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Research Article

Gait and Function in Class III Obesity

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Walking, more specifically gait, is an essential component of daily living. Walking is a very different activity for individuals with a Body Mass Index (BMI) of 40 or more (Class III obesity) compared with those who are overweight or obese with a BMI between 26–35. Yet all obesity weight classes receive the same physical activity guidelines and recommendations. This observational study examined the components of function and disability in a group with Class III obesity and a group that is overweight or has Class I obesity. Significant differences were found between the groups in the areas of gait, body size, health condition, and activity capacity and participation. The Timed Up and Go test, gait velocity, hip circumference, and stance width appear to be most predictive of activity capacity as observed during gait assessment. The findings indicate that Class III-related gait is pathologic and not a normal adaptation.

1. Introduction

Everyone needs to walk and move about in order to participate in life. Watching groups of people in public areas, you typically see people walking in a straightforward manner, putting one foot in front of the other. However, if that person is carrying 1.5 to 2 times the recommended weight for their height (Class III obesity or a body mass index of 40 or greater), then their walk or gait takes on a side-to-side shuffle and looks very different. Changes in gait parameters are observed in persons with Class III obesity to accommodate the increased mass [1] compared to persons of normal weight [2–4]. Speed, distance traveled, and steps taken are important measurable parameters of gait [5]. An underlying presumption in the literature and in clinical practice is that gait parameter changes in individuals with Class III obesity are a variation of normal. However, it is unclear whether these changes are an adaptation to promote movement and daily functioning or if the changes are an indication of mobility disability.

Walking or gait requires balance, control of trunk and upper and lower limb movement, and the ability to respond to changes in the external environment [6, 7]. Gait patterns associated with pathologic conditions such as stroke or Parkinson's disease also differ from normal gait parameters. Individuals with these conditions demonstrate changes in gait that may result in diminished function and decreased activity and participation in daily life [7, 8]. Gait characteristics observed in individuals with Class III obesity more closely resemble changes in gait following stroke than normal gait parameters [4]. While those with stroke or Parkinson's disease are frequently referred to physical therapy for rehabilitation to improve gait, individuals with Class III obesity as a single diagnosis or "condition" are not typically referred for rehabilitation because of payment limitations. Rehabilitation for individuals with Class III obesity is usually denied because it is not considered to be medically necessary [9].

Current activity guidelines and research practices do not uniformly distinguish between overweight and obese weight classes when making activity recommendations [10–12]. These recommendations implicitly presume that all people carrying extra weight can achieve functional mobility outcomes such as walking for 30 minutes or taking 10,000 steps daily [10]. This presumption is questionable when viewed alongside the epidemiologic evidence that people with Class III obesity suffer the highest rates of obesity-related morbidity, and these conditions can have additional negative impacts on mobility (such as arthritis, diabetes, and asthma) [13, 14]. Class III obesity has also been associated with significant barriers to mobility-dependent activity and participation in other activities of daily living [15–17]. These barriers range from the size of furniture and equipment (example: belt width and weight ratings on treadmills) to the negative attitudes of other people. The current assumption that the gait pattern associated with Class III obesity represents a normal gait should be scrutinized given the evidence of significant gait variation in individuals with Class III obesity, the documented weight-class-specific health-related mobility constraints, and the potential barriers to full activity and participation in everyday life.

The purpose of this observational study was to examine the gait and function associated with Class III obesity. The study's first aim was to compare gait components and activity of a group with Class III obesity and a group with lower body mass indexes (BMIs) but who are still overweight or have Class I obesity (BMI of >25 but <35). The second aim was to identify potentially predictive gait and anthropometric measures that can be used in a clinical or community setting. Identification of these predictive measures is intended to lay the groundwork for future participant screening and program design. The results of this research are intended to improve the focus of weight class-specific physical activity interventions.

2. Methods

2.1. Study Design. Given the multiple impacting factors, examining gait in this population requires a comprehensive and contextual framework. The measurement blueprint for this study is the World Health Organization's (WHO) International Classification of Functioning, Disability, and Health (ICF). The ICF includes social context, health conditions, body structure, activity, and participation as components in an explanatory model of function and disability [18]. Each of these components impacts each other and the combined output falls on a continuum that ranges from functional (fully actualized and engaged in life) to disabled (extremely limited). The model defines these complex components and relationships and also provides an explicit, internationally standardized language and classification system for defining functioning and disability in clinical and research settings [19].

2.2. Measures. Each instrument measured a component of the ICF model. Bodily structure refers to human anatomic composition, and bodily function refers to what the body is able to do or how it is able to move [18]. For this study, bodily structure includes anthropomorphic characteristics such as height, weight, stance width, and waist and hip circumference. Resting Metabolic Rate (RMR) is an indicator of body mass and metabolic function at rest. It was measured by the MedGem, a hand-held device that calculates indirect calorimetry [20, 21].

The bodily function component refers to physiologic functions or "fitness of gait," quantified as the gait measures of velocity, cadence, and stride length. These components were measured through gait observation during a 6-minute-timed walk. The distance in meters walked at a self-selected comfortable pace serves as a measure of endurance [6, 7, 22, 23].

The activity and participation component, or the ability to complete tasks was measured through self-report and direct observation. These self-reports include the modified Physical Activity portion of the Weight and Lifestyle Inventory (mWALI-Part L) and the modified Craig Handicap Assessment and Reporting Technique short form (mCHARTsf). These self-reports measured the frequency of engagement in daily activities as well as longer term patterns of interpersonal and community participation. The WALI part L is a 9-item questionnaire concerning daily tasks, activity levels, participation in sports, and sedentary behaviors. WALI is used for bariatric presurgical assessment and is a reliable clinical data collection instrument [24]. To date other sections of the WALI have been published test-retest reliability correlations from 0.70 to 0.90, although the physical activity component has not been examined in this way [25, 26]. The CHARTsf questionnaire was used to measure participation performance. This questionnaire is designed to determine levels of social participation in six different areas for people with disabilities [27]. Those areas are physical independence, cognitive independence, mobility, occupation, social integration, and economic self-sufficiency [28, 29]. CHART scores have been found to be directly correlated with self-reports of activity participation by persons with several different conditions including stroke, burns, spinal cord injury, and multiple sclerosis: the higher the CHART score, the greater the level of participation [28]. The short form uses about half the questions and its validity and reliability are consistent with the original instrument [29, 30].

Observational measures of mobility functionality included a quantification of mobility capacity using the Talk Test (TT) and performance of multiple types of movement with the Timed Up and Go (TUG) test. The TT is an observational method of gauging an individual's capacity to sustain mobility/activity [31]. The point at which an individual can no longer comfortably carry on a conversation has been strongly associated with both exertional cardiac ischemic insufficiency in patients with CAD and anaerobic threshold in healthy individuals [32, 33]. The TUG test consisted of having the participant sit in a chair with arms, stand up, walk 3 meters one way, turn around, walk back, and then sit back down [34]. These actions are all basic components of mobility and daily activity. The TUG has been found to have very good reliability (intraclass coefficient correlations of >0.95) and has been correlated with gait velocity as an indicator of both improvement and decline of mobility associated with stroke, multiple sclerosis, orthopedic injuries, and aging [35–38]. These two instruments quantified activity outcomes and capacity to engage in activity and participation [34, 37].

Potential health barriers were measured using the WALI-Part Q and the Physical Activities Readiness Questionnaire (PAR-Q). Part Q of the WALI refers to the medical history section of the inventory [39]. The first question of this section contains a list of 25 health conditions that a person may

Table 1: Study inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
BMI > 25 and < 35 BMI > 40	Non-english speaking
≤2 yes responses on PAR-Q with no provider exemption or 1 yes response	Pregnant
Age ≥ 18 years	

have been or still is being treated for and an open-ended "other" category. The Physical Activity Readiness Questionnaire is a 7-item screening instrument for discerning those most at risk for activity-related injury or death [40]. The intent of the questionnaire is to identify those people with musculoskeletal injuries and cardiovascular risk factors for whom unsupervised exercise could be hazardous [41].

Information regarding environmental and social barriers was gathered using the Craig Hospital Inventory of Environmental Factors short form (CHIEFsf). The CHIEFsf is a 12-item questionnaire that measures the presence or absence of barriers to mobility in the areas of physical/structural, attitudes and support, services and assistance, policies, and work/school [30, 42]. The questionnaire has a test-retest reliability of 0.93 and has been found to have direct and significant correlations with scales of disability and limited participation [30, 42]. There is a negative relationship between CHIEF and CHART scores, meaning that the greater the barriers faced in the environment, the less an individual is participating in everyday activities [42].

2.3. Participants and Recruitment. This pilot study was designed to obtain estimates of effect sizes and variability for the outcome measures rather than testing hypotheses. Therefore, sample size justification focused on precision on estimates rather than power. Participants were recruited through weight-loss groups, the University's clinical research web site, snowball methods, flyer distribution, faith-based groups, and social networks. Once identified, potential participants were phone screened using the PAR-Q, inclusion and exclusion criteria (Table 1). If eligible, an appointment was made for a one-time visit for data collection. People with Class II obesity were specifically excluded in order to allow for clear distinction between gait characteristics between the Class III and non-Class III groups. Based on previous research with Class III participants, it was estimated that 4% of people identified as potential participants would agree to be screened. Of those who were screened, we estimated that 23% would meet eligibility criteria and agree to participate. The final enrollment was 11 participants in the Class III cohort and 18 in the non-Class III group.

2.4. Study Protocol. The University's Institutional Review Board reviewed and approved the project. The study was also reviewed and sponsored by the University's Clinical Translational Research Center (CTRC). All data collection took place within the CRTC, located within the University's hospital complex. Upon arrival, participants were consented by the principal investigator (PI), who collected all data. Data collection had three phases: survey and self-report completion, anthropomorphic measurements, and the active walking segments (Figure 1). The survey and anthropomorphic components were completed in an exam room while the walking components were accomplished in a broad, well-lit and low-traffic hallway. A 14 × 6-foot "track" was marked by brightly colored tape at 1-foot intervals. Bariatric-rated seating was available in two areas. All walking segments were videoed using a Sony digital camcorder locked on a tripod at one end of the walkway. At the conclusion of the data collection session, participants were given a $10 gift card as an honorarium.

2.5. Statistics. Data were analyzed using R (R version 2.10.1). Each measurement item was analyzed, found to reflect the ICF model, and was included in the analysis [43]. The participants were coded into two groups: Class III and non-Class III. The non-Class III group included those people with a BMI > 25 and < 35. Between group comparison of continuous, variables were compared using Welch's version of the student t-tests (as there were no indications that the two groups have the same variance) while between group comparisons of the categorical measures used Pearson's chi square test.

Exploratory logistic and multiple linear regression analysis was performed within the Class III group to investigate potential relationships between gait and anthropomorphic measures that could possibly be predictive of activity and participation. As this was a pilot project, identification of measures that could potentially predict a specific outcome was important to lay the foundation for future interventions and research.

3. Results

3.1. Demographics. A total of 180 potential participants were approached, 61 were screened, 50 were enrolled, 21 declined participation or did not show for the screening appointment, 8 were found ineligible, and 32 completed the study. The study participants ranged in age from 26–63, were primarily female (87%), and almost evenly split between African American and white backgrounds (Table 2). All of the participants were employed at least part-time with mean income self-reported at $50,000 per year.

3.2. Between Group Differences. The first aim of this project was to determine which (if any) differences exist between the Class III and non-Class III groups. Several significant differences were found between the groups (Table 3 chi square and Table 4 t-test). The number of exercises that a participant claimed to like, how active the individual claimed to be daily, RMR, stance width, velocity, waist, and hip circumference were all statistically significant with a P value of <0.05. The TUG mean difference was also statistically significant. None of the items collected through the CHARTsf and CHIEFsf surveys were statistically significant.

Given the small sample size of this pilot study, statistical significance was not the only criteria for evaluation. Variables

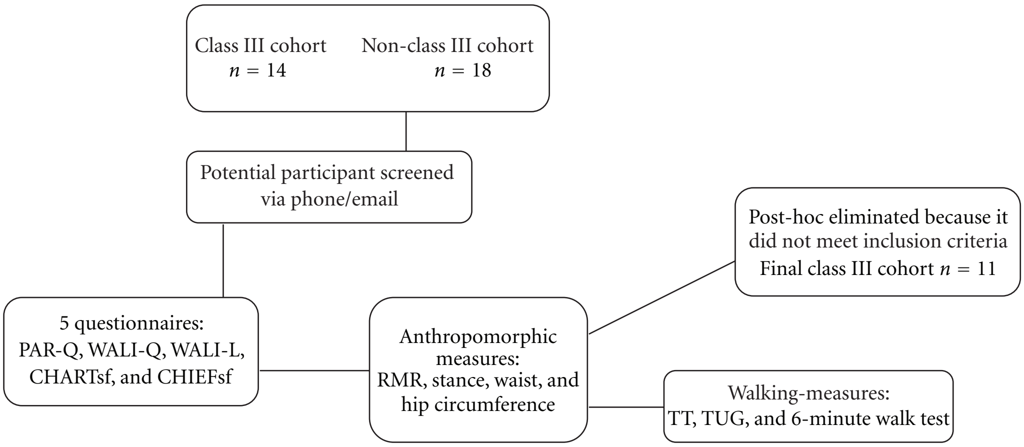

Figure 1: Data collection workflow.

Table 2: Sample demographics by BMI group.

	BMI*	Gender	Race	Age	Employed	Income
Overall	36.8 (26–61.2)	87% female	41% african american	45 (26–66)	100%	Mean-$50,000 annually
Non-Class III	31.8 (30.3–34.2)	94% female	35% african american	50.6 (26–66)	100%	Mean-$50,000 annually
Class III	43 (40.4–61.2)	73% female	45% african american	42.6 (30–60)	100%	Mean-$50,000 annually

*Mean (range).

that were found not to be statistically significant but with P values of 0.06–0.1 were still considered to have merit. These variables were retained for further analysis because they could potentially prove significant with a larger sample.

3.3. Potentially Predictive Relationships. Two types of regression were used to explore predictive relationships in the Class III cohort. The purpose of the exploration was to determine if gait and anthropomorphic measures would be predictive of activity outcomes or capacity, controlling for age and gender. Only those variables found to be actually or potentially significantly different in the between group analysis were included. The principal independent variables (velocity, stance, cadence, RMR, systolic blood pressure, hip, and waist circumference) were all continuous. Age and gender were covariates in all models. Multiple regression analysis was used with the continuous-dependent variable (TUG mean). Logistic regression was used with categorical-dependent variables (TV weekend, number of activities liked, how active, and CHIEF work). The only significant relationships involved TUG mean with hip circumference, velocity, and stance (Table 5). The variation in TUG scores has an inverse relationship with velocity and cadence and a direct relationship with hip circumference, the higher the TUG score, the slower the movement, while the larger the hip circumference, the higher the TUG scores. Keep in mind that higher TUG scores reflect mobility dysfunction.

4. Discussion

The study yields significant findings regarding both aims of this study. For the first aim of comparing the measures of the Class III and non-Class III cohorts, the gait and functional capacity data for the Class III cohort appears to be pathologic rather than normative. For the second aim of exploring potentially predictive measures, TUG test performance has significant predictive relationships with gait characteristics and hip circumference.

The gait and functional outcome findings for the Class III cohort are not reflective of a normal variation but indicate a more pathologic process. Normal and pathologic gaits show specific variations in gait characteristics [5, 7]. The normal range for velocity is 1.2–1.6 m/sec and cadence is 110–120 steps/minute for healthy individuals [4]. If a gait pattern is a functional variation of normal, then velocity (the distance traveled per unit of time) would stay the same and cadence (steps taken per unit of time) would increase [5, 7]. However, if a gait is not a functional variation or is pathologic, then velocity would decrease and eventually so would cadence [5, 7].

Mean velocity and cadence for the Class III cohort both decreased in comparison with the Non-Class III group and with normative values. Additionally, this group's mean TUG score more closely resembled that found in patients with multiple sclerosis and the frail elderly than healthy norms or the lower weight cohort (pathologic > 13 seconds versus healthy 9-10 seconds) [34, 35]. Given these findings, the gait characteristics exhibited by the Class III group are consistent with individuals with pathology.

This study's findings are consistent with evidence found in the published literature. When compared with the lower weight cohort, this Class III group had decreased velocity, wider stance, higher RMR, larger waist, and hip circumferences and reported a greater number of comorbid conditions

Table 3: Frequency distribution of participants by BMI group and self-reported variables.

Variable	Class III	Non-Class III	χ^2	*df*	*P* value
Hours of TV viewing on weekends			3.84	2	0.14
Category 1 (0–4 hours)	9% (1/11)	33.3% (6/18)			
Category 2 (5–10 hours)	36% (4/11)	44.5% (8/18)			
Category 3 (11+ hours)	55% (6/11)	22.2% (4/18)			
Number of physical activities liked (no participation necessary)			14.45	2	0.0007
Category 1 (listed 1)	9% (1/11)	0% (0/18)			
Category 2 (listed 2)	27% (3/11)	94% (17/18)			
Category 3 (listed > 2)	64% (7/11)	6% (1/18)			
Self-report of how physical active each day			11.18	2	0.0037
Category 1 (not at all)	9% (1/11)	16.5% (3/18)			
Category 2 (<2 hours/day)	18% (2/11)	83% (15/18)			
Category 3 (>2 hours/day)	73% (8/11)	16.5% (3/18)			
CHIEF work, how frequently were other attitudes a barrier to working			4.94	2	0.08
Category 1 (infrequent, small problem)	82% (9/11)	44% (8/18)			
Category 2 (more frequent or larger problem)	0% (0/11)	28% (5/18)			
Category 3 (more frequent or larger problem)	18% (2/11)	28% (5/18)			
WALI-Q - number of comorbid medical conditions reported			3.99	2	0.13
Category 1 (listed 0)	9% (1/11)	44% (8/18)			
Category 2 (listed 1)	27% (3/11)	17% (3/18)			
Category 3 (listed > 1)	64% (7/11)	39% (7/18)			
Number of physical activities engaged in weekly			4.87	2	0.09
Category 1 (none)	64% (7/11)	28% (5/18)			
Category 2 (1)	27% (3/11)	28% (5/18)			
Category 3 (more than 1)	9% (1/11)	44% (8/18)			

and participating in fewer physical activities. Previous studies of weight class effects on gait have determined that velocity and cadence decrease while stance width increase with higher weight class [4]. RMR is expected to be higher in the Class III cohort because RMR is a measure of overall mass and not specific tissue composition [44]. Logically, the amount of energy needed for basic metabolic functions increases as the amount of mass with metabolic demand increases. Waist and hip circumference have similarly been found to increase with increased BMI [45, 46]. The literature has also noted increased prevalence of sedentary behaviors among those with increased BMIs. There is some debate as to whether the sedentary behavior is a cause of the increased BMI, is a result of it, or reflects a combination of cause and outcome [47, 48]. Decreased leisure activity participation has been noted in states reporting higher BMIs, South Carolina being one example [49, 50]. Those with obesity have been reported to sit more, be less active over all, and spend more hours watching television than lean cohorts [51–53]. This study noted similar reports of decreased leisure activity.

Table 4: Mean* BP, anthropometric, and gait measures by BMI group.

Variable	Class III	Non-Class III	95% CI	t	df	P value
Systolic BP	131.1 (10.4)	123.9 (9.0)	−0.8; 15.1	1.9	19.2	0.07
Waist	126.0 (17.6)*	94.08 (6.0)*	19.9; 43.9	5.8	11.4	<0.0001
Hip circumference	141.77 (16.99)*	111.69 (3.77)	18.59; 41.58	5.79	10.61	0.0001
TUG mean	10.32 (1.44)*	8.59 (1.41)*	0.59; 2.87	5.79	10.61	0.005
Stance	21.72 (8.79)*	13.39 (5.19)*	2.08; 14.58	2.85	14.32	0.01
Velocity	0.92 (0.16)*	1.06 (0.17)*	−0.27; −0.007	−2.18	22.55	0.04
Cadence	68.49 (9.39)*	76.69 (13.44)*	−16.9; 0.52	−1.93	26.39	0.06
RMR	1992 (346.96)*	1541.77 (214.66)*	201.89; 700.04	3.86	14.99	0.002

*Mean (SD).

Table 5: Parameter estimates from multiple linear regression with TUG as dependent variable adjusted for age and gender.

Independent variable	β	SE	t	P value	R^2
Velocity	−6.39	1.49	−4.28	0.0037	0.82
Cadence	−0.10	0.02	−4.06	0.005	0.81
Hip circumference	0.05	0.02	3.38	0.012	0.75

With respect to the second aim of exploring potentially predictive measures, the TUG test yields significant predictive relationships. This test has been found to have very good reliability (intraclass coefficient correlations of >0.95) and has been correlated with gait velocity as an indicator of both deterioration or improvement of mobility with stroke, multiple sclerosis, orthopedic injuries, and aging. Velocity and cadence appear to have an inverse relationship with TUG mean, indicating that as velocity and cadence decrease, TUG mean will increase. Hip circumference and TUG mean appear to have a direct relationship so that as hip circumference increases, so will the time it takes to perform the TUG.

An incidental finding that could support the pathologic nature of the Class III gait pattern is a speech pattern found during analysis of the TT. During conversations that were initiated in the 6-minute walk, Class III participants would have pauses while talking that were not attributable to breathlessness or activity intolerance. These were pauses in speech patterns that were not noticeable during the seated conversations that took place immediately prior to the walking segments. These pauses were clearly patterns of speech and not dyspnea. Similar patterns have previously been found in people who have suffered a stroke, are at risk for falls, or have Multiple Sclerosis [54]. There is no evidence in the literature that dual task studies (measurement of simultaneous walking and talking) have been performed with obese populations. These speech patterns were an incidental finding and were not objectively measured, other than to note that they were present during the walks of 72% of the Class III participants. The presence of this speech pattern during the walks of people with Class III obesity does warrant more thorough investigation and lends credence to a pathologic nature of gait in this cohort [55].

4.1. Limitations. The imprecision of observational data collection methods and the probable skewed representativeness of this Class III sample need to be kept in mind while interpreting the results. The limited sample size associated with the pilot study design limits its power and generalizability. Observational methods of data collection were initially chosen to be easily replicable in community and clinical settings. However, using only observable methods for the gait variable collection proved to be less than rigorous. The stride measurement was limited to estimates based on the 1-foot markings of the walkway and was discarded from analysis because of lack of accuracy. The single camera angle was insufficient for an accurate assessment of total body movement, so that some other measures initially planned for activity capacity had to be eliminated from the study altogether.

The final limitation is derived from the Class III sample established by the inclusion and exclusion criteria. The exclusion criteria eliminated potentially physically limited individuals from participating (specifically ruling out potential participants who had two or more risks for joint pain or cardiovascular compromise with increased activity through PAR-Q screening). It should also be noted that as the study was conducted at an urban-based institution with limited public transportation, thus individuals with mobility issues could not easily participate. As a result, these participants were very likely skewed towards highly functioning compared to the Class III population as a whole.

The findings in this study are clinically relevant. Assumptions that a one-size-fits-all plan for walking should be applied to all obesity weight classes warrant further scrutiny. Rehabilitative interventions for Class III obesity may provide a critical element for improving physical activity and decreasing sedentary behaviors. The immediate implication of the findings is that it would be prudent to assess capacity through self-reports or TUG testing when providing physical activity counseling for people with Class III obesity. When making activity recommendations for this group in practice and community settings, providers can begin physical activity discussions with dialogue about current activity levels, in other words, start with what they can and are doing everyday. While evidence-based interventions specific to this group still need to be developed, it is prudent to examine physical activity expectations within an individual's context.

Disclosure

The views expressed in this paper are those of the authors and do not reflect the views or official policy or position of the Uniformed Services University of the Health Science, Department of Defense or the USA Government. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Center For Research Resources or the National Institutes of Health.

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