperature changes) in real time.

Appendix F Evaluation of a Simulation suit

ID: Gender: Age: BMI: GR:

Without Simulation suit:

This task was easy to complete	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
Walking	1	2	3	4	5	6
Stair walking	1	2	3	4	5	6
Timed up and Go	1	2	3	4	5	6
Obstacle crossing	1	2	3	4	5	6
This was a frustrating task	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
Walking	1	2	3	4	5	6
Stair walking	1	2	3	4	5	6
Timed up and Go	1	2	3	4	5	6
Obstacle crossing	1	2	3	4	5	6

With Simulation suit:

This task was easy to complete	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree
Walking	1	2	3	4	5	6
Stair walking	1	2	3	4	5	6
Timed up and Go	1	2	3	4	5	6
Obstacle crossing	1	2	3	4	5	6
This was a frustrating task	Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree

Walking	1	2	3	4	5	6
Stair walking	1	2	3	4	5	6
Timed up and Go	1	2	3	4	5	6
Obstacle crossing	1	2	3	4	5	6

Appendix G Borg Rating of Perceived Exertion (Borg GA, 1998)

Rating	**Descriptor**
6	No Exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Appendix H Data Collection sheet: Descriptive Stats

CASE REPORT FORM

The Impact of a Bariatric Simulation Suit on Functional Mobility in Adults Without Obesity

Patient ID # ☐☐☐☐

Date of Initial Consultation Visit ____/____/_______
dd mm yyyy

DEMOGRAPHICS

Date of Birth ____/____/_______ Age _______ Sex Male ☐ Female ☐
dd mm yyyy

Ethnicity

☐ Aboriginal (First Nations/North American Indian, Metis, or Inuk/Inuit)

☐ White ☐ Black ☐ Filipino ☐ Latin American

☐ Chinese ☐ Korean ☐ Japanese ☐ Arab

☐ South Asian (e.g. East Asian, Pakistani, Sri Lankan, etc.)

☐ Southeast Asian (e.g. Vietnamese, Cambodian, Laotian, Thai, etc.)

☐ West Asian (e.g. Iranian, Afghan, etc.) ☐ Other, specify ____________

ANTHROPOMETRICS

Weight _________kg Height__________cm BMI _________kg/m^2

Waist circumference ________cm ________cm ________cm Average : ________cm

Hip circumference ________cm ________cm ________cm Average : ________cm

Waist to hip ratio ___________

WEIGHT HISTORY

How long have you been on this weight? __________
What was your weight one year ago? _________

Please check all applicable conditions.

☐ weight stable in past year

☐ weight gained in past year when and how much weight? ____________

☐ weight lost in past year when and how much weight? ____________

QUALITY OF LIFE and LEVEL OF FEAR OF FALLING

EQ-5D completed? Score: __________________

Fear of Falling Avoidance Behavior Questionnaire Score: __________________

Borg grading scale:

Walking:	
Stair walking:	
Time up and Go:	
Obstacle crossing:	

Appendix I MATLAB Code

Spatiotemporal Parameters for Walking and Stairs Climbing

```
%Change the name of the file within the quotations here
markers=dataRead("I01 NB Stairs2.csv");

prime(1)=((markers(37).data(end)-markers(37).data(1))+(markers(40).data(end)-
markers(40).data(1)))/2;
prime(2)=((markers(39).data(end)-markers(39).data(1))+(markers(42).data(end)-
markers(42).data(1)))/2;

mag=sqrt(prime(1)^2+prime(2)^2);
prime(1)=prime(1)/mag;
prime(2)=prime(2)/mag;

theta=acos(dot(prime,[0 1]));
R = [cos(theta) -sin(theta); sin(theta) cos(theta)];
dir=[markers(37).data; markers(39).data];
left=R*dir;
dir=[markers(40).data; markers(42).data];
right=R*dir;

vel_right=right(2,3:end)-right(2,1:end-2);
vel_left=left(2,3:end)-left(2,1:end-2);

dir=[markers(7).data; markers(9).data];
left=R*dir;
dir=[markers(10).data; markers(12).data];
right=R*dir;

vel_right_toe=right(2,3:end)-right(2,1:end-2);
vel_left_toe=left(2,3:end)-left(2,1:end-2);

n=length(vel_right);
step_count=0;
step_count_left=0;
step_count_right=0;
stride_count_right=0;
stride_count_left=0;
gait_right_count=0;
gait_left_count=0;
gait_right_flag=false;
gait_left_flag=false;
walk_flag=false;
```

```
tol=0.01; %0.01
min_stride=0.05;
double_support_flag1=false;
double_support_count1=0;
double_support_flag2=false;
double_support_count2=0;
first_step_right=true;
stance_flag_right=false;
stance_flag_left=false;
stance_count_right=0;
stance_count_left=0;
cadence_right=0;
cadence_left=0;
height_left_count=0;
height_right_count=0;

gait_right_frame(1)=0;
gait_left_frame(1)=0;
double_support_frame1(1)=0;
double_support_frame2(1)=0;
gait_cycle_left(1)=0;
gait_cycle_right(1)=0;
double_support_time1(4)=0;
double_support_time2(4)=0;
support_percent_left(1)=0;
support_percent_right(1)=0;
stance_frame_right(1,2)=0;
stance_frame_left(1,2)=0;
swing_frame_right(1,2)=0;
swing_frame_left(1,2)=0;
stride_speed_left_each(1)=0;
stride_speed_right_each(1)=0;
stance_phase_left(1)=0;
stance_phase_right(1)=0;
step_length(1)=0;
step_width_right(1)=0;
step_width_left(1)=0;
stride_length_left(1)=0;
stride_length_right(1)=0;
swing_phase_left(1)=0;
swing_phase_right(1)=0;
height_left(1)=0;
height_right(1)=0;
step_left(1)=0;
step_right(1)=0;
```

```
for ii=1:n
   if ~walk_flag
      if ((abs(vel_right(ii))>tol)||(abs(vel_left(ii))>tol))
         walk_flag=true;
         if (abs(vel_right(ii))>tol)
            first_step_right=true;
         else
            first_step_right=false;
         end
      end
   else
      if ((abs(vel_right(ii))<tol)&&(abs(vel_left(ii))<tol))
         step_count=step_count+1;
         %step_length(step_count)=abs(markers(39).data(ii)-markers(42).data(ii));
         step_length(step_count)=abs(left(2,ii)-right(2,ii));
         if ~first_step_right
            step_count_left=step_count_left+1;
            step_left(step_count_left)=step_length(step_count);
            step_width_left(step_count_left)=abs(left(1,ii)-right(1,ii));
            step_frame_left(step_count_left)=ii;
            %step_width_left(step_count_left)=abs(markers(37).data(ii)-markers(40).data(ii));
         else
            step_count_right=step_count_right+1;
            step_right(step_count_right)=step_length(step_count);
            step_width_right(step_count_right)=abs(left(1,ii)-right(1,ii));
            step_frame_right(step_count_right)=ii;
            %step_width_right(step_count_right)=abs(markers(37).data(ii)-markers(40).data(ii));
         end
         step_frame(step_count)=ii;
         walk_flag=false;
         if step_count>2
            %stride=(markers(42).data(step_frame(step_count))-
markers(42).data(step_frame(step_count-1)));
            stride=(right(2,step_frame(step_count))-right(2,step_frame(step_count-1)));
            if (stride>0.2)
               stride_count_right=stride_count_right+1;
               stride_length_right(stride_count_right)=stride;
               stride_speed_right_each(stride_count_right)=stride/((step_frame(step_count)-
step_frame(step_count-2))*0.008333);
            end
            %stride=(markers(39).data(step_frame(step_count))-
markers(39).data(step_frame(step_count-1)));
            stride=(left(2,step_frame(step_count))-left(2,step_frame(step_count-1)));
            if (stride>0.2)
               stride_count_left=stride_count_left+1;
               stride_length_left(stride_count_left)=stride;
```

```
                stride_speed_left_each(stride_count_left)=stride/((step_frame(step_count)-
step_frame(step_count-2))*0.008333);
            end
         end
      elseif ((abs(vel_right(ii))<tol)&&gait_right_flag)
         gait_right_flag=false;
         gait_right_count=gait_right_count+1;
         gait_right_frame(gait_right_count)=ii;
      elseif ((abs(vel_left(ii))<tol)&&gait_left_flag)
         gait_left_flag=false;
         gait_left_count=gait_left_count+1;
         gait_left_frame(gait_left_count)=ii;
      elseif (abs(vel_right(ii)>tol)&&~gait_right_flag)
         gait_right_flag=true;
         height_right_count=height_right_count+1;
         height_right(height_right_count)=0;
      elseif (abs(vel_left(ii)>tol)&&~gait_left_flag)
         gait_left_flag=true;
         height_left_count=height_left_count+1;
         height_left(height_left_count)=0;
      elseif (gait_right_flag)
         if (height_right(height_right_count)<markers(41).data(ii))
            height_right(height_right_count)=markers(41).data(ii);
         end
      elseif (gait_left_flag)
         if (height_left(height_left_count)<markers(38).data(ii))
            height_left(height_left_count)=markers(38).data(ii);
         end
      end
   end
   if ((abs(vel_right(ii))<tol)&&(abs(vel_left_toe(ii))<tol)&&~double_support_flag1)
      double_support_flag1=true;
      double_support_count1=double_support_count1+1;
      double_support_frame1(double_support_count1,1)=ii;
   elseif (((abs(vel_right(ii))>tol)||(abs(vel_left_toe(ii))>tol))&&double_support_flag1)
      double_support_flag1=false;
      double_support_frame1(double_support_count1,2)=ii;
   end
   if ((abs(vel_right_toe(ii))<tol)&&(abs(vel_left(ii))<tol)&&~double_support_flag2)
      double_support_flag2=true;
      double_support_count2=double_support_count2+1;
      double_support_frame2(double_support_count2,1)=ii;
   elseif (((abs(vel_right_toe(ii))>tol)||(abs(vel_left(ii))>tol))&&double_support_flag2)
      double_support_flag2=false;
      double_support_frame2(double_support_count2,2)=ii;
   end
```

```
    if ((abs(vel_right(ii))<tol)&&(abs(vel_right_toe(ii))>tol)&&~stance_flag_right)
      stance_flag_right=true;
      stance_count_right=stance_count_right+1;
      stance_frame_right(stance_count_right,1)=ii;
    elseif ((abs(vel_right_toe(ii))>tol)&&(abs(vel_right(ii)>tol))&&stance_flag_right)
      stance_flag_right=false;
      stance_frame_right(stance_count_right,2)=ii;
    end
    if ((abs(vel_left(ii))<tol)&&(abs(vel_left_toe(ii))>tol)&&~stance_flag_left)
      stance_flag_left=true;
      stance_count_left=stance_count_left+1;
      stance_frame_left(stance_count_left,1)=ii;
    elseif ((abs(vel_left_toe(ii))>tol)&&(abs(vel_left(ii)>tol))&&stance_flag_left)
      stance_flag_left=false;
      stance_frame_left(stance_count_left,2)=ii;
    end
end
if double_support_count1 ~= 0
    double_support_frame1(double_support_count1,2)=n;
end
if double_support_count2 ~= 0
    double_support_frame2(double_support_count2,2)=n;
end

n=length(gait_right_frame);
for jj=1:n-1
    gait_cycle_right(jj)=(gait_right_frame(jj+1)-gait_right_frame(jj))*0.008333;
end

m=length(gait_left_frame);
for jj=1:m-1
    gait_cycle_left(jj)=(gait_left_frame(jj+1)-gait_left_frame(jj))*0.008333;
end

n=length(double_support_frame1);
if n>1
    for jj=1:n
      double_support_time1(jj)=abs(double_support_frame1(jj,2)-
double_support_frame1(jj,1))*0.008333;
    end
end

n=length(double_support_frame2);
if n>1
    for jj=1:n
```

```
        double_support_time2(jj)=abs(double_support_frame2(jj,2)-
double_support_frame2(jj,1))*0.008333;
    end
end

if first_step_right
    for ii=1:length(gait_cycle_left)
        support_percent_left(ii)=(double_support_time1(2*ii+1)+double_support_time2(2*ii+1))/...
    gait_cycle_left(ii);
    end
    for ii=1:length(gait_cycle_right)

support_percent_right(ii)=(double_support_time1(2*ii+2)+double_support_time2(2*ii+2))/...
    gait_cycle_right(ii);
    end

    for ii=1:length(stance_phase_right)
        stance_phase_right(ii)=((stance_frame_right(ii,2)-stance_frame_right(ii,1))*0.008333)/...
            gait_cycle_right(ii);
        swing_phase_right(ii)=1-stance_phase_right(ii);
    end
    for ii=1:(step_count_right-2)
        cadence_right=cadence_right+step_right(ii+1);
    end
    cadence_right=cadence_right/(step_count_right-2);
    for ii=1:length(stance_phase_left)
        stance_phase_left(ii)=((stance_frame_left(ii,2)-stance_frame_left(ii,1))*0.008333)/...
            gait_cycle_left(ii); %+1
        swing_phase_left(ii)=1-stance_phase_left(ii);
    end
    for ii=1:(step_count_left-2)
        cadence_left=cadence_left+step_left(ii+1);
    end
    cadence_left=cadence_left/(step_count_left-2);
else
    for ii=1:length(gait_cycle_right)

support_percent_right(ii)=(double_support_time1(2*ii+1)+double_support_time2(2*ii+1))/...
    gait_cycle_right(ii);
    end
    for ii=1:length(gait_cycle_left)
        support_percent_left(ii)=(double_support_time1(2*ii+2)+double_support_time2(2*ii+2))/...
    gait_cycle_left(ii);
    end

    for ii=1:length(stance_phase_right)
```

```
        stance_phase_right(ii)=((stance_frame_right(ii,2)-stance_frame_right(ii,1))*0.008333)/...
            gait_cycle_right(ii); %+1
        swing_phase_right(ii)=1-stance_phase_right(ii);
    end
    for ii=1:step_count_right-2
        cadence_right=cadence_right+step_right(ii+1);
    end
    cadence_right=cadence_right/(step_count_right-2);
    for ii=1:length(stance_phase_left)
        stance_phase_left(ii)=((stance_frame_left(ii,2)-stance_frame_left(ii,1))*0.008333)/...
            gait_cycle_left(ii);
        swing_phase_left(ii)=1-stance_phase_left(ii);
    end
    for ii=1:step_count_left-2
        cadence_left=cadence_left+step_left(ii+1);
    end
    cadence_left=cadence_left/(step_count_left-2);
end

% cadence_right=((step_frame_right(end-1)-step_frame_right(2))*0.008333)/(step_count_right-
2);
% cadence_left=((step_frame_left(end-1)-step_frame_left(2))*0.008333)/(step_count_left-2);
% cadence_ave=((step_frame(end-2)-step_frame(2))*0.008333)/(step_count-2);
cadence_right=(1/cadence_right)*60;
cadence_left=(1/cadence_left)*60;
cadence_ave=(cadence_right+cadence_left)/2;
stride_speed_right=0;
stride_speed_left=0;

for ii=1:length(stride_speed_left_each)-1
    stride_speed_left=stride_speed_left+stride_speed_left_each(ii);
end
stride_speed_left=stride_speed_left/(length(stride_speed_left_each)-1);
for ii=1:length(stride_speed_right_each)-1
    stride_speed_right=stride_speed_right+stride_speed_right_each(ii);
end
stride_speed_right=stride_speed_right/(length(stride_speed_right_each)-1);
stride_speed_ave=(stride_speed_right+stride_speed_left)/2;


nneck=zeros(length(markers(49).data),3);
for ii=1:length(nneck)

nneck(ii,1)=(markers(49).data(ii)+markers(100).data(ii)+markers(127).data(ii)+markers(136).dat
a(ii))/4;
```

```
nneck(ii,2)=(markers(50).data(ii)+markers(101).data(ii)+markers(128).data(ii)+markers(137).dat
a(ii))/4;

nneck(ii,3)=(markers(51).data(ii)+markers(102).data(ii)+markers(129).data(ii)+markers(138).dat
a(ii))/4;
end

nhead=zeros(length(markers(55).data),3);

for ii=1:length(nhead)
   nhead(ii,1)=(markers(55).data(ii)+markers(79).data(ii)+markers(121).data(ii))/3;
   nhead(ii,2)=(markers(56).data(ii)+markers(80).data(ii)+markers(122).data(ii))/3;
   nhead(ii,3)=(markers(57).data(ii)+markers(81).data(ii)+markers(123).data(ii))/3;
end

nsacral=zeros(length(markers(13).data),3);
for ii=1:length(nsacral)
   nsacral(ii,1)=(markers(13).data(ii)+markers(16).data(ii)+markers(19).data(ii))/3;
   nsacral(ii,2)=(markers(14).data(ii)+markers(17).data(ii)+markers(20).data(ii))/3;
   nsacral(ii,3)=(markers(15).data(ii)+markers(18).data(ii)+markers(21).data(ii))/3;
end

nprime(1)=nhead(1,1)-nneck(1,1);
nprime(2)=nhead(1,3)-nneck(1,3);
mag=sqrt(nprime(1)^2+nprime(2)^2);
nprime(1)=nprime(1)/mag;
nprime(2)=nprime(2)/mag;
theta1=acos(dot(nprime,[0,1]));

nR=[cos(theta1) -sin(theta1); sin(theta1) cos(theta1)];
ndir=[nhead(:,1)'; nhead(:,3)'];
head=nR*ndir;
head(3,:)=nhead(:,2);
ndir=[nneck(:,1)'; nneck(:,3)'];
neck=nR*ndir;
neck(3,:)=nneck(:,2);

vec1(1)=head(1,1)-neck(1,1);
vec1(2)=head(3,1)-neck(3,1);
mag1=sqrt(vec1(1)^2+vec1(2)^2);

for ii=1:length(head)
   vec2(1)=head(1,ii)-neck(1,ii);
   vec2(2)=head(3,ii)-neck(3,ii);
   mag2=sqrt(vec2(1)^2+vec2(2)^2);
```

```
    hn_flex_angle(ii)=acos(dot(vec2,vec1)/(mag1*mag2));
end

hn_flex_count=0;
for ii=1:length(hn_flex_angle)
    if (hn_flex_angle(ii)>0.34906585)
        hn_flex_count=hn_flex_count+1;
        hn_flex_time(hn_flex_count)=ii*0.008333;
    end
end

if (hn_flex_count==0)
    hn_flex_time=0;
end

nprime(1)=nhead(1,1)-nsacral(1,1);
nprime(2)=nhead(1,3)-nsacral(1,3);
mag=sqrt(nprime(1)^2+nprime(2)^2);
nprime(1)=nprime(1)/mag;
nprime(2)=nprime(2)/mag;
theta2=acos(dot(nprime,[0,1]));

nR=[cos(theta2) -sin(theta2); sin(theta2) cos(theta2)];
ndir=[nhead(:,1)'; nhead(:,3)'];
head=nR*ndir;
head(3,:)=nhead(:,2);
ndir=[nsacral(:,1)'; nsacral(:,3)'];
sacral=nR*ndir;
sacral(3,:)=nsacral(:,2);

vec1(1)=head(1,1)-sacral(1,1);
vec1(2)=head(3,1)-sacral(3,1);
mag1=sqrt(vec1(1)^2+vec1(2)^2);

for ii=2:length(head)
    vec2(1)=head(1,ii)-sacral(1,ii);
    vec2(2)=head(3,ii)-sacral(3,ii);
    mag2=sqrt(vec2(1)^2+vec2(2)^2);
    hs_flex_angle(ii)=acos(dot(vec2,vec1)/(mag1*mag2));
end

hs_flex_count=0;
for ii=1:length(hs_flex_angle)
    if (hs_flex_angle(ii)>0.34906585)
        hs_flex_count=hs_flex_count+1;
        hs_flex_time(hs_flex_count)=ii*0.008333;
```

```
    end
end

if (hs_flex_count==0)
    hs_flex_time=0;
end

nprime(1)=nneck(1,1)-nsacral(1,1);
nprime(2)=nneck(1,3)-nsacral(1,3);
mag=sqrt(nprime(1)^2+nprime(2)^2);
nprime(1)=nprime(1)/mag;
nprime(2)=nprime(2)/mag;
theta3=acos(dot(nprime,[0,1]));

nR=[cos(theta3) -sin(theta3); sin(theta3) cos(theta3)];
ndir=[nsacral(:,1)'; nsacral(:,3)'];
sacral=nR*ndir;
sacral(3,:)=nsacral(:,2);
ndir=[nneck(:,1)'; nneck(:,3)'];
neck=nR*ndir;
neck(3,:)=nneck(:,2);

vec1(1)=neck(1,1)-sacral(1,1);
vec1(2)=neck(3,1)-sacral(3,1);
mag1=sqrt(vec1(1)^2+vec1(2)^2);

for ii=1:length(head)
    vec2(1)=neck(1,ii)-sacral(1,ii);
    vec2(2)=neck(3,ii)-sacral(3,ii);
    mag2=sqrt(vec2(1)^2+vec2(2)^2);
    ns_flex_angle(ii)=acos(dot(vec2,vec1)/(mag1*mag2));
end

ns_flex_count=0;
for ii=1:length(ns_flex_angle)
    if (ns_flex_angle(ii)>0.34906585)
        ns_flex_count=ns_flex_count+1;
        ns_flex_time(ns_flex_count)=ii*0.008333;
    end
end

if (ns_flex_count==0)
    ns_flex_time=0;
end

%cadence_ave=(cadence_left+cadence_right)/2;
```

```
gait_cycle_ave=(mean(gait_cycle_left)+mean(gait_cycle_right))/2;
stance_phase_ave=(mean(stance_phase_left)+mean(stance_phase_right))/2;
step_length_ave=mean(step_length(1:end-1));
step_width_ave=(mean(step_width_right)+mean(step_width_left))/2;
stride_length_ave=(mean(stride_length_left(1:end-1))+mean(stride_length_right(1:end-1)))/2;
support_percent_ave=(mean(support_percent_left)+mean(support_percent_right))/2;
swing_phase_ave=(mean(swing_phase_left)+mean(swing_phase_right))/2;
height_ave=(mean(height_left)+mean(height_right))/2;

max_size=length(hn_flex_angle);

A={'gait speed left','gait speed right','gait speed ave','stride length left','stride length right','stride length ave',...
   'step length left','step length right','step length ave','step width left','step width right','step width ave',...
   'step height left','step height right','step height ave','Cadence left','Cadence right','Cadence ave',...
   '% double support time left','% double support time right','% double support ave','stance phase left','stance phase right','stance phase ave',...
   'swing phase left','swing phase right','swing phase ave','gait cycle left','gait cycle right','gait cycle ave',...
   'head neck flex','head neck flex count','head neck flex times','head sacral flex','head sacral flex count','head sacral flex times',...
   'neck sacral flex','neck sacral flex count','neck sacral flex times';...

stride_speed_left(1),stride_speed_right(1),stride_speed_ave(1),stride_length_left(1),stride_length_right(1),stride_length_ave(1),...

step_left(1),step_right(1),step_length_ave(1),step_width_left(1),step_width_right(1),step_width_ave(1),...

height_left(1),height_right(1),height_ave(1),cadence_left(1),cadence_right(1),cadence_ave(1),...

support_percent_left(1),support_percent_right(1),support_percent_ave(1),stance_phase_left(1),stance_phase_right(1),stance_phase_ave(1),...

swing_phase_left(1),swing_phase_right(1),swing_phase_ave(1),gait_cycle_left(1),gait_cycle_right(1),gait_cycle_ave(1),...

hn_flex_angle(1),hn_flex_count(1),hn_flex_time(1),hs_flex_angle(1),hs_flex_count(1),hs_flex_time(1),...
   ns_flex_angle(1),ns_flex_count(1),ns_flex_time(1)};

for ii=1:max_size
   if (ii>length(stride_speed_left))
       A{ii+1,1}=-1;
```

```
else
   A{ii+1,1}=stride_speed_left(ii);
end
if (ii>length(stride_speed_right))
   A{ii+1,2}=-1;
else
   A{ii+1,2}=stride_speed_right(ii);
end
if (ii>length(stride_speed_ave))
   A{ii+1,3}=-1;
else
   A{ii+1,3}=stride_speed_ave(ii);
end
if (ii>length(stride_length_left))
   A{ii+1,4}=-1;
else
   A{ii+1,4}=stride_length_left(ii);
end
if (ii>length(stride_length_right))
   A{ii+1,5}=-1;
else
   A{ii+1,5}=stride_length_right(ii);
end
if (ii>length(stride_length_ave))
   A{ii+1,6}=-1;
else
   A{ii+1,6}=stride_length_ave(ii);
end
if (ii>length(step_left))
   A{ii+1,7}=-1;
else
   A{ii+1,7}=step_left(ii);
end
if (ii>length(step_right))
   A{ii+1,8}=-1;
else
   A{ii+1,8}=step_right(ii);
end
if (ii>length(step_length_ave))
   A{ii+1,9}=-1;
else
   A{ii+1,9}=step_length_ave(ii);
end
if (ii>length(step_width_left))
   A{ii+1,10}=-1;
else
```

```
    A{ii+1,10}=step_width_left(ii);
end
if (ii>length(step_width_right))
    A{ii+1,11}=-1;
else
    A{ii+1,11}=step_width_right(ii);
end
if (ii>length(step_width_ave))
    A{ii+1,12}=-1;
else
    A{ii+1,12}=step_width_ave(ii);
end
if (ii>length(height_left))
    A{ii+1,13}=-1;
else
    A{ii+1,13}=height_left(ii);
end
if (ii>length(height_right))
    A{ii+1,14}=-1;
else
    A{ii+1,14}=height_right(ii);
end
if (ii>length(height_ave))
    A{ii+1,15}=-1;
else
    A{ii+1,15}=height_ave(ii);
end
if (ii>length(cadence_left))
    A{ii+1,16}=-1;
else
    A{ii+1,16}=cadence_left(ii);
end
if (ii>length(cadence_right))
    A{ii+1,17}=-1;
else
    A{ii+1,17}=cadence_right(ii);
end
if (ii>length(cadence_ave))
    A{ii+1,18}=-1;
else
    A{ii+1,18}=cadence_ave(ii);
end
if (ii>length(support_percent_left))
    A{ii+1,19}=-1;
else
    A{ii+1,19}=support_percent_left(ii);
```

```
end
if (ii>length(support_percent_right))
   A{ii+1,20}=-1;
else
   A{ii+1,20}=support_percent_right(ii);
end
if (ii>length(support_percent_ave))
   A{ii+1,21}=-1;
else
   A{ii+1,21}=support_percent_ave(ii);
end
if (ii>length(stance_phase_left))
   A{ii+1,22}=-1;
else
   A{ii+1,22}=stance_phase_left(ii);
end
if (ii>length(stance_phase_right))
   A{ii+1,23}=-1;
else
   A{ii+1,23}=stance_phase_right(ii);
end
if (ii>length(stance_phase_ave))
   A{ii+1,24}=-1;
else
   A{ii+1,24}=stance_phase_ave(ii);
end
if (ii>length(swing_phase_left))
   A{ii+1,25}=-1;
else
   A{ii+1,25}=swing_phase_left(ii);
end
if (ii>length(swing_phase_right))
   A{ii+1,26}=-1;
else
   A{ii+1,26}=swing_phase_right(ii);
end
if (ii>length(swing_phase_ave))
   A{ii+1,27}=-1;
else
   A{ii+1,27}=swing_phase_ave(ii);
end
if (ii>length(gait_cycle_left))
   A{ii+1,28}=-1;
else
   A{ii+1,28}=gait_cycle_left(ii);
end
```

```
if (ii>length(gait_cycle_right))
    A{ii+1,29}=-1;
else
    A{ii+1,29}=gait_cycle_right(ii);
end
if (ii>length(gait_cycle_ave))
    A{ii+1,30}=-1;
else
    A{ii+1,30}=gait_cycle_ave(ii);
end
if (ii>length(hn_flex_angle))
    A{ii+1,31}=-1;
else
    A{ii+1,31}=hn_flex_angle(ii);
end
if (ii>length(hn_flex_count))
    A{ii+1,32}=-1;
else
    A{ii+1,32}=hn_flex_count(ii);
end
if (ii>length(hn_flex_time))
    A{ii+1,33}=-1;
else
    A{ii+1,33}=hn_flex_time(ii);
end
if (ii>length(hs_flex_angle))
    A{ii+1,34}=-1;
else
    A{ii+1,34}=hs_flex_angle(ii);
end
if (ii>length(hs_flex_count))
    A{ii+1,35}=-1;
else
    A{ii+1,35}=hs_flex_count(ii);
end
if (ii>length(hs_flex_time))
    A{ii+1,36}=-1;
else
    A{ii+1,36}=hs_flex_time(ii);
end
if (ii>length(ns_flex_angle))
    A{ii+1,37}=-1;
else
    A{ii+1,37}=ns_flex_angle(ii);
end
if (ii>length(ns_flex_count))
```

```
        A{ii+1,38}=-1;
    else
        A{ii+1,38}=ns_flex_count(ii);
    end
    if (ii>length(ns_flex_time))
        A{ii+1,39}=-1;
    else
        A{ii+1,39}=ns_flex_time(ii);
    end
end

xlswrite('I01 NB Stairs2_resuslts.xlsx',A);
```

Spatiotemporal Parameters for Walking and Stairs Climbing

```
%Change the name of the file within the quotations here

markers=dataRead("C04 Stairs2.csv");


prime(1)=((markers(37).data(end)-markers(37).data(1))+(markers(40).data(end)-
markers(40).data(1)))/2;

prime(2)=((markers(39).data(end)-markers(39).data(1))+(markers(42).data(end)-
markers(42).data(1)))/2;


mag=sqrt(prime(1)^2+prime(2)^2);

prime(1)=prime(1)/mag;

prime(2)=prime(2)/mag;


theta=acos(dot(prime,[0 1]));

R = [cos(theta) -sin(theta); sin(theta) cos(theta)];

dir=[markers(37).data; markers(39).data];

left=R*dir;

dir=[markers(40).data; markers(42).data];

right=R*dir;
```

```
vel_right=right(2,3:end)-right(2,1:end-2);

vel_left=left(2,3:end)-left(2,1:end-2);

vel_up_right=markers(41).data(3:end)-markers(41).data(1:end-2);

vel_up_left=markers(38).data(3:end)-markers(38).data(1:end-2);


dir=[markers(7).data; markers(9).data];

left=R*dir;

dir=[markers(10).data; markers(12).data];

right=R*dir;


vel_right_toe=right(2,3:end)-right(2,1:end-2);

vel_left_toe=left(2,3:end)-left(2,1:end-2);


n=length(vel_right);

step_count=0;

step_count_left=0;

step_count_right=0;
```

```
stride_count_right=0;

stride_count_left=0;

gait_right_count=0;

gait_left_count=0;

gait_right_flag=false;

gait_left_flag=false;

walk_flag=false;

tol=0.01; %0.01

min_stride=0.1;

double_support_flag1=false;

double_support_count1=0;

double_support_flag2=false;

double_support_count2=0;

first_step_right=true;

stance_flag_right=false;

stance_flag_left=false;

stance_count_right=0;

stance_count_left=0;
```

```
cadence_right=0;

cadence_left=0;

height_left_count=0;

height_right_count=0;


gait_right_frame(1)=0;

gait_left_frame(1)=0;

double_support_frame1(1)=0;

double_support_frame2(1)=0;

gait_cycle_left(1)=0;

gait_cycle_right(1)=0;

double_support_time1(4)=0;

double_support_time2(4)=0;

support_percent_left(1)=0;

support_percent_right(1)=0;

stance_frame_right(1,2)=0;

stance_frame_left(1,2)=0;

swing_frame_right(1,2)=0;
```

```
swing_frame_left(1,2)=0;

stride_speed_left_each(1)=0;

stride_speed_right_each(1)=0;

stance_phase_left(1)=0;

stance_phase_right(1)=0;

step_length(1)=0;

step_width_right(1)=0;

step_width_left(1)=0;

stride_length_left(1)=0;

stride_length_right(1)=0;

swing_phase_left(1)=0;

swing_phase_right(1)=0;

height_left(1)=0;

height_right(1)=0;

step_left(1)=0;

step_right(1)=0;


for ii=1:n
```

```
if ~walk_flag
    if (((abs(vel_right(ii))>tol)&&(abs(vel_up_right(ii))>tol))...
            ||((abs(vel_left(ii))>tol)&&(abs(vel_up_left(ii))>tol)))
        walk_flag=true;
        if ((abs(vel_right(ii))>tol)||(abs(vel_up_right(ii))>tol))
            first_step_right=true;
        else
            first_step_right=false;
        end
    end
else
    if ((abs(vel_right(ii))<tol)&&(abs(vel_left(ii))<tol)...
            ||((abs(vel_up_right(ii))<tol)&&(abs(vel_up_left(ii))<tol)))
        step_count=step_count+1;
        %step_length(step_count)=abs(markers(39).data(ii)-markers(42).data(ii));
        step_length(step_count)=abs(left(2,ii)-right(2,ii));
        if ~first_step_right
            step_count_left=step_count_left+1;
```

```
        step_left(step_count_left)=step_length(step_count);
        step_width_left(step_count_left)=abs(left(1,ii)-right(1,ii));
        step_frame_left(step_count_left)=ii;
        %step_width_left(step_count_left)=abs(markers(37).data(ii)-markers(40).data(ii));
    else
        step_count_right=step_count_right+1;
        step_right(step_count_right)=step_length(step_count);
        step_width_right(step_count_right)=abs(left(1,ii)-right(1,ii));
        step_frame_right(step_count_right)=ii;
        %step_width_right(step_count_right)=abs(markers(37).data(ii)-markers(40).data(ii));
    end
    step_frame(step_count)=ii;
    walk_flag=false;
    if step_count>2
        %stride=(markers(42).data(step_frame(step_count))-
markers(42).data(step_frame(step_count-1)));
        stride=(right(2,step_frame(step_count))-right(2,step_frame(step_count-1)));
        if (stride>0.2)
            stride_count_right=stride_count_right+1;
```

```
                stride_length_right(stride_count_right)=stride;

                stride_speed_right_each(stride_count_right)=stride/((step_frame(step_count)-
step_frame(step_count-2))*0.008333);

            end

            %stride=(markers(39).data(step_frame(step_count))-
markers(39).data(step_frame(step_count-1)));

            stride=(left(2,step_frame(step_count))-left(2,step_frame(step_count-1)));

            if (stride>0.2)

                stride_count_left=stride_count_left+1;

                stride_length_left(stride_count_left)=stride;

                stride_speed_left_each(stride_count_left)=stride/((step_frame(step_count)-
step_frame(step_count-2))*0.008333);

            end

        end

    elseif ((abs(vel_right(ii))<tol)&&gait_right_flag)

        gait_right_flag=false;

        gait_right_count=gait_right_count+1;

        gait_right_frame(gait_right_count)=ii;

    elseif ((abs(vel_left(ii))<tol)&&gait_left_flag)
```

```
    gait_left_flag=false;
    gait_left_count=gait_left_count+1;
    gait_left_frame(gait_left_count)=ii;
elseif (abs(vel_right(ii)>tol)&&~gait_right_flag)
    gait_right_flag=true;
    height_right_count=height_right_count+1;
    height_right(height_right_count)=0;
elseif (abs(vel_left(ii)>tol)&&~gait_left_flag)
    gait_left_flag=true;
    height_left_count=height_left_count+1;
    height_left(height_left_count)=0;
elseif (gait_right_flag)
    if (height_right(height_right_count)<markers(41).data(ii))
        height_right(height_right_count)=markers(41).data(ii);
    end
elseif (gait_left_flag)
    if (height_left(height_left_count)<markers(38).data(ii))
        height_left(height_left_count)=markers(38).data(ii);
```

```
        end
    end
end
if ((abs(vel_right(ii))<tol)&&(abs(vel_left_toe(ii))<tol)&&~double_support_flag1)
    double_support_flag1=true;
    double_support_count1=double_support_count1+1;
    double_support_frame1(double_support_count1,1)=ii;
elseif (((abs(vel_right(ii))>tol)||(abs(vel_left_toe(ii))>tol))&&double_support_flag1)
    double_support_flag1=false;
    double_support_frame1(double_support_count1,2)=ii;
end
if ((abs(vel_right_toe(ii))<tol)&&(abs(vel_left(ii))<tol)&&~double_support_flag2)
    double_support_flag2=true;
    double_support_count2=double_support_count2+1;
    double_support_frame2(double_support_count2,1)=ii;
elseif (((abs(vel_right_toe(ii))>tol)||(abs(vel_left(ii))>tol))&&double_support_flag2)
    double_support_flag2=false;
    double_support_frame2(double_support_count2,2)=ii;
```

```
end

if (((abs(vel_right(ii))<tol)&&(abs(vel_right_toe(ii))>tol))...
        &&(abs(vel_up_right(ii))<tol)&&~stance_flag_right)
    stance_flag_right=true;
    stance_count_right=stance_count_right+1;
    stance_frame_right(stance_count_right,1)=ii;
elseif (((abs(vel_right_toe(ii))>tol)&&(abs(vel_right(ii))>tol))...
        &&(abs(vel_up_right(ii)>tol))&&stance_flag_right)
    stance_flag_right=false;
    stance_frame_right(stance_count_right,2)=ii;
end
if (((abs(vel_left(ii))<tol)&&(abs(vel_left_toe(ii))>tol))...
        &&(abs(vel_up_left(ii))<tol)&&~stance_flag_left)
    stance_flag_left=true;
    stance_count_left=stance_count_left+1;
    stance_frame_left(stance_count_left,1)=ii;
elseif (((abs(vel_left_toe(ii))>tol)&&(abs(vel_left(ii))>tol))...
```

```
            &&(abs(vel_up_left(ii))>tol)&&stance_flag_left)
        stance_flag_left=false;
        stance_frame_left(stance_count_left,2)=ii;
    end
end
if double_support_count1 ~= 0
    double_support_frame1(double_support_count1,2)=n;
end
if double_support_count2 ~= 0
    double_support_frame2(double_support_count2,2)=n;
end

n=length(gait_right_frame);
for jj=1:n-1
    gait_cycle_right(jj)=(gait_right_frame(jj+1)-gait_right_frame(jj))*0.008333;
end

m=length(gait_left_frame);
```

```
for jj=1:m-1
    gait_cycle_left(jj)=(gait_left_frame(jj+1)-gait_left_frame(jj))*0.008333;
end


n=length(double_support_frame1);
if n>1
    for jj=1:n
        double_support_time1(jj)=abs(double_support_frame1(jj,2)-
double_support_frame1(jj,1))*0.008333;
    end
end


n=length(double_support_frame2);
if n>1
    for jj=1:n
        double_support_time2(jj)=abs(double_support_frame2(jj,2)-
double_support_frame2(jj,1))*0.008333;
    end
end
```

```
if first_step_right
    for ii=1:length(gait_cycle_left)
        support_percent_left(ii)=(double_support_time1(2*ii+1)+double_support_time2(2*ii+1))/...
    gait_cycle_left(ii);
    end
    for ii=1:length(gait_cycle_right)

support_percent_right(ii)=(double_support_time1(2*ii+2)+double_support_time2(2*ii+2))/...
    gait_cycle_right(ii);
    end


    for ii=1:length(stance_phase_right)
        stance_phase_right(ii)=((stance_frame_right(ii,2)-stance_frame_right(ii,1))*0.008333)/...
            gait_cycle_right(ii);
        swing_phase_right(ii)=1-stance_phase_right(ii);
    end
    for ii=1:(step_count_right-2)
        cadence_right=cadence_right+step_right(ii+1);
```

```
    end
    cadence_right=cadence_right/(step_count_right-2);
    for ii=1:length(stance_phase_left)
        stance_phase_left(ii)=((stance_frame_left(ii,2)-stance_frame_left(ii,1))*0.008333)/...
            gait_cycle_left(ii+1); %+1
        swing_phase_left(ii)=1-stance_phase_left(ii);
    end
    for ii=1:(step_count_left-2)
        cadence_left=cadence_left+step_left(ii+1);
    end
    cadence_left=cadence_left/(step_count_left-2);
else
    for ii=1:length(gait_cycle_right)

support_percent_right(ii)=(double_support_time1(2*ii+1)+double_support_time2(2*ii+1))/...
    gait_cycle_right(ii);
    end
    for ii=1:length(gait_cycle_left)
        support_percent_left(ii)=(double_support_time1(2*ii+2)+double_support_time2(2*ii+2))/...
```

```
gait_cycle_left(ii);
end


for ii=1:length(stance_phase_right)
   stance_phase_right(ii)=((stance_frame_right(ii,2)-stance_frame_right(ii,1))*0.008333)/...
      gait_cycle_right(ii+1); %+1
   swing_phase_right(ii)=1-stance_phase_right(ii);
end
for ii=1:step_count_right-2
   cadence_right=cadence_right+step_right(ii+1);
end
cadence_right=cadence_right/(step_count_right-2);
for ii=1:length(stance_phase_left)
   stance_phase_left(ii)=((stance_frame_left(ii,2)-stance_frame_left(ii,1))*0.008333)/...
      gait_cycle_left(ii);
   swing_phase_left(ii)=1-stance_phase_left(ii);
end
for ii=1:step_count_left-2
```

```
        cadence_left=cadence_left+step_left(ii+1);
    end
    cadence_left=cadence_left/(step_count_left-2);
end


% cadence_right=((step_frame_right(end-1)-step_frame_right(2))*0.008333)/(step_count_right-2);
% cadence_left=((step_frame_left(end-1)-step_frame_left(2))*0.008333)/(step_count_left-2);
% cadence_ave=((step_frame(end-2)-step_frame(2))*0.008333)/(step_count-2);
cadence_right=(1/cadence_right)*60;
cadence_left=(1/cadence_left)*60;
cadence_ave=(cadence_right+cadence_left)/2;
stride_speed_right=0;
stride_speed_left=0;


for ii=1:length(stride_speed_left_each)-1
    stride_speed_left=stride_speed_left+stride_speed_left_each(ii);
end
stride_speed_left=stride_speed_left/(length(stride_speed_left_each)-1);
```

```
for ii=1:length(stride_speed_right_each)-1
    stride_speed_right=stride_speed_right+stride_speed_right_each(ii);
end
stride_speed_right=stride_speed_right/(length(stride_speed_right_each)-1);
stride_speed_ave=(stride_speed_right+stride_speed_left)/2;



nneck=zeros(length(markers(49).data),3);
for ii=1:length(nneck)

nneck(ii,1)=(markers(49).data(ii)+markers(100).data(ii)+markers(127).data(ii)+markers(136).dat
a(ii))/4;

nneck(ii,2)=(markers(50).data(ii)+markers(101).data(ii)+markers(128).data(ii)+markers(137).dat
a(ii))/4;

nneck(ii,3)=(markers(51).data(ii)+markers(102).data(ii)+markers(129).data(ii)+markers(138).dat
a(ii))/4;
end
```

```
nhead=zeros(length(markers(55).data),3);

for ii=1:length(nhead)
   nhead(ii,1)=(markers(55).data(ii)+markers(79).data(ii)+markers(121).data(ii))/3;
   nhead(ii,2)=(markers(56).data(ii)+markers(80).data(ii)+markers(122).data(ii))/3;
   nhead(ii,3)=(markers(57).data(ii)+markers(81).data(ii)+markers(123).data(ii))/3;
end

theta=acos(dot(prime,[0 1]));
R = [cos(theta) -sin(theta); sin(theta) cos(theta)];
dir=[markers(37).data; markers(39).data];
left=R*dir;
dir=[markers(40).data; markers(42).data];
right=R*dir;

nprime(1)=nhead(1,1)-nneck(1,1);
nprime(2)=nhead(1,3)-nneck(1,3);
mag=sqrt(nprime(1)^2+nprime(2)^2);
```

```
nprime(1)=nprime(1)/mag;
nprime(2)=nprime(2)/mag;
theta=acos(dot(nprime,[0,1]));

nR=[cos(theta) -sin(theta); sin(theta) cos(theta)];
ndir=[nhead(:,1)'; nhead(:,3)'];
head=R*ndir;
head(3,:)=nhead(:,2);
ndir=[nneck(:,1)'; nneck(:,3)'];
neck=R*ndir;
neck(3,:)=nneck(:,2);

vec1(1)=head(1,1)-neck(1,1);
vec1(2)=head(3,1)-neck(3,1);
mag1=sqrt(vec1(1)^2+vec1(2)^2);

for ii=1:length(head)
    vec2(1)=head(1,ii)-neck(1,ii);
```

```
    vec2(2)=head(3,ii)-neck(3,ii);

    mag2=sqrt(vec2(1)^2+vec2(2)^2);

    flex_angle(ii)=acos(dot(vec2,vec1)/(mag1*mag2));

end



flex_count=0;

for ii=1:length(flex_angle)

    if (flex_angle(ii)>0.34906585)

        flex_count=flex_count+1;

        flex_time(flex_count)=ii*0.008333;

    end

end



if (flex_count==0)

    flex_time=0;

end



%cadence_ave=(cadence_left+cadence_right)/2;
```

```
gait_cycle_ave=(mean(gait_cycle_left)+mean(gait_cycle_right))/2;

stance_phase_ave=(mean(stance_phase_left)+mean(stance_phase_right))/2;

step_length_ave=mean(step_length(1:end-1));

step_width_ave=(mean(step_width_right)+mean(step_width_left))/2;

stride_length_ave=(mean(stride_length_left(1:end-1))+mean(stride_length_right(1:end-1)))/2;

support_percent_ave=(mean(support_percent_left)+mean(support_percent_right))/2;

swing_phase_ave=(mean(swing_phase_left)+mean(swing_phase_right))/2;

height_ave=(mean(height_left)+mean(height_right))/2;


max_size=length(flex_angle);


A={'gait speed left','gait speed right','gait speed ave','stride length left','stride length right','stride length ave',...
    'step length left','step length right','step length ave','step width left','step width right','step width ave',...
    'step height left','step height right','step height ave','Cadence left','Cadence right','Cadence ave',...
    '% double support time left','% double support time right','% double support ave','stance phase left','stance phase right','stance phase ave',...
```

```
    'swing phase left','swing phase right','swing phase ave','gait cycle left','gait cycle right','gait cycle ave',...
    'neck flex','neck flex count','neck flex times';...

stride_speed_left(1),stride_speed_right(1),stride_speed_ave(1),stride_length_left(1),stride_length_right(1),stride_length_ave(1),...

step_left(1),step_right(1),step_length_ave(1),step_width_left(1),step_width_right(1),step_width_ave(1),...

height_left(1),height_right(1),height_ave(1),cadence_left(1),cadence_right(1),cadence_ave(1),...

support_percent_left(1),support_percent_right(1),support_percent_ave(1),stance_phase_left(1),stance_phase_right(1),stance_phase_ave(1),...

swing_phase_left(1),swing_phase_right(1),swing_phase_ave(1),gait_cycle_left(1),gait_cycle_right(1),gait_cycle_ave(1),...
    flex_angle(1),flex_count(1),flex_time(1)};

for ii=1:max_size
    if (ii>length(stride_speed_left))
```

```
  A{ii+1,1}=-1;
else
  A{ii+1,1}=stride_speed_left(ii);
end
if (ii>length(stride_speed_right))
  A{ii+1,2}=-1;
else
  A{ii+1,2}=stride_speed_right(ii);
end
if (ii>length(stride_speed_ave))
  A{ii+1,3}=-1;
else
  A{ii+1,3}=stride_speed_ave(ii);
end
if (ii>length(stride_length_left))
  A{ii+1,4}=-1;
else
  A{ii+1,4}=stride_length_left(ii);
```

```
end
if (ii>length(stride_length_right))
    A{ii+1,5}=-1;
else
    A{ii+1,5}=stride_length_right(ii);
end
if (ii>length(stride_length_ave))
    A{ii+1,6}=-1;
else
    A{ii+1,6}=stride_length_ave(ii);
end
if (ii>length(step_left))
    A{ii+1,7}=-1;
else
    A{ii+1,7}=step_left(ii);
end
if (ii>length(step_right))
    A{ii+1,8}=-1;
```

```
else
    A{ii+1,8}=step_right(ii);
end
if (ii>length(step_length_ave))
    A{ii+1,9}=-1;
else
    A{ii+1,9}=step_length_ave(ii);
end
if (ii>length(step_width_left))
    A{ii+1,10}=-1;
else
    A{ii+1,10}=step_width_left(ii);
end
if (ii>length(step_width_right))
    A{ii+1,11}=-1;
else
    A{ii+1,11}=step_width_right(ii);
end
```

```
if (ii>length(step_width_ave))
    A{ii+1,12}=-1;
else
    A{ii+1,12}=step_width_ave(ii);
end
if (ii>length(height_left))
    A{ii+1,13}=-1;
else
    A{ii+1,13}=height_left(ii);
end
if (ii>length(height_right))
    A{ii+1,14}=-1;
else
    A{ii+1,14}=height_right(ii);
end
if (ii>length(height_ave))
    A{ii+1,15}=-1;
else
```

```
    A{ii+1,15}=height_ave(ii);
end
if (ii>length(cadence_left))
    A{ii+1,16}=-1;
else
    A{ii+1,16}=cadence_left(ii);
end
if (ii>length(cadence_right))
    A{ii+1,17}=-1;
else
    A{ii+1,17}=cadence_right(ii);
end
if (ii>length(cadence_ave))
    A{ii+1,18}=-1;
else
    A{ii+1,18}=cadence_ave(ii);
end
if (ii>length(support_percent_left))
```

```
    A{ii+1,19}=-1;
else
    A{ii+1,19}=support_percent_left(ii);
end
if (ii>length(support_percent_right))
    A{ii+1,20}=-1;
else
    A{ii+1,20}=support_percent_right(ii);
end
if (ii>length(support_percent_ave))
    A{ii+1,21}=-1;
else
    A{ii+1,21}=support_percent_ave(ii);
end
if (ii>length(stance_phase_left))
    A{ii+1,22}=-1;
else
    A{ii+1,22}=stance_phase_left(ii);
```

```
end
if (ii>length(stance_phase_right))
    A{ii+1,23}=-1;
else
    A{ii+1,23}=stance_phase_right(ii);
end
if (ii>length(stance_phase_ave))
    A{ii+1,24}=-1;
else
    A{ii+1,24}=stance_phase_ave(ii);
end
if (ii>length(swing_phase_left))
    A{ii+1,25}=-1;
else
    A{ii+1,25}=swing_phase_left(ii);
end
if (ii>length(swing_phase_right))
    A{ii+1,26}=-1;
```

```
else
    A{ii+1,26}=swing_phase_right(ii);
end
if (ii>length(swing_phase_ave))
    A{ii+1,27}=-1;
else
    A{ii+1,27}=swing_phase_ave(ii);
end
if (ii>length(gait_cycle_left))
    A{ii+1,28}=-1;
else
    A{ii+1,28}=gait_cycle_left(ii);
end
if (ii>length(gait_cycle_right))
    A{ii+1,29}=-1;
else
    A{ii+1,29}=gait_cycle_right(ii);
end
```

```
if (ii>length(gait_cycle_ave))
    A{ii+1,30}=-1;
else
    A{ii+1,30}=gait_cycle_ave(ii);
end
if (ii>length(flex_angle))
    A{ii+1,31}=-1;
else
    A{ii+1,31}=flex_angle(ii);
end
if (ii>length(flex_count))
    A{ii+1,32}=-1;
else
    A{ii+1,32}=flex_count(ii);
end
if (ii>length(flex_time))
    A{ii+1,33}=-1;
else
```

```
        A{ii+1,33}=flex_time(ii);

    end

end



xlswrite('C04 Stairs2_resuslts.xlsx',A);
```

Neck/ Trunk Flexion

```
%Change the name of the file within the quotations here
markers=dataRead("C09 Obstacles1.csv");


nneck=zeros(length(markers(49).data),3);
for ii=1:length(nneck)

nneck(ii,1)=(markers(49).data(ii)+markers(100).data(ii)+markers(127).data(ii)+markers(136).dat
a(ii))/4;

nneck(ii,2)=(markers(50).data(ii)+markers(101).data(ii)+markers(128).data(ii)+markers(137).dat
a(ii))/4;

nneck(ii,3)=(markers(51).data(ii)+markers(102).data(ii)+markers(129).data(ii)+markers(138).dat
a(ii))/4;
end

nhead=zeros(length(markers(55).data),3);

for ii=1:length(nhead)
   nhead(ii,1)=(markers(55).data(ii)+markers(79).data(ii)+markers(121).data(ii))/3;
   nhead(ii,2)=(markers(56).data(ii)+markers(80).data(ii)+markers(122).data(ii))/3;
   nhead(ii,3)=(markers(57).data(ii)+markers(81).data(ii)+markers(123).data(ii))/3;
end

nsacral=zeros(length(markers(13).data),3);
for ii=1:length(nsacral)
   nsacral(ii,1)=(markers(13).data(ii)+markers(16).data(ii)+markers(19).data(ii))/3;
   nsacral(ii,2)=(markers(14).data(ii)+markers(17).data(ii)+markers(20).data(ii))/3;
   nsacral(ii,3)=(markers(15).data(ii)+markers(18).data(ii)+markers(21).data(ii))/3;
end

nprime(1)=nhead(1,1)-nneck(1,1);
nprime(2)=nhead(1,3)-nneck(1,3);
mag=sqrt(nprime(1)^2+nprime(2)^2);
nprime(1)=nprime(1)/mag;
nprime(2)=nprime(2)/mag;
theta1=acos(dot(nprime,[0,1]));

nR=[cos(theta1) -sin(theta1); sin(theta1) cos(theta1)];
ndir=[nhead(:,1)'; nhead(:,3)'];
head=nR*ndir;
head(3,:)=nhead(:,2);
ndir=[nneck(:,1)'; nneck(:,3)'];
```

```
neck=nR*ndir;
neck(3,:)=nneck(:,2);

vec1(1)=head(1,1)-neck(1,1);
vec1(2)=head(3,1)-neck(3,1);
mag1=sqrt(vec1(1)^2+vec1(2)^2);

flex_flag = false;

for ii=1:length(head)
   vec2(1)=head(1,ii)-neck(1,ii);
   vec2(2)=head(3,ii)-neck(3,ii);
   mag2=sqrt(vec2(1)^2+vec2(2)^2);
   hn_flex_angle(ii)=acos(dot(vec2,vec1)/(mag1*mag2));
end

hn_flex_count=0;
hn_flex_frame(1,1)=0;
hn_flex_frame(1,2)=0;
for ii=1:length(hn_flex_angle)
   if ((hn_flex_angle(ii)>0.34906585)&&~flex_flag)
      flex_flag = true;
      hn_flex_count=hn_flex_count+1;
      hn_flex_frame(hn_flex_count,1)=ii;
   elseif ((hn_flex_angle(ii)<0.34906585)&&flex_flag)
      flex_flag = false;
      hn_flex_frame(hn_flex_count,2)=ii;
   end
end

if (hn_flex_count ~= 0)
   if (hn_flex_frame(hn_flex_count,2)==0)
      hn_flex_frame(hn_flex_count,2)=length(markers(49).data);
   end
end

for ii=1:hn_flex_count
   hn_flex_time(ii)=(hn_flex_frame(ii,2)-hn_flex_frame(ii,1))*0.008333;
end

if (hn_flex_count==0)
   hn_flex_time=0;
end

nprime(1)=nhead(1,1)-nsacral(1,1);
nprime(2)=nhead(1,3)-nsacral(1,3);
```

```
mag=sqrt(nprime(1)^2+nprime(2)^2);
nprime(1)=nprime(1)/mag;
nprime(2)=nprime(2)/mag;
theta2=acos(dot(nprime,[0,1]));

nR=[cos(theta2) -sin(theta2); sin(theta2) cos(theta2)];
ndir=[nhead(:,1)'; nhead(:,3)'];
head=nR*ndir;
head(3,:)=nhead(:,2);
ndir=[nsacral(:,1)'; nsacral(:,3)'];
sacral=nR*ndir;
sacral(3,:)=nsacral(:,2);

vec1(1)=head(1,1)-sacral(1,1);
vec1(2)=head(3,1)-sacral(3,1);
mag1=sqrt(vec1(1)^2+vec1(2)^2);

for ii=2:length(head)
   vec2(1)=head(1,ii)-sacral(1,ii);
   vec2(2)=head(3,ii)-sacral(3,ii);
   mag2=sqrt(vec2(1)^2+vec2(2)^2);
   hs_flex_angle(ii)=acos(dot(vec2,vec1)/(mag1*mag2));
end

hs_flex_count=0;
flex_flag=false;
hs_flex_frame(1,1)=0;
hs_flex_frame(1,2)=0;
for ii=1:length(hs_flex_angle)
   if ((hs_flex_angle(ii)>0.34906585)&&~flex_flag)
      flex_flag = true;
      hs_flex_count=hs_flex_count+1;
      hs_flex_frame(hs_flex_count,1)=ii;
   elseif ((hs_flex_angle(ii)<0.34906585)&&flex_flag)
      flex_flag = false;
      hs_flex_frame(hs_flex_count,2)=ii;
   end
end

if (hs_flex_count ~= 0)
   if (hs_flex_frame(hs_flex_count,2)==0)
      hs_flex_frame(hs_flex_count,2)=length(markers(49).data);
   end
end

for ii=1:hs_flex_count
```

```
    hs_flex_time(ii)=(hs_flex_frame(ii,2)-hs_flex_frame(ii,1))*0.008333;
end

if (hs_flex_count==0)
    hs_flex_time=0;
end

nprime(1)=nneck(1,1)-nsacral(1,1);
nprime(2)=nneck(1,3)-nsacral(1,3);
mag=sqrt(nprime(1)^2+nprime(2)^2);
nprime(1)=nprime(1)/mag;
nprime(2)=nprime(2)/mag;
theta3=acos(dot(nprime,[0,1]));

nR=[cos(theta3) -sin(theta3); sin(theta3) cos(theta3)];
ndir=[nsacral(:,1)'; nsacral(:,3)'];
sacral=nR*ndir;
sacral(3,:)=nsacral(:,2);
ndir=[nneck(:,1)'; nneck(:,3)'];
neck=nR*ndir;
neck(3,:)=nneck(:,2);

vec1(1)=neck(1,1)-sacral(1,1);
vec1(2)=neck(3,1)-sacral(3,1);
mag1=sqrt(vec1(1)^2+vec1(2)^2);

for ii=1:length(head)
    vec2(1)=neck(1,ii)-sacral(1,ii);
    vec2(2)=neck(3,ii)-sacral(3,ii);
    mag2=sqrt(vec2(1)^2+vec2(2)^2);
    ns_flex_angle(ii)=acos(dot(vec2,vec1)/(mag1*mag2));
end

ns_flex_count=0;
flex_flag=false;
ns_flex_frame(1,1)=0;
ns_flex_frame(1,2)=0;
for ii=1:length(ns_flex_angle)
    if ((ns_flex_angle(ii)>0.34906585)&&~flex_flag)
        flex_flag = true;
        ns_flex_count=ns_flex_count+1;
        ns_flex_frame(ns_flex_count,1)=ii;
    elseif ((ns_flex_angle(ii)<0.34906585)&&flex_flag)
        flex_flag = false;
        ns_flex_frame(ns_flex_count,2)=ii;
    end
```

```
end

if (ns_flex_count~=0)
   if (ns_flex_frame(ns_flex_count,2)==0)
      ns_flex_frame(ns_flex_count,2)=length(markers(49).data);
   end

end

for ii=1:ns_flex_count
   ns_flex_time(ii)=(ns_flex_frame(ii,2)-ns_flex_frame(ii,1))*0.008333;
end

if (ns_flex_count==0)
   ns_flex_time=0;
end

max_size=length(hn_flex_angle);

A={'head neck flex','head neck flex count','head neck flex times','head sacral flex','head sacral
flex count','head sacral flex times',...
   'neck sacral flex','neck sacral flex count','neck sacral flex times';...

hn_flex_angle(1),hn_flex_count(1),hn_flex_time(1),hs_flex_angle(1),hs_flex_count(1),hs_flex_t
ime(1),...
   ns_flex_angle(1),ns_flex_count(1),ns_flex_time(1)};

for ii=1:max_size
   if (ii>length(hn_flex_angle))
      A{ii+1,1}=-1;
   else
      A{ii+1,1}=hn_flex_angle(ii);
   end
   if (ii>length(hn_flex_count))
      A{ii+1,2}=-1;
   else
      A{ii+1,2}=hn_flex_count(ii);
   end
   if (ii>length(hn_flex_time))
      A{ii+1,3}=-1;
   else
      A{ii+1,3}=hn_flex_time(ii);
   end
   if (ii>length(hs_flex_angle))
      A{ii+1,4}=-1;
   else
```

```
        A{ii+1,4}=hs_flex_angle(ii);
    end
    if (ii>length(hs_flex_count))
        A{ii+1,5}=-1;
    else
        A{ii+1,5}=hs_flex_count(ii);
    end
    if (ii>length(hs_flex_time))
        A{ii+1,6}=-1;
    else
        A{ii+1,6}=hs_flex_time(ii);
    end
    if (ii>length(ns_flex_angle))
        A{ii+1,7}=-1;
    else
        A{ii+1,7}=ns_flex_angle(ii);
    end
    if (ii>length(ns_flex_count))
        A{ii+1,8}=-1;
    else
        A{ii+1,8}=ns_flex_count(ii);
    end
    if (ii>length(ns_flex_time))
        A{ii+1,9}=-1;
    else
        A{ii+1,9}=ns_flex_time(ii);
    end
end

xlswrite('C09 Obstacles1_resuslts.xlsx',A);
```