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Effects of obesity on walking patterns and adaptability during obstacle crossing

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Boston University
EFFECTS OF OBESITY ON WALKING PATTERNS AND ADAPTABILITY DURING OBSTACLE CROSSING

by

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ABSTRACT

Obesity is a worldwide public health epidemic with no sign of yet abating. Although previous studies have examined the impact of obesity on walking, little is known about the effects of practice on walking patterns in individuals with obesity. The purpose of this current study was to evaluate whether an obstacle-crossing task may detect walking deficits in a group of adults electing to undergo bariatric surgery. With a cross-sectional design, we collected walking parameters as 24 adults (\( M\) age= 46.19, \( SD=12.90 \)) with obese body mass index (BMI) scores (\( M\) BMI= 41.68, \( SD=5.80 \)) and 26 adults (\( M\) age= 21.88, \( SD=3.48 \)) with normal BMI scores (\( M\) BMI= 23.09, \( SD=4.47 \)) walked in 5 conditions for 5 trials each: on flat ground, crossing over low, medium, and high obstacles, and again on flat ground. The timing and distance of participants’ steps were collected with a mechanized gait carpet (GAITRite, Inc.). We conducted 5 (condition) repeated measures (RM) ANOVAs on our main dependent variables, which measured how fast (velocity) and long (step length) participants’ steps were and how much time they spent with one (single limb support time) versus two (double limb support time) feet on the ground. The results showed within session improvements in participants’ walking patterns. Comparisons of the first and last trials on flat ground showed that participants took longer, faster steps by increasing step length and velocity (\( ps<.01 \)). They also spent more time with one versus two feet on the ground via increased
single limb support time and decreased double limb support time \((p < .001)\). Our findings suggest that an obstacle-crossing task may help spur improvements in walking patterns even before adults elect to undergo bariatric surgery.
TABLE OF CONTENTS

TITLE ................................................................................................................. i
COPYRIGHT PAGE ............................................................................................ ii
READER APPROVAL PAGE ................................................................................ iii
ACKNOWLEDGMENTS ....................................................................................... iv
ABSTRACT ........................................................................................................... v
TABLE OF CONTENTS ....................................................................................... vii
LIST OF TABLES ................................................................................................. viii
LIST OF FIGURES .............................................................................................. ix
LIST OF ABBREVIATIONS ............................................................................... xi
INTRODUCTION ................................................................................................. 1
   Specific Aims .................................................................................................... 13
METHODS ........................................................................................................... 17
DISCUSSION ......................................................................................................... 40
LIST OF JOURNAL ABBREVIATIONS ............................................................... 46
REFERENCES ....................................................................................................... 47
CURRICULUM VITAE ......................................................................................... 57

vii
<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Demographic Information of Obese and Control Subjects</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>Mean Comparison of Initial and Final Baseline Gait Parameters in Obese BMI and Normal BMI Subjects</td>
<td>25</td>
</tr>
</tbody>
</table>
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prevalence of obesity worldwide in males 15 to 100 years old in 2010.</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>Body Mass Index Classification of Obesity.</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>Gait Cycle Phases.</td>
<td>16</td>
</tr>
<tr>
<td>4</td>
<td>Example of gait cycle parameter measurement.</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>GAITRite® Carpet.</td>
<td>21</td>
</tr>
<tr>
<td>6</td>
<td>BioSensics body sensors and LEGSys+™ software.</td>
<td>21</td>
</tr>
<tr>
<td>7</td>
<td>GaitRITETM Carpet and Obstacle crossing.</td>
<td>23</td>
</tr>
<tr>
<td>8</td>
<td>Initial versus Final Baseline Comparisons.</td>
<td>26</td>
</tr>
<tr>
<td>9</td>
<td>Body Mass Index and Velocity Before and After Crossing Obstacles.</td>
<td>27</td>
</tr>
<tr>
<td>10</td>
<td>Cadence.</td>
<td>29</td>
</tr>
<tr>
<td>11</td>
<td>BMI and Step Length Before and After Crossing Obstacle.</td>
<td>31</td>
</tr>
<tr>
<td>12</td>
<td>Step Width Before and After Crossing Obstacle.</td>
<td>32</td>
</tr>
<tr>
<td>13</td>
<td>Step Width and BMI.</td>
<td>32</td>
</tr>
<tr>
<td>14</td>
<td>BMI and Single Limb Support Time (SLST) Before and After Crossing Obstacles.</td>
<td>34</td>
</tr>
</tbody>
</table>
BMI and Double Limb Support Time (DLST) Before and After Crossing Obstacles.

Anterior Posterior Sway and Body Mass Index.

Medial Lateral Sway and BMI.

Medial Lateral Sway and Obstacle.

Plant Leg and Single Limb Support Time (SLST).

Body Mass Index and Double Limb Support Time (DLST) of Crossing Step.
LIST OF ABBREVIATIONS

BMI ........................................................................................................ Body Mass Index
BSX ....................................................................................................... Bariatric Surgery
BU ......................................................................................................... Boston University
CDC .............................................................. Centers for Disease Control and Prevention
COM ....................................................................................................... Center of Mass
DLST ................................................................................................. Double Limb Support Time
SLST ...................................................................................................... Single Limb Support Time
WOMAC ........................................................ Western Ontario and McMaster Universities Arthritis Index
INTRODUCTION

Background

Obesity has become one of the most important public health issues worldwide. From a global perspective, there are nearly 2 billion adults considered overweight and of these, over 600 million are clinically obese (World Health Organization [WHO], 2015). The prevalence of obesity has increased dramatically in the past three decades virtually in every country. Figure 1 illustrates the global epidemiology of obesity represented in adult males. In the United States alone there are more than 78.6 million adults that are classified as obese according to the CDC (Centers for Disease Control and Prevention [CDC], 2014). Alarmingly, obesity rates have nearly doubled for adults and tripled in children in America since the 1980s (“Obesity Rates & Trends Overview,” 2015). According to a 2014 study published in The Lancet, it was estimated that in the year 2010, 3.4 million deaths were attributed to being overweight or obese (Ng et al., 2014). Researchers and clinicians use body mass index or BMI (weight in kilograms/height \(^2\) in meters) to categorize body weight (Figure 2). Correspondingly, obesity is defined as having a BMI \(\geq 30\) kg/m\(^2\) (CDC, 2014).

Obesity and Health Outcomes

Obesity is associated with many negative health outcomes such as cardiovascular disease, stroke, hypertension, cancer, hypercholesterolemia, type 2 diabetes, gallbladder
disease, gastroesophageal reflux disease, sleep apnea, and osteoarthritis (Rubenstein, 2005; National Heart, Lung, and Blood Institute, 2012). Studies show obese adults have a substantially increased risk for developing type 2 diabetes compared to normal-weight adults (Bell, Kivimaki, & Hamer, 2014). Similarly, hypertension is twice as prevalent in the obese population (Kotchen, 2008). One explanation for this is that excess adipocytes secrete numerous cytokines (cell signaling proteins), which promote vascular dysfunction seen in hypertension and hypercholesterolemia (Redinger, 2007). Obesity has also been found to be a major risk factor for many cancers due to its disruptive effect on immune function (Redinger, 2007). According to the National Cancer Institute at the National Institutes of Health, obesity increases the risk for developing cancers of the esophagus, pancreas, colon, breast (after menopause), endometrium, kidney, thyroid, and gall bladder (2012). Obesity contributes to all of these comorbidities mainly through excessive adiposity. Because adipose tissue is involved in endocrine, paracrine, and autocrine regulatory pathways in the body, excessive amounts can disrupt the physiological functions of many organs (Redinger, 2007). In addition, obesity has also been associated with higher rates of knee, hip, and joint osteoarthritis (OA). Physiologically, obesity contributes to knee OA through increased joint loading, systemic inflammation, changes in body weight distribution, and loss of protective muscle strength (R. S. Gill et al., 2011; Wluka, Lombard, & Cicuttini, 2013). Being overweight by just 4.5 kg equates to a 30-60-fold increase of force sustained by the knee (“Osteoarthritis : Role of Body Weight in Osteoarthritis - Weight Management,” 2015). Likewise, researchers have shown that the risk for knee OA increases by 36% for every 2 unit increases in BMI, or 5 kg of weight
gain (Lementowski & Zelicof, 2008). In comparison to normal BMI individuals, overweight individuals have a 4-5 times greater risk of developing knee OA (R. S. Gill et al., 2011). Consequently, the progression of OA is much faster in obese compared to normal weight individuals (Vincent, Heywood, Connelly, & Hurley, 2012a). Obesity and knee OA are comorbidities commonly associated with each other and as a result have detrimental effects on mobility and postural stability: both are associated with increased postural instability and fall risks (Finkelstein, Chen, Prabhu, Trogdon, & Corso, 2007a; Himes & Reynolds, 2012; Khalaj, Abu Osman, Mokhtar, Mehdikhani, & Wan Abas, 2014). Accordingly, several studies have reported that for obese patients, weight loss through bariatric surgery has been associated with a marked improvement in hip and knee OA symptoms and reduced risk of incident (R. S. Gill et al., 2011; Vincent, Heywood, Connelley, & Hurley, 2012; Vincent, Heywood, Connelly, & Hurley, 2012b).

Subsequently, certain comorbidities to obesity such as in obstructive sleep apnea, result from the space-occupying effects of accumulated adipose tissue to a confined region (Redinger, 2007). Moreover, in women, obesity is strongly related to infertility issues, menstrual irregularities, pregnancy complications, and gynecological and breast cancers (“Pathophysiology, epidemiology, and assessment of obesity in adults. - PubMed - NCBI,” 2014). Besides being associated with adverse health consequences, researchers have also reported that obesity affects overall quality of life as well. Obese individuals tend to have lower health-related quality of life scores (HRQL) (Forhan & Gill, 2013a). Lower HRQL scores are associated with lower self-esteem and mood, social isolation, and functional mobility (Forhan & Gill, 2013a; Taylor, Forhan, Vigod, McIntyre, &
Morrison, 2013). Recent evidence has shown that weight loss associated with bariatric surgery has significantly improved quality of life measures in previously obese patients (Major et al., 2015). Consequently, obesity affects not only physiological aspects of the body, but mental health as well. For example, it has been documented that there is an increased risk of depression associated with obesity (Luppino et al., 2010).

**Obesity Causes and Prevention**

Researchers and public health officials posit that there are several factors that contribute to obesity. The rise in obesity has been primarily attributed to behavioral changes in society - the “big two” contributing factors to obesity: lack of physical activity and overconsumption of calories (McAllister et al., 2009). First, changes in the amount of physical activity may be explained in part to our society’s dependence on cars as a means to commute as opposed to walking, and increases in sedentary lifestyles in the school, work, and home environment (“Congributing Factors to Overweight and Obesity,” n.d.). According to *The Obesity Prevention Source* from the Harvard School of Public Health, sedentary behaviors that attribute to increased daily “sit time” and therefore a greater risk for obesity, include prolonged TV viewing, computer and mobile-device use, sitting at work, playing video games, and driving (“Television Watching and ‘Sit Time’ | Obesity Prevention Source | Harvard T.H. Chan School of Public Health,” 2015). Second, changes in dietary habits may be influenced by increased portion sizes, increased accessibility of ‘fast food’ or pre-packaged foods, eating out more at restaurants, and
misleading marketing of foods that may be ‘low-fat’, but high in sugar and calories (“The Surgeon General’s Vision for a Healthy and Fit Nation,” 2010). Other factors contributing to body weight are genes, metabolism, stress, environment, culture, and socioeconomic status (“Contributing Factors to Overweight and Obesity,” n.d.). Although genetics may play a role in one’s susceptibility to weight gain, ultimately it is an energy surplus over a long period of time that results in excess body weight, which is a modifiable factor (“The Surgeon General's Vision for a Healthy and Fit Nation”, 2010). This excess weight, in turn, can lead to chronic obesity and the major health problems discussed earlier. More recently, research findings have associated increased daily sitting time to a greater risk for all-cause mortality (Chau et al., 2013).

More and more evidence points to moderate-to-vigorous physical activity as a means to mitigate the mortality risk associated with obesity (Bravata et al., 2007). Currently, The Office of Disease Prevention and Health Promotion has set forth physical activity recommendations for adults between the ages of 18-64 years old to adhere to: a minimum of 150 minutes (2 hours and 30 minutes) per week of moderate-intensity aerobic activity, for example walking briskly, or cycling (Office of Disease Prevention and Health Promotion, 2015). For children and adolescents, the recommendation is to engage in at least 60 minutes of physical activity per day (CDC, 2015). Unfortunately, nearly 80% of adults fail to meet these physical activity guidelines (CDC, 2013).

*Walking as a Physical Activity*
Walking is a popular and cost-effective physical activity, which can be adapted to meet these guidelines. It is a free, low-impact physical activity that does not require any special equipment and at any pace expends energy (Morris & Hardman, 1997). In addition, walking is a form of exercise that is highly accessible to people from all socioeconomic backgrounds (Murtagh, Murphy, & Boone-Heinonen, 2010). Moreover, recent technological advancements such as smart phones, apps, and wearable pedometers have made walking time, pace, and distance easy to track (Murtagh et al., 2010).

*Biomechanics of Walking*

The rhythmical motion of walking requires careful synchronization and communication of the body’s musculoskeletal and central nervous systems. The kinesiology of walking is described through gait analysis with specific terminology and will be summarized here briefly. Walking is a cyclic activity that advances the body through space via one limb swinging forward while the contralateral limb supports body weight (Kharb et al., 2011). The ability to transition from quiet standing to the dynamic movement pattern of walking is a task, which must be initiated using the body’s momentum and postural control to maintain balance. Gait initiation (GI) involves anticipatory postural adjustments in the anterior-posterior and medio-lateral directions, and occurs prior to gross movements of the lower limbs (Cau et al., 2014a; Mille, Simoneau, & Rogers, 2014). Engagement of muscular activity and neural coordination at
the ankle and hip level is also necessary (Cau et al., 2014b). The gait cycle is a single sequence of this repetitious cycle by one limb and is divided into two main phases: the swing phase and the stance phase (Kharb et al., 2011). The stance phase is the period when the foot is in contact with the ground and makes up approximately 62% of the gait cycle in walking. Accordingly, the swing phase is when the foot is in the air, and makes up about 38% of the gait cycle (“Phases of the Normal Gait Cycle,” n.d.). The cycle can further be divided into six periods: 1) initial double limb support 2) single limb support 3) second double support 4) initial swing 5) mid-swing and 6) terminal swing. The stance phase is comprised of periods 1-3, and the swing phase is comprised of periods 4-6. ‘Gait cycle’ is synonymous with ‘stride’, and stride duration is the time it takes to complete one gait cycle. Stride length is the distance between successive heel strikes of the same foot or 2 times greater than the step length. Step length is the distance between the heel strike of one foot and the other foot. Step width is the mediolateral distance between the heels of both feet during double limb support. The rate at which a person walks is known as the cadence (steps per minute) (Kharb et al., 2011). Walking at a self-selected pace, adults have an average cadence of 100-115 steps/min (“walking gait cycle - parameters,” n.d.). Walking speed is normally expressed as velocity in meters per second. Double limb support time is the time interval during which both feet are on the ground supporting body weight, whereas, single limb support time is the time interval when one foot is on the ground supporting the entire body weight, while the other foot is off the ground, in swing (Kharb et al., 2011). Equally important to the successful biomechanics of walking is the integration of postural control. For example, (GI) requires both propulsion in the
forward direction and upright postural control (Cau et al., 2014). Maintenance of center of mass (COM) is key to preserving postural stability and remaining upright in bipedal walking (Yang & Pai, 2014). Research has shown that postural control over one’s balance while walking can be affected by aging, anxiety, muscular fatigue, and certain medical conditions (Sudarsky L, 2012).

*Obesity Affects on Walking*

Previous studies have shown that obesity affects walking in negative ways. Increases in body mass are associated with a progressive worsening in functionality and mobility. For instance, when BMI is greater than 40 kg/m², an inverse relationship exists between the average number of steps taken during the day and body mass (King et al., 2008). In addition, the peak intensity of the physical activity that is exerted is less than of healthy weight subjects (King et al., 2008). Research has been shown that overweight and obese people tend to walk slower with reduced velocity, take shorter strides, and have greater step widths compared to normal weight people (Ko, Stenholm, & Ferrucci, 2010). In addition, obese individuals keep their feet in contact with the ground more, or in other words have greater double limb support time (Forhan & Gill, 2013). Another recent study suggested obese individuals adjust their gait patterns in order to maintain stability by increasing their stance time and slowing down cadence (steps/min) (S. V. Gill, 2015). Obesity is also associated with an altered foot structure, as recent studies have demonstrated that obese persons have flatter feet, an inversion-eversion range of motion
of the feet, and higher peak plantar pressure while walking (Butterworth et al., 2014).

Moreover, the distribution of body fat to the abdomen causes displacement of the anterior posterior (AP) center of pressure by forcing the person to lean forward and carry the weight towards the front of their feet which greatly disrupts postural stability in obese persons. Obese adults also experience greater medio-lateral center of mass displacement or body sway when walking. The amount of medio-lateral displacement experienced was significantly related to the percentage of body fat (Peyrot et al., 2009). Furthermore, the range of motion is limited at the knee, hip, and ankle while walking for overweight and obese adults (S. V. Gill, 2015).

This reduction in postural control while walking can potentially lead to frequent loss of balance, increased injuries, and greater fall risk. Obese individuals may try to compensate for their lack of postural stability by employing and their leg muscles more to better control their center of mass. However, recent studies have shown that obese individuals actually tend to have diminished muscular strength in their lower limbs, which could account for their reduced performance in motor tasks (Cau et al., 2014a; Ponta, Gozza, Giacinto, Gradaschi, & Adami, 2014). Consequently, weight loss has been shown to help improve balance over center of mass (Ponta et al., 2014).

Obesity is also associated with a higher incidence of knee, hip, and joint osteoarthritis, which research studies have identified is one of the leading causes of disability in the United States (Lementowski & Zelicof, 2008). Accordingly,
symptomatic osteoarthritis of lower limb joints in obesity results from biomechanical stress imposed by excess adipose tissue on knee and hip joints, as well as endocrine immune dysfunction (Fransen, Simic, & Harmer, 2014). Recently, a 2013 study published in *Arthritis Care and Research*, reported that obesity in adults with knee osteoarthritis significantly attributes to physical inactivity (Lee et al., 2013). Also, research has shown that induced knee pain via saline injections, as to mimic knee OA symptoms in healthy subjects leads to increased sway in both anterior-posterior and medial-lateral directions (Forhan & Gill, 2013). This suggests that obese patients with knee OA would experience even greater postural instability when walking. The association between obesity and osteoarthritis presents a major concern for mobility and postural stability in obese individuals due to the potential for increased knee pain and greater fall risk.

In addition, obesity may limit walking and mobility by impairing motor planning and adaptation. Recent evidence suggests that obesity may affect cognitive function, which may contribute to difficulties in mobility and functional task performance in obese individuals. Studies have demonstrated that obese adults (BMI > 35) have reduced performance in cognitive tasks, executive function tasks involving planning, and mental flexibility compared to adults of normal weight. Although more research is needed on the causes behind the connection of obesity and cognitive impairment, some studies suggest it may due to the decrease of blood flow of oxygen to the brain from lack of physical activity or other metabolic conditions (Forhan & Gill, 2013).
**Obesity and Fall Risk**

These ways in which obesity influences walking, such as having greater double limb support, at first would seem like it should increase stability, but it actually is associated with an increased risk of falling. Fall risks are 12% higher for obese adults (BMI of 30-34.9), 26% higher for severely obese adults (BMI of 35-39), and 50% higher for morbid obese adults (BMI of 40 and above) compare to their normal weight peers (Himes & Reynolds, 2012). This same study that examined the propensity of obese adults to fall, found that being heavier is associated not only with a greater fall risk, but also an increased risk for an ADL (activities of daily living) disability following a fall (Himes & Reynolds, 2012). Correspondingly, the likelihood of sustaining an injury after falling increases with BMI, by 15% (overweight) to 48% (morbidly obese) (Finkelstein, Chen, Prabhu, Trogdon, & Corso, 2007b). Moreover, obese adults experience a higher incidence of knee OA. When considering knee osteoarthritis alone, study findings show that knee OA increases fall risks and impairs balance in individuals, and that adults with knee OA experience a loss of proprioception (Khalaj et al., 2014). Consequently, when examining obesity and knee OA together, the risk for falls in obese adults with knee OA is compounded. Thus, obesity and knee OA together escalates the risk of falls and fall related injuries for individuals when being physical active. Furthermore, obese individuals face a 57% higher risk of believing nothing could be done to prevent falls (Mitchell, Lord, Harvey, & Close, 2014).
Much of what we know about the effects of obesity on walking is about walking on flat ground, however, walking in everyday life requires more motor skill, coordination, and adaptability than just the ability to walk on flat ground. It necessitates the ability to modify walking to meet the demands of a continuously changing environment. Everyday environments typically contain pathway obstructions, for example, curbs, uneven sidewalks, stairways, and potholes. This ‘real world’ obstacle course is where people are most likely to fall while walking and may be more susceptible to injury. In order to maintain safety during walking, it is crucial that postural stability is maintained and gait pattern modified to successfully cross over obstacles such as stepping on and off a curb.

Although obstacle crossing has been studied in patients afflicted with neurological diseases, it is still unclear how obesity affects gait patterns and adaptability during functional tasks, such as obstacle crossing. Although valuable, most research studies have assessed spatio-temporal gait patterns, knee pain, and postural control in obese subjects while walking on flat ground. However, little is understood about gait patterns and COM range of motion associated with walking beyond flat-ground, such as during obstacle negotiation. Atypical gait related to obesity that is less obvious during walking on flat ground may be more pronounced when having to perform a functional task (i.e. crossing over obstacles, stepping up and down a stair) (Close, Lord, Menz, & Sherrington, 2005). Previous studies have demonstrated that obese persons experience difficulty and perform
at slower speeds at functional tasks related to postural control such as chair rise (rising from a chair), stair climbing, and timed up-and-go tasks (Vincent, Heywood, Connelly, et al., 2012), however little quantifiable research exists on obstacle crossing in obese persons. Furthermore, it is crucial to understand the changes in gait patterns and postural stability while crossing obstacles as crossing obstacles while walking is frequently associated with fall risk.

Specific Aims

This is a cross-sectional research study, designed to prospectively evaluate the effects of obesity on gait adaptability, spatiotemporal motor coordination, and postural stability during obstacle negotiation in adults with knee osteoarthritis. We are particularly interested in how obesity influences the ability to complete a functional task: crossing obstacles of various heights. We are also interested in whether improvements in walking could be observed from the beginning to the end of one session.

Our aims include: (1) to examine gait adaptability (velocity, step length, swing time, single and double limb support times, and stance time), and center of mass (COM) measures during obstacle crossing in obese adults compared to non-obese adults and (2) to evaluate gait kinematics between initial and final baseline trials within a single session in obese individuals. We hypothesized that obese adults will have overall impaired spatio-temporal gait parameters (decreased velocity, increased double limb support time,
increased cadence, decreased single limb support time, decreased step length), and greater postural instability (greater medial-lateral and anterior-posterior COM range of motion) during obstacle crossing compared to normal weight subjects. In addition, we hypothesized that there could be a quantifiable change in gait performance and postural transition in obese subjects following trial repetitions within a single session.

Table 1. Demographic Information of Obese and Control Subjects.

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<thead>
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<th></th>
<th>Obese BMI group</th>
<th>Normal BMI group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean Age</strong></td>
<td>46.19 (SD=12.90)</td>
<td>21.88 (SD=3.48)</td>
</tr>
<tr>
<td><strong>Mean BMI</strong></td>
<td>41.68 (SD=5.80)</td>
<td>23.09 (SD=4.47)</td>
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Figure 1. Prevalence of obesity worldwide in males 15 to 100 years old in 2010. This figure represents the prevalence of obesity (BMI>30 kg/m²) among males on a global


Figure 4. Example of gait cycle parameter measurement. This picture shows limb steps for both the right foot (teal) and left foot (purple). Step length can be quantified by measuring the distance, usually in centimeters, between the heel strike of the right foot and the heel strike of the left foot. Conversely, stride length is the distance between the consecutive heel strikes of the same foot. B. Bashinskaya. Copyright 2015 by Boston University.
METHODS

Participants

Participants were patients recruited from either one of two weight loss clinics at Boston Medical Center: the Bariatric Surgery Clinic or the Nutrition and Weight Management Center. In order to be included in this study, participants needed to be between the ages of 30-60 years old, have a Body Mass Index (BMI) classification of Class II obesity or greater with a score $\geq 35$ kg/m$^2$, be approved for bariatric surgery (BSX) for BSX subjects, and have knee pain on most days in at least one knee within the past 30 days. Knee pain measurements were both self-reported by participants and measured using a validated assessment called the WOMAC. Those subjects that had or were planning to undergo total knee replacement surgery, anterior cruciate ligament surgery, or meniscal surgery within the next 12 months were ineligible to participate in the study. All subjects needed to be able to walk on their own, without the assistance of a walking device (e.g. walker). BSX participants are assessed twice, one year apart, before and after undergoing BSX. However, the data in this thesis will focus on the pre-test visit. Healthy participants with normal BMI scores were chosen as control subjects. The healthy participants were college students recruited from Boston University Charles River Campus. This study requires for control subjects to be assessed only once.
Subjects were excluded from the study if they had serious health problems that could interfere with their ability to participate in the research. Exclusion criteria included having one or more of the following medical conditions: rheumatoid arthritis (RA) or any other inflammatory arthritis, being treated or having recently been told by a doctor that they had cancer (excluding skin cancer) in the past 3 years, receiving dialysis, being treated for alcohol or drug abuse, being a participant in another study for knee osteoarthritis for which there is a treatment, or have any other health ailment that would make it difficult to engage in the research tasks over a one year period. All subjects who agreed to participate in this study were able to read and speak English. All subjects were able to comply with study procedures and agreed to participate in the study by signing an informed consent. In addition, financial compensation was provided to all subjects for their participation. The Institutional Review Board of Boston University Medical Campus and Boston Medical Center approved this study.

**Demographics.** A total number of 50 participants were included in this study. There were a total of 24 adults ($M$ age=46.19, $SD=12.90$) in the obese BMI group ($M$ BMI=41.68, $SD=5.80$) that were planning to undergo BSX, and 26 adults ($M$ age=21.88, $SD=3.48$) in the normal BMI control group ($M$ BMI=23.09, $SD=4.47$) that were not electing to undergo BSX. From the 24 adults in the obese group, 21 of the subjects were female and 3 were male. From the 26 adults in the control group, 19 of the subjects were female and 7 were male. Subjects were recruited from the greater Boston area. Table 1 exemplifies the study participants’ demographic data.
Study Design

**Equipment.** Several technologies were used in this study to record participants’ walking patterns. The GAITRite® Electronic Walkway system (CIR Systems, Inc., Sparta NJ), an electronic floor mat equipped with pressure-activated sensors was used to measure spatial-temporal gait parameters. Temporal (timing) and two-dimensional geometrical measurements calculated parameters, such as walking velocities. Sensor pads along the walkway record measurements using x and y coordinates and converted the distance into centimeters (cm) and time into seconds (s). GAITRite® software contains special algorithms that use these coordinates to determine various parameters for gait analysis. The electronic walkway mat is composed of anti-slip vinyl material on its top cover and open cell neoprene rubber on the bottom cover. The GAITRite® carpet measures approximately 610 cm (6.10 m) in length and 60.1 cm (.601 m) in width, with a spatial accuracy of +/− 1.27 cm (0.0127 m).

In addition to testing participants’ baseline gait and range of motion patterns, participants were also asked to step over obstacles of varying heights during the data collection. Obstacles were created using a wooden dowel (121 cm long) and two rectangular towers (9cm x 10 cm x 22 cm), each with holes drilled into them at 4 cm, 11 cm, and 16 cm (low, medium, and high obstacle height). The obstacle heights were chosen to represent everyday obstacles that subjects may encounter in their daily lives. During non-baseline walking recordings, the towers were placed at the halfway point (8...
m) of the GAITRite® mat. The dowel was then inserted at a predetermined low, medium, or high height into the towers to create an obstacle for participants to step over.

In conjunction with the GAITRite® system, we used the Locomotion Evaluation and Gait System, or LEGSys+™ (BioSensics LLC, Cambridge, MA) wearable motion sensor technology to capture the body’s center of mass (COM) and range of motion data recordings. Furthermore, LEGSys+™ measurements provided more detailed gait analysis parameters, such as speed, number of steps, stride length and duration, cadence, knee and hip angles, and pelvis movement. The LEGSys+™ biometric sensors are 5.0 cm x 4.2 cm x 1.2 cm in size, weigh 25 grams, have a sample frequency of 100 Hertz, and amount to a 4 hour battery life. LEGSys+™ biosensors contain two motion sensors, the triaxial gyroscope (+/-2000 deg/s) and the triaxial accelerometer (+/-2g), that measure body mechanics. Data output from participants is transmitted in real-time wirelessly through Bluetooth technology to a laptop containing LEGSys+™ software.

A total of five BioSensics sensors were positioned on each participant. The sensors were fitted onto subjects in a standardized fashion: anterior-medially above the right and left knee, anterior-medially above the left and right ankle, and one posteriorly on the small of the back wrapped around the waist. The sensors were worn forward, with the label facing out, and were secured to elastic straps with Velcro closure.
Study Procedure and Data Collection. A lab space at the Boston University Medical Center Campus was chosen with a long corridor as an ideal location to set up the GAITRite® electronic carpet. First, anthropometric measurements were obtained for all participants at both visits. These measurements included height, weight, BMI, and waist circumference. A stadiometer was used to measure height to the nearest 0.1 cm. Participants were weighed to the nearest 0.1 kg using a 500 lb. capacity Ohaus digital scale (Model #: D51P250QX2). Subsequently, participant’s BMI was calculated with the formula: weight (kg)/height (m²). Participants were also evaluated for knee pain and dynamic balance. To assess knee pain, participants completed the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) health status questionnaire, designed specifically for patients with knee osteoarthritis. The completed questionnaire (Likert form), which consisted of five questions, was scored, with scores ranging from 0 (no pain) to 20 (extreme pain).
Dynamic balance was tested using the Functional Gait Assessment (FGA), a clinical gait assessment tool with 10 gait functional tasks. As part of the functional task assessment, subjects will be asked to step up and down a 10 cm stair. Gait performance was measured on an ordinal scale from 0 to 4, with total score ranging from 0 to 30. A score $\leq 22$ was classified as a fall risk.

Figure 7. GaitRITE™ Carpet and Obstacle crossing. Top: This image represents a subject walking down the gait carpet. Reprinted from *John Hopkins Medicine*, n.d.
Next, participants were fitted with five wearable bands containing the BioSensics sensors, and the sensors were calibrated via Bluetooth to the LEGSys+™ software on the laptop. Participants walked for a total of 25 trials down the GAITRite® carpet during each visit. They were instructed to walk at their normal everyday pace.

Initially, participants walk five times on flat ground (no obstacles) at their self-selected pace to determine a baseline measurement. For the next fifteen trials, in a counterbalanced order, participants step over a low, medium, or high obstacle five times at each height. Lastly, participants walk another five times on flat ground on the GAITRite® carpet to determine the final baseline measurements. During obstacle crossing, participants are monitored closely to ensure their safety.

**Statistical Analysis.** All data analyses were conducted using SPSS version 20.0. Results were presented as means and standard deviations or standard error. To examine the effect of practice of an obstacle crossing functional task on walking patterns in obese BMI patients, a 2 group (normal, obese BMI) by 2 condition (initial, final baseline) two-way ANOVA with repeated measures (RM) was performed. We selected a two-way RM
ANOVA when we looked at gait parameters as we examined two categorically different independent variables (normal and obese BMI), and aimed to assess not only if there was a main effect for each condition (low, medium, high obstacle), but also if there were any interactions. A 3 obstacle (low, medium, high) by 2 BMI group (normal, obese) by step section (approach, end) RM ANOVA was conducted to determine if differences in walking patterns exist when walking across various obstacle heights based on one’s body mass index. Similarly, a 3 obstacle (low, medium, high) by 2 BMI group (normal, obese) RM ANOVA was calculated to examine gait parameters of the steps initiating (immediately prior to) obstacle crossing. To determine changes in body movement patterns during walking from the sensor data, we used a 3 obstacle (low, medium, high) by 2 BMI group (normal, obese) RM ANOVA for analysis.

### Table 2. Mean Comparison of Initial and Final Baseline Gait Parameters in Obese BMI and Normal BMI Subjects.

<table>
<thead>
<tr>
<th></th>
<th>Initial Baseline</th>
<th>Final Baseline</th>
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<tbody>
<tr>
<td></td>
<td>Normal BMI</td>
<td>Obese BMI</td>
</tr>
<tr>
<td>Mean Velocity (cm/s)</td>
<td>123.97 (SD = 15.92)</td>
<td>102.93 (SD = 14.94)</td>
</tr>
<tr>
<td>Mean Cadence (step/min)</td>
<td>113.63 (SD = 6.74)</td>
<td>104.58 (SD = 9.99)</td>
</tr>
<tr>
<td>Mean Step length (cm)</td>
<td>55.86 (SD = 4.15)</td>
<td>54.03 (SD = 5.08)</td>
</tr>
<tr>
<td>Mean Step width (cm)</td>
<td>7.42 (SD = 1.67)</td>
<td>11.28 (SD = 4.09)</td>
</tr>
<tr>
<td>Mean Step time (s)</td>
<td>0.45 (SD = 0.03)</td>
<td>0.53 (SD = 0.07)</td>
</tr>
<tr>
<td>Mean Double limb support time (s)</td>
<td>0.16 (SD = 0.03)</td>
<td>0.30 (SD = 0.08)</td>
</tr>
<tr>
<td>Mean Single limb support time (s)</td>
<td>0.30 (SD = 0.02)</td>
<td>0.34 (SD = 0.05)</td>
</tr>
</tbody>
</table>
Figure 8. Initial versus Final Baseline Comparisons. This figure shows overall comparisons of mean gait parameters for initial versus final baseline walking and body mass index.
RESULTS

Initial vs. Final Baseline

Main Effects and Interactions – Gait Parameters

For velocity, the RM ANOVA revealed main effects for obstacle height: \(F(2, 96)=39.25, p < .001\). Velocity was fastest at the low versus both medium and high obstacles \((ps < .001)\). We also found an effect for BMI: \(F(1,48)= 43.82, p < .001\) adults with normal BMI had higher velocities than adults with obese BMI. There was interaction between condition and BMI group: \(F(2, 96)= 4.96, p < .01\) at every obstacle height, participants with normal BMI had higher velocities than those with obese BMI. (Figure 9) A 3-way interaction was also observed: \(F(2, 96)= 3.86, p < .05\) at every obstacle height, adults with normal BMI had faster velocities during both the approach and end portions of the trial compared to obese BMI adults \((ps < .001)\).

<table>
<thead>
<tr>
<th>Obstacle Height</th>
<th>Normal BMI</th>
<th>Obese BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Medium</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>High</td>
<td>200</td>
<td>150</td>
</tr>
</tbody>
</table>

Approach to Obstacle Velocity and BMI

![Approach to Obstacle Velocity and BMI](image)
Figure 9. Body Mass Index and Velocity Before and After Crossing Obstacles. Top: This graph shows the average velocity (measured in centimeters per second) for approaching obstacles at low, medium, and high heights in normal and obese BMI subjects. Bottom: This graph shows the average velocity of normal and obese BMI subjects after crossing over the obstacles at the various heights. Findings revealed that at every obstacle height (before and after crossing), normal BMI subjects had significantly ($p < .001$) higher velocities compared to obese BMI subjects.

For **cadence**, the RM ANOVA revealed main effects for obstacle ($F(2, 96)= 55.08, p < .001$); cadence was highest at the low versus medium and high obstacles ($ps < .001$), and for BMI ($F(1, 48)= 23.15, p < .001$) adults with normal BMI had higher cadences than adults with obese BMI. The graph in Figure 10 highlights these findings.
Figure 10. Cadence. Left: This graph shows the average cadence (measured as steps per minute) for obstacles at low, medium, and high height for all subjects. Cadence was observed to be significantly ($p < .001$) higher at the low versus medium and high obstacles. Right: This graph shows the average cadence for normal versus obese BMI groups. Adults with normal BMI had significantly higher ($p < .001$) cadences than obese BMI subjects.

For **step length**, the RM ANOVA revealed main effects for step section ($F(1,48)=166.36, p < .001$). Step length was shorter during the approach to the obstacle compared to after crossing the obstacle or end section. We also found an effect for BMI group ($F(1,48)=11.83, p < .01$); adults with normal BMI took longer steps than those with obese BMI. There was an interaction (Figure 11) between obstacle and BMI group ($F(2, 96)=5.85, p < .01$) at every obstacle height, those with normal BMI took longer steps than those with obese BMI ($ps < .001$), and between step section and BMI group ($F(1,48)=43.72, p < .001$) at the end section, those with obese BMI took shorter steps than those with normal BMI.
For **step width**, the RM ANOVA revealed main effects for step section: \( F(1,48)=96.55, p < .001 \) step width was larger during the approach to the obstacle than after crossing and a main effect for BMI \( F(1,48)=23.05, p < .001 \) step width was larger for the obese versus the normal BMI group. The graphs in Figures 12 and 13 illustrate these differences.

For **step time**, the RM ANOVA revealed main effects for obstacle \( F(2,96)=26.37, p < .001 \). Step time was longest during the high versus the low and medium obstacles \( ps < .01 \). We also found effects for step section \( F(1,48)=51.45, p < .001 \); step time was shorter during the approach to the obstacle compared to after crossing over, and for BMI group \( F(1,48)=27.84, p < .001 \) step time was longer for the obese versus the normal BMI group. An interaction was found between step section and BMI group \( F(1,48)=24.31, p < .001 \). For the normal BMI group, step time was shorter during the approach than during the end section \( p < .001 \).
Figure 11. BMI and Step Length Before and After Crossing Obstacle. Top: This graph shows the average step lengths (measured in centimeters) for normal and obese BMI subjects for walking up to obstacles at low, medium, and high height. Bottom: This graph shows the average step lengths for normal and obese BMI subjects after stepping over the obstacles. Findings revealed that at every obstacle height, normal BMI subjects took longer steps than obese BMI subjects, and that after crossing over (end section) obese BMI subjects took shorter steps than normal BMI subjects.
Figure 12. Step Width Before and After Crossing Obstacle. This figure shows the step width before and after crossing over obstacles of various heights (low, medium, high) for all subjects. Findings revealed that step width was significantly larger ($p < .001$) before crossing versus after crossing over the obstacle.

Figure 13. Step Width and BMI. This figure demonstrates the significant ($p < .001$) difference in step width (measured in centimeters) that exists between the obese and normal BMI groups during walking while crossing over obstacles. Step width was larger for obese subjects compared to non-obese subjects.

For single limb support time, the RM ANOVA revealed main effects for obstacle ($F(2,96)=38.81, p < .001$); single limb support time was longest during the high versus the
low and medium obstacles \((ps < .001)\), for step section \(F(1,48)=376.23, p < .001\) single limb support time was longer during the approach versus the end section, and for BMI group \(F(1,48)=19.07, p < .001\) single limb support time was smaller in the normal BMI group. (Figure 14) There was an interaction found between obstacle and step section \(F(2,96)=24.88, p < .001\); for the approach, single limb support time was longest during the high versus the low and medium obstacles \((ps < .001)\).

For **double limb support time**, the RM ANOVA revealed main effects for obstacle \(F(2,96)=3.92, p < .05\) double limb support time was higher at high versus low obstacle height \((p < .01)\). We also found effects for step section \(F(1,48)=105.34, p < .001\); double limb support time was longer during the approach versus the end section, and for BMI group \(F(1,48)=65.59, p < .001\); double limb support time was longer for the obese BMI group compared to the normal BMI group. An interaction was found between obstacle and BMI group \(F(2,96)=4.56, p < .05\); the normal BMI group had shorter double limb support times than the obese BMI group at every obstacle height \((ps < .001)\), and between obstacle and step section \(F(2,96)=3.41, p < .05\); for the approach section, double limb support time was larger during the high versus the low obstacle \((p < .01)\). The graphs in Figure 15 represent the results for DLST.
Figure 14. BMI and Single Limb Support Time (SLST) Before and After Crossing Obstacles. Top: This graph shows the SLST or time spent on a single limb in seconds prior to crossing over the obstacle for normal and obese BMI groups. Bottom: This graph shows the SLST after crossing over the obstacle for both BMI groups. Findings revealed that SLST was significantly shorter ($p < .001$) in the normal BMI group before and after crossing over the obstacles. It was also found that during the approach, SLST was longest for the high versus the low and medium obstacles for all subjects.
Figure 15. BMI and Double Limb Support Time (DLST) Before and After Crossing Obstacles. Top: This graph shows the average DLST time in seconds spent on both feet before crossing over obstacles of low, medium, and high height for normal and obese BMI subjects. DLST was found to be greater \((p < .001)\) for the obese BMI group than for the normal BMI group at every obstacle height. Bottom: DLST after crossing for normal and obese BMI subjects. DLST was greater after crossing for obese BMI subjects for every obstacle than for normal BMI subjects.

Body Sensors

Main Effects – Body Movement Parameters
For **degrees of sway in the anterior-posterior direction**, the RM ANOVA revealed main effects for BMI group ($F(1,46)=13.87, p < .01$). Adults in the obese weight group had a higher degree of sway (Figure 16) in the anterior-posterior direction than adults in the normal weight group.

For **degrees of sway in the medial-lateral direction**, the RM ANOVA revealed main effects for condition ($F(2,92)=3.11, p < .05$); degree of sway in the medial-lateral direction was higher on high (Figure 18) versus low obstacles ($p < .01$), and for BMI group: ($F(1,46)=13.00, p < .01$); adults in the obese group had a higher degree of medial-lateral sway (Figure 17) than adults in the normal weight group.

**Figure 16.** Anterior Posterior Sway and Body Mass Index. This graph shows the mean degrees of sway observed in the anterior-posterior direction for all obese and control subjects during walking when performing the obstacle crossing functional task. Obese subjects showed a significantly higher sway in the anterior-posterior direction than the normal weight subjects.
**Figure 17.** Medial Lateral Sway and BMI. This graph shows the mean degrees of sway observed in the medial-lateral direction for all obese and control subjects during walking when performing the obstacle crossing functional task. Obese subjects showed a significantly higher sway in the medial-lateral direction than the normal weight subjects.

**Figure 18.** Medial Lateral Sway and Obstacle. This graph displays the degrees of sway in the medial-lateral direction observed for all subjects during walking while crossing over obstacles of low, medium, and high height. A significantly ($p < .01$) higher degree of sway was observed for the high versus the low obstacles.

*Obstacle Crossing*
Main Effect and Interactions – Gait Parameters

For **plant leg single limb support time**, the RM ANOVA revealed main effects for condition \(F(2,66)=21.91, p < .001\); single limb support time with the plant leg (the leg on the ground right before obstacle crossing) was highest before crossing high versus low and medium obstacles \((p_s < .001)\), and for BMI group \(F(1,33)=7.84, p < .01\); single limb support time was higher for the obese versus the normal BMI group. The graphs in Figure 19 represent the results of the plant leg data.

For **crossing step double limb support time**, the RM ANOVA revealed main effects for condition \(F(2,66)=6.17, p < .01\); double limb support time for the step prior to obstacle crossing was larger before high versus low and medium obstacles \((p_s < .01)\), and for BMI group \(F(1,33)=64.18, p < .001\); double limb support time is greater for the obese versus normal weight group (Figure 20). There was an interaction found between condition and BMI group \(F(2,66)=3.31, p < .05\). At every obstacle height, double limb support time is greater for the step prior to obstacle crossing for the obese versus the normal weight group \((p_s < .001)\).
Figure 19. Plant Leg and Single Limb Support Time (SLST). Top: This graph shows the single limb support time in seconds of the plant leg (the supporting leg on the ground immediately prior to crossing over the obstacle) for each obstacle height (low, medium, high). Results reveal that SLST was highest for high versus low and medium obstacles for all subjects ($p < .001$). Bottom: This graph compares the plant leg SLST of the normal and obese BMI group. Plant leg SLST was found to be higher ($p < .01$) for obese subjects than for normal weight subjects (this finding shows that obese subjects have the wherewithal to maintain longer SLST to cross over obstacles and may need more time with motor planning prior to executing a step).
**DISCUSSION**

In this study we focused on the kinematics of human movements during balance related functional tasks in both obese and normal body mass index subjects. We also assessed the temporal nature of task repetition on measurement gait parameters. Our quantifiable measurement instruments (Biosensics wearable sensors, GAITRite® carpet) are subject to task repetition variances that have a tendency towards improved walking performance with additional practice. Our major findings suggest that obese individuals with knee OA will experience more difficulty crossing over obstacles during walking in

![Figure 20. Body Mass Index and Double Limb Support Time (DLST) of Crossing Step. This figure demonstrates the time spent on both legs on the step immediately prior to crossing over an obstacle. Analyses revealed that DLST was significantly greater ($p < .001$) in the obese BMI group compared with the normal BMI group prior to stepping across the obstacle.](image)
their everyday environment compared to healthy normal BMI subjects. Obstacle heights selected for this study are representative of environmental terrains that may be observed in daily living situations. The obstacle-crossing task was sensitive enough to detect impairments in walking, such as slower velocity, lower cadence, shorter step lengths, larger step widths, and longer step times for the obese BMI group. Our results also suggest obese subjects may have spent more time motor planning their steps to cross over the obstacle, as they had higher single limb support time for the plant leg and higher double limb support time for the crossing step at every obstacle height compared to the controls. Likewise, we showed that obesity increased sway in both anterior-posterior and medial-lateral directions, which would make it more taxing and dangerous to maintain balance throughout a dynamic task such as walking with obstacle negotiation. However, we also found that practice with a functional task such as crossing over obstacles revealed improvements in walking patterns within session, and it may be beneficial to examine the effects of practice in walking patterns in patients electing to undergo bariatric surgery.

Significance

Current research shows that patients who are obese modify their gait while walking to support their excess body weight and temporarily protect their joints, however by doing so they actually put themselves at a greater risk for increased knee pain and fall related injuries. The results from this study examine improvements in walking and postural parameters in situations beyond flat ground walking, which may be used to help
create new methods using functional tasks such as obstacle crossing for detecting fall risks.

This study provides the preliminary baseline data needed to study the effect of interventions, such as bariatric surgery. Traditional means of assessing outcomes from bariatric surgery include weight loss, high blood pressure, and diabetes control, among other things. While these metrics are very straightforward, the effect of weight loss surgery may be farther reaching than is seen with metabolic measures. Effect on psychiatric conditions, immunity, and even its effect on biomechanics may be important. Since bariatric surgery carries significant risk and cost, complete elucidation of the potential benefits should be vetted in order to establish efficacy. Beyond this, these findings may aid in developing novel methods for detecting and diagnosing fall risks in obese patients.

Advantages

In this study we were able to use innovative technology to take direct and quantifiable measurements of gait parameters and postural changes occurring in the daily lives of patients. We used innovative, lightweight, portable, kinematic motion sensors (Biosensics, LLC) for monitoring postural transition measures associated with fall risks. The wearable body sensors conveniently transmit real-time data wirelessly via Bluetooth a laptop equipped with LEGSys™ software. In addition, we used a portable GAITRite® walkway system, which allowed us to easily set up an obstacle over it to take quantifiable spatio-temporal gait parameters.
Our research lab was integrated with the weight loss center at Boston Medical Center where we were able to follow up with individual obese subjects over the course of a year. We were able to collect data from bariatric surgery candidates primarily with a very high body mass index, class II obesity (BMI=X). We would like to identify that this research was approved by the Institutional Review Board to protect human subjects involved in this study.

Limitations

Interpretation of this preliminary investigation is limited by certain features common for its’ nature. The most obvious of these points is a lack of treatment group. Future study regarding the effect of bariatric surgery is underway in order to draw classical “before” and “after” comparisons. This preliminary study was meant as a proof of principle; that our instrument is valid in measuring gait kinematics during obstacle negotiation in pre-bariatric surgery patients. Measurements were taken in the laboratory, however it is unclear to the degree these findings would translate outside of a controlled environment.

Additional limitations are the small sample size, which is subject to selection bias. While we attempted to enroll consecutive patients that presented for weight loss surgery, we were not able to achieve 100% enrollment. It is possible that more obese patients with less mobility were less inclined to participate in our study. It is also possible that
psychiatric influencers, that are common in patients with morbid obesity, may have influenced enrollment. Socioeconomic influences may also have played a role in selection bias, with patients with transportation and family support more likely to participate in the study. The control subjects selected for the present study were not matched in age to the obese subjects, which is another limitation. Due to the sample size, the majority of the subjects enrolled were female; thus results extrapolated for this study may not be entirely representative for male subjects. Future studies can address these limitations by including a larger sample size with age and gender matched controls.

Future directions

This research can lead to innovations in diagnostic tools and interventions that can help minimize fall risks in obese patients with knee OA. Although our present research revealed improvements in walking performance in obese participants following repetition, further research can be performed to determine if gait retraining before even undergoing surgery would be of benefit to patients recovering from bariatric surgery.

This study is part of a larger ongoing investigation that aims to determine the effect of bariatric surgery on biomechanical gait kinematics. Using individual subjects as their own controls, serial temporal measurements are being obtained to measure outcomes following bariatric surgery. It is likely that as weight loss is achieved, patient’s scores approach those of non-obese patients. These may be important in mitigating the effects that obesity has on decreased mobility, acceleration of arthritis, and
the development of musculoskeletal pain (back pain, etc.). Future studies can use these findings to create a randomized controlled trial to prospectively examine speed of recovery in postural instability in bariatric surgery patients and determine the benefits of gait retraining after massive weight loss.
### LIST OF JOURNAL ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Name</th>
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<tbody>
<tr>
<td>IJCEM</td>
<td>International Journal of Clinical and Experimental Medicine</td>
</tr>
<tr>
<td>JAMA</td>
<td>JAMA: The Journal of the American Medical Association</td>
</tr>
<tr>
<td>NCBI</td>
<td>National Center for Biotechnology Information</td>
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REFERENCES


47


http://doi.org/10.1016/j.soard.2008.08.022


http://doi.org/10.1161/HYPERTENSIONAHA.108.120915


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http://www.utdallas.edu/atec/midori/Handouts/walkingGraphs.htm#Step


http://doi.org/10.1038/nrrheum.2012.224

http://doi.org/10.1016/j.jbiomech.2014.06.001
CURRICULUM VITAE

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bbashin@bu.edu
Year of Birth: 1987

EDUCATION

Boston University School of Medicine
Boston, Massachusetts 02215
Masters in Medical Sciences, May 2015 (anticipated)

Boston University
Boston, Massachusetts 02215
Bachelor of Science, Biology-Neuroscience, May 2011
Minor, Visual Arts

EXPERIENCE

Research Internships
Clinical Research Assistant
Dr. Simone V. Gill, Motor Development Laboratory
2014 – Present
http://www.bu.edu/motordevlab/people/
(Department of Occupational Therapy, Boston University School of Medicine & Sargent College)

- Collected data from bariatric surgery patients using innovative BioSensics and GAITRite technology
- Performed data processing using LEGSys+ and GAITRite software
- Assisted with data analysis using SPSS statistical software
- Performed video coding using Datavyu software
- Participated in weekly lab meeting discussions

Research Assistant
Dr. Emad N. Eskandar, Sensorimotor Laboratory
2008 – 2009
http:// eskandar.mgh.harvard.edu/index.html
Investigated the role of the anterior striatum and hippocampus during novel stimulus-response learning
- Trained non-human subjects to perform associative learning and memory tasks
- Assisted in data collection and analysis of single electrode recordings in subjects
- Performed data entry and literature searches

**PUBLICATIONS**


**PRESENTATION**

*Poster (Abstract submitted: Effects of Practice on Walking Patterns in Pre-Bariatric Surgery Candidates)*
2015 Graduate Research Symposium, Boston University, March 31, 2015

**EMPLOYMENT**

*Teacher and Tutor for Grades K-8*
- Instructed and motivated up to 30 students in kindergarten through 8th grade in a classroom setting
- Helped multiple students improve their test scores
- Taught fundamental and advanced math and verbal concepts
- Interacted with parents by discussing their child’s progress reports
Sales Associate
Equinox Fitness Club, Highland Park, IL 2004 – 2005

- Provided excellent customer service and performed administrative tasks
- Met or exceeded sales quotas during tenure
- Maintained positive, professional relationships with coworkers and managers

ACTIVITIES

Volunteer Work
Christopher’s Haven, Boston, MA 2014 - Present
- Activities Volunteer, coordinated arts and crafts activities for pediatric cancer patients, assisted in fundraiser events

Tufts Community Health, Boston, MA 2011 – 2012
- Clinical Volunteer, duties include insurance coverage checks for MassHealth, coordination of patient appointments, management of patient health records

Sigma Alpha Lambda: Member (National Leadership and Honors Organization)

Interests: Running (5K and 10K), Hiking, Oil and Acrylic Painting

SKILLS

- Excellent interpersonal, verbal, and written communication skills
- Advanced research and documentation skills
- Knowledge of medical terminology
- Data Entry, data analysis, and problem-solving skills
- Ability to prioritize work
- Computer skills: Full working proficiency with MS Office (Word, Excel, Outlook, Power Point), Mac OSX, Adobe Professional Software, EndNote, Java (Basic)

LANGUAGES

- English (Fluent), Russian (Native), Spanish (Basic)