Research article

Body mass index changes over 3 years and effect of obesity on community mobility for persons with chronic spinal cord injury

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Objective: To identify the prevalence of obesity in persons with chronic spinal cord injury (SCI), determine change in body mass index (BMI) over time, and identify impact of obesity on community mobility.

Design: Prospective three year longitudinal study.

Setting: Outpatient clinic of rehabilitation center.

Participants: Convenience sample of 222 persons with paraplegia between 2–20 years post SCI.

Outcome Measures: BMI at baseline and three years; community mobility (daily wheelchair propulsion distance and velocity, average number of daily transfers and depression raises).

Results: Participants were 34.1 (27.3, 40.3) years of age and median duration of SCI was 8.7 (3.2, 15.1) years. The SCI adjusted BMI classification identified 44% of participants as obese. BMI increased over time with 13% moving into a higher weight category. Median change in BMI was 0.46 (−0.92, 1.50) kg/m² ($z = -2.684$, $P = 0.007$), and increased at a rate of 0.15 kg/m²/yr. Average BMI was negatively correlated with daily wheelchair propulsion distance ($r = -0.179$, $P = 0.009$), however there was no significant relationship with velocity, number of daily transfers or depression raises.

Conclusion: The majority of participants with chronic SCI were overweight (23%) or obese (44%) and BMI increased by 0.46 kg/m² over three years. Those with higher BMIs pushed their wheelchairs shorter distances, but other mobility measures were not impacted by body weight. Continued mobility activities with increasing body weight can increase risk for shoulder injury. Identifying persons who are obese allows for directed and timely health and mobility intervention.

Keywords: Community mobility, Obesity, Spinal cord injury

Introduction

Obesity is a modifiable risk factor affecting health and mobility for persons with and without disability. According to the National Center for Health Statistics (NCHS), 36% of adults, or 78 million men and women over the age of 20 were obese in 2009–2010.^{1,2} The prevalence of persons with spinal cord injury (SCI) who are overweight or obese from time of onset to a mean of five years post injury ranges between 40–66%.^{3–5} There is a significant increase in body weight of approximately 15 pounds during the acute period of SCI.^{5,6} Metabolic

and physiologic changes after SCI combined with limits in physical activity increase the likelihood of body fat and weight gain.^{4,7} Limited information is available about the prevalence and change in obesity over time for persons with chronic SCI. Identification of the trends of obesity over time following onset of SCI can facilitate appropriate and timely intervention to help persons with SCI attain/maintain a healthy weight and avoid health complications and mobility limitations associated with obesity.

Obesity contributes to declines in health, mobility, and function for persons living and aging with a SCI. Health consequences of obesity are well documented and include high risk for cardiovascular disease, one of the primary causes of mortality after SCI.^{3,7–12} Whereas weight loss

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as low as 5% for persons who are overweight or obese has been shown to reduce or eliminate disorders associated with obesity, produce health benefits such as improvements in blood pressure, blood cholesterol, and blood sugars, and is associated with improvements in cardiovascular disease risk factors.^{13–15} Mobility and functional consequences of being overweight and obese for persons with SCI include difficulty with activities of daily living (ADLs), self-care, transfers, and manual wheelchair propulsion (WCP).^{6,7,16–18} Increased body weight intensifies the demands of transfers owing to the need to lift increased weight with the same muscle capacity.^{6,18} Moreover, manual WCP becomes more challenging because greater body weight increases rolling resistance on flat as well as inclined surfaces.¹⁹ The increased demand on a person's already overworked arms place them at risk for upper extremity overuse injury, carpal tunnel syndrome, and osteoarthritis.⁷ The prevalence of persons with long-term SCI (20–47 years) who reported the need for additional help with mobility and ADLs over time was 45%.¹⁷ Those reporting the need for help were significantly older, had greater weight gain, and had more shoulder pain than those whose need for help had not increased.

Obesity is defined as an accumulation of excess body fat.^{4,7,9,20} The most widely used method of measuring obesity is calculating body mass index (BMI). BMI is advocated by the World Health Organization (WHO) as the standard for recording obesity statistics since the early 1980's and is favored because it can be easily calculated in most populations with minimal time, expense, and effort.²¹ However, measuring and defining obesity for the SCI population is challenging and controversial.^{4,7} Laughton et al. demonstrated that the traditional BMI cut-off of 30 kg/m² fails to identify 73.9% of persons with SCI who are truly obese based upon the combined risk factor of high percentage of fat mass and high C-reactive protein.²² Persons with SCI commonly have 8–18% more body fat than able-bodied controls.^{7,9,20} Because of these limitations, the use of an adjusted BMI classification for persons with SCI with lower BMI ranges is recommended (Table 1).^{20,22}

To date, we are not aware of a study that has investigated BMI over time for persons with chronic paraplegia from SCI. Therefore, the objectives of this study were: (i) to identify the prevalence of obesity for persons with *chronic* paraplegia from SCI using both the WHO and the SCI adjusted BMI classifications, (ii) to determine change in BMI over time for the total sample and identify groups of those whose BMI changed more than 5% of their baseline BMI, (iii) to identify differences in BMI across demographic and SCI lesion characteristics for the total sample and groups, and (iiii) to identify the impact of body weight on community mobility and participation for the total sample and groups.

We hypothesized that (i) because persons with SCI are predisposed to weight gain, those with chronic SCI will have a greater BMI than the general population; (ii) BMI will increase over time; (iii) BMI will be influenced by demographic and SCI lesion characteristics such as race/ethnicity, age, and duration of SCI, (iiii) obesity will affect community mobility and participation, specifically by decreasing number of transfers and depression raises performed, WCP velocity and distance, and participation in sports.

Methods

Design

Data for the current study were collected as part of a three year, prospective, longitudinal study investigating predictors of shoulder pain in manual wheelchair (WC) users with paraplegia from SCI. Evaluations were performed at baseline (entry into the study) and at three years. Participants were contacted by phone once every one to two months.

Because this manuscript represents a secondary analysis of data collected from the parent study to determine predictors of shoulder pain, persons were excluded if they presented with shoulder pain or pathology at entry into the study. The parent study measured upper extremity biomechanics during WCP using a WC ergometer having a maximum weight limit of 250 pounds for safety purposes. Thus,

Table 1 Adult body mass index weight categories as defined by the World Health Organization and a scale adjusted for persons with spinal cord injury

WHO BMI Classification		SCI Adjusted BMI Classification	
Underweight	BMI < 18.5 kg/m ²	NA	NA
Normal (healthy weight)	18.5 ≤ BMI < 24.9 kg/m ²	Recommended BMI	BMI < 21.9 kg/m ²
Overweight	25 ≤ BMI < 29.9 kg/m ²	Overweight	22 ≤ BMI < 24.9 kg/m ²
Obese	BMI ≥ 30 kg/m ²	Obese	BMI ≥ 25 kg/m ²

Abbreviations and Definitions: WHO = World Health Organization, BMI = Body mass index (kg/m²). NA = not applicable because this category does not exist in the SCI Adjusted BMI Classification.

persons were excluded if their body weight was greater than this weight limit.

Participants

Participants with chronic paraplegia from SCI were recruited predominately from the outpatient center at Rancho Los Amigos National Rehabilitation Center.

Inclusion criteria were established for the parent study and are as follows: paraplegia from SCI (traumatic or non-traumatic), absence of shoulder pain with a total score of ≤ 12 on the Wheelchair User's Shoulder Pain Index (WUSPI), between 2 and 20 years post SCI, manual WC user (for $\geq 50\%$ of locomotion), and ≥ 18 years of age. Exclusion criteria consisted of the presence of rotator cuff tendinopathy, bicipital tendonitis, adhesive capsulitis, cervical radiculopathy, shoulder injury or surgery, or injuries impacting upper extremity function. Persons were excluded from the study if they had pain with isometric external rotation when the shoulder was positioned at neutral or had a positive result on any of the following shoulder pathology tests: Empty Can Test, Codman's Drop Arm Test, Speed's Test, and Hawkins-Kennedy Impingement Test. Persons were excluded if their body weight was greater than 250 pounds.

Of those screened, 102 were excluded for not meeting inclusion criteria, 80 due to the presence of shoulder pain or having shoulder pathology, 19 due to being more than 20 years post injury, and three for body weight greater than 250 pounds.

Prior to data collection, participants read and signed an informed consent that had been approved by the hospital's Institutional Review Board.

Procedures and equipment

BMI

BMI was calculated at the two evaluation time points using the formula of body mass (kg)/[height (m)]². Total weight was measured using a WC platform scale that the participant rolled onto in his/her WC (Arlyn Scales; New York, www.arlynscales.com). The participant then transferred out of his/her WC and the WC was weighed alone. Body weight was calculated by subtracting WC weight from the total weight. Height was self-reported at entry into the study. All measures were recorded by a research physical therapist. Both the WHO BMI classification and the SCI adjusted BMI classification were used to define the weight categories (Table 1).^{21,22} Because fluctuations in BMI over the three year time period were likely, an average BMI value was calculated using the baseline and three year time points to provide a representative value. Change in BMI over time was calculated by subtracting the BMI

at baseline from BMI at the three year time point. In addition, groups were developed to identify persons whose BMI remained stable over the three years, those whose BMI increased (gained weight) and those whose BMI decreased (lost weight). Groups were defined as a change in BMI greater than 5% of their baseline BMI.

Demographics and SCI lesion characteristics

Demographic information including gender, race/ethnicity and age were collected at entry into the study. SCI lesion characteristics such as duration of SCI, level of injury, and completeness of injury (as determined by the research physical therapist using the American Spinal Injury Association Impairment Scale, AIS)²³ were collected at entry into the study.

Community mobility and participation

Community mobility variables included average number of transfers and depression raises performed in the preceding 24 hours, and average daily WCP velocity and distance. Participants were contacted by phone once every one to two months and were asked to recall the number of transfers and number of depression raises performed in the last 24 hours. Community WC usage was measured using the Topeak® bicycle odometer system (Topeak Inc., Taichung, Taiwan). Each participant's manual WC was equipped with a sensor mounted onto the WC frame, two magnets mounted to each wheel (so the wheels could be interchanged), and an odometer computer to capture velocity and distance data. The odometer was calibrated according to the WC wheel circumference. Data were collected on all manual WCs used more than 4 hours per week. Those individuals who used an additional manual WC, such as for sports, had the second WC similarly equipped. Participants reported their odometer information during the once every one to two month phone calls.

Participation measures included vocational status (vocation defined as participation in paid work, volunteer work or student), and regular participation on a recreational sports team. This information was collected at entry into the study.

Statistical analysis

Data were analyzed using the SPSS 12.0 software (SPSS, Inc., Chicago, IL). The Shapiro Wilk statistical test for normality of distribution identified a non-normal distribution of the average BMI over three years, change in BMI, and BMI at baseline of 0.001, 0.001, and 0.000 respectively. Consequently nonparametric statistics were used for analyses. Significance was set at a P value of 0.05. When more than two groups were

compared, the P value was adjusted for multiple comparisons using the Bonferroni correction.

BMI prevalence

The median BMI was calculated using descriptive statistics. A One-Sample Wilcoxon Signed Rank Test was used to compare the baseline BMI of study participants to the mean BMI of the U.S. population of 28.7 kg/m².¹

Change in BMI over time

A nonparametric Sign Test was used to compare BMI over the two time points of baseline and three years.

Demographic and SCI lesion characteristics

A Mann-Whitney U Test was used to identify differences in average BMI over three years between men and women and between those with high and low levels of paraplegia (high level = T2-T7, low level = T8 and below). Differences in average BMI between race/ethnicity groups (Hispanic, African American, Caucasian and Asian) and between categories of SCI completeness (AIS groups A, B, C, D) were assessed using a Kruskal-Wallis Test. Spearman's Correlations were used to identify correlations between baseline BMI and age and between duration of SCI.

Community mobility and participation measures

Spearman's Correlations were calculated to identify correlations between the mobility measures (average number of daily transfers, depression raises, WCP daily velocity and distance) and average BMI over three years. A Mann-Whitney U Test was used to compare average BMI over three years between those who did and did not engage in a vocation (full/part time and no vocation) and sports on a regular basis (regular versus non-regular participation).

BMI change over time group analyses

Participants were grouped according to the magnitude of change in BMI over the three years, those whose BMI remained stable, increased, or decreased. A Kruskal-Wallis Test identified differences in change in BMI over time *between* groups, and a Sign Test was used to identify change in BMI for *within* group analyses.

Between group analysis for associations between BMI change group and gender, race/ethnicity, level and completeness of injury, and engagement in vocations and sports activities was completed using Spearman's Two-tailed Tests. Age, duration of SCI, daily number of transfers, depression raises, and velocity and distance of WCP were compared between BMI change groups with Kruskal-Wallis Tests.

Analysis of change in community mobility over time *within* individual BMI change groups was performed by comparing averaged community mobility variables from the initial six months and the final six months of participation within groups. Sign Tests identified changes in mobility between the first and last six months of participation in the study *within* each group. Mann-Whitney U Tests was used to compare average BMI over three years between those who did and did not engage in a vocation (full/part time and no vocation) and sports on a regular basis (regular versus non-regular participation) *within* each group.

Results

Participants

222 adults (198 men and 24 women) with chronic paraplegia from SCI and non-painful shoulders participated. BMI over time was calculated for 86% (190) of participants who returned for their three year evaluations. Of the 32 participants who did not return, 15 were lost to contact, 5 were deceased, 2 moved out of the country, 2 moved out of state, 1 was incarcerated, and 7 declined to return.

Prevalence of BMI

The median BMI over the three years was 24.2 (21.0, 28.4) kg/m², and median body weight was 73.8 (63.4, 85.3) kg. The baseline BMI for this study sample was significantly less compared to the U.S. population (U.S. population mean BMI = 28.7 kg/m²),¹ ($z = -9.4$, $P = 0.000$). The most prevalent BMI category for the U.S. population is obese (35.7%) as defined by the WHO BMI classification.²⁴ Similarly in this study, obese was the most common BMI category at baseline according to the SCI adjusted BMI classification (44%). In contrast, when using the WHO classification normal weight was the most common category at baseline (45%), (Figure 1).

Change in BMI over time

BMI increased over the three year study with a median change in BMI of 0.46 (-0.92 , 1.50) kg/m², and median change in weight of 1.4 (-2.7 , 4.7) kg, ($z = -2.684$, $P = 0.007$). According to the SCI adjusted BMI classification, 79% ($n = 150$) remained in the same weight category of either the recommended weight, overweight or obese. Of our study participants, 13% ($n = 24$) moved into a higher weight category, and 8% ($n = 16$) shifted to a lower weight category (Figure 2).

Demographic and SCI lesion characteristics

Average BMI over three years was not significantly different between men and women ($z = -1.191$, $P =$

Figure 1. Prevalence of research study subjects' BMI weight category according to the SCI Adjusted Classification and WHO classification, and the U.S. population's BMI (per WHO classification).

0.234). BMI was significantly greater for Hispanic individuals compared to African American participants ($z = -3.167$, $P = 0.002$). BMI at baseline was positively correlated with age ($r = 0.232$, $P = 0.000$), (Table 2).

There was no significant correlation between BMI at baseline and duration of SCI ($r = -0.062$, $P = 0.355$). Average BMI over three years was not significantly different between those with high paraplegia and low

Figure 2. Change in BMI weight category over time using the SCI Adjusted BMI Classification. 42.1% of persons remained obese, and 4.7% shifted into the obese category over three years.

Table 2 BMI over three years, demographic and SCI lesion characteristics, and mobility and participation measures

Total Sample			BMI Change Over Time Groups			
	N = 222	Statistical test	Stable N = 95 (50%)	Increased N = 61 (32%)	Decreased N = 34 (18%)	Between Group Statistical test
BMI over three years, kg/m², (N = 190)						
Median (IQ)	24.2 (21.0, 28.4)	$z = -2.684$ P = 0.007 * [±]	24.5 (21.8, 28.6)	26.3 (20.7, 28.9)	22.2 (20.3, 26.3)	P = 0.000 * [†]
Demographic and SCI Lesion Characteristics						
Gender, (N = 222)						
Male, n (%)	198 (89)	$z = -1.191$ P = 0.234 [†]	87 (51)	51 (30)	31 (18)	$r = 0.106$ P = 0.146 ^α
Female, n (%)	24 (11)		8 (38)	10 (48)	3 (14)	
Race/Ethnicity, (N = 213)						
Hispanic, n (%)	143 (67)	$z = -3.167$ P = 0.002 * [¥]	67 (54)	42 (34)	16 (13)	$r = 0.032$ P = 0.668 ^α
African American, n (%)	40 (19)		15 (42)	10 (28)	11 (31)	
Caucasian, n (%)	25 (12)		7 (39)	5 (28)	6 (33)	
Asian, n (%)	5 (2)		2 (67)	0 (0)	1 (33)	
Age baseline, (y), (N = 222)						
Median (IQ)	34.1 (27.3, 40.3)	$r = 0.232$ P = 0.000 ^α	33.9 (29.3, 40.6)	34.2 (26.7, 39.0)	37.6 (26.1, 43.2)	P = 0.398 [†]
Avg. duration of SCI (y), (N = 222)						
Median (IQ)	8.7 (3.2, 15.1)	$r = -0.062$ P = 0.355 ^α	10.0 (3.5, 15.5)	5.6 (2.8, 14.3)	5.9 (2.7, 13.4)	P = 0.205 [†]
Level of Injury, (N = 222)						
High paraplegia, n (%)	94 (42)	$z = -1.150$ P = 0.250 [†]	39 (49)	30 (38)	11 (14)	$r = -0.057$ P = 0.432 ^α
Low paraplegia, n (%)	128 (58)		56 (51)	31 (28)	23 (21)	
AIS category,(N = 189)						
A, n (%)	135 (71)	P = 0.555 [†]	64 (51)	39 (31)	23 (18)	$r = 0.022$ P = 0.770 ^α
B, n (%)	15 (8)		5 (33)	6 (40)	4 (27)	
C, n (%)	33 (17)		17 (53)	10 (31)	5 (16)	
D, n (%)	6 (3)		3 (50)	2 (33)	1 (17)	
Mobility Measures						
Avg. # Transfers/day, (N = 217)						
Median (IQ)	12.1 (8.1, 17.2)	$r = -0.123$ P = 0.071 ^α	11.7 (8.1, 18.6)	12.4 (8.7, 15.6)	12.3 (7.8, 18.6)	P = 0.946 [†]
Avg. # Raises/day, (N = 217)						
Median (IQ)	8.6 (4.0, 14.8)	$r = 0.007$ P = 0.924 ^α	8.0 (4.5, 12.8)	8.8 (3.9, 16.1)	10.7 (5.5, 18.6)	P = 0.363 [†]
Avg. Distance propelled/day, (km), (N = 210)						
Median (IQ)	2.1 (1.4, 3.0)	$r = -0.179$ P = 0.009 * ^α	2.3 (1.4, 3.1)	2.0 (1.4, 2.9)	2.0 (1.3, 3.0)	P = 0.529 [†]
Avg. Velocity/day, (km/hr), (N = 210)						
Median (IQ)	2.4 (1.9, 3.0)	$r = -0.046$ P = 0.511 ^α	2.4 (1.9, 3.0)	2.3 (1.8, 3.0)	2.4 (1.8, 3.5)	P = 0.861 [†]
Participation Measures						
Vocation (work, student, volunteer), (N = 217)						
Yes, n (%)	91 (42)	$z = -0.767$ P = 0.443 [†]	56 (51)	34 (31)	20 (18)	$r = -0.030$ P = 0.688 ^α
No, n (%)	126 (58)		36 (48)	25 (33)	14 (19)	
Sports, (N = 222)						
Yes, n (%)	50 (23)	$z = -0.465$ P = 0.642 [†]	22 (54)	15 (37)	4 (.10)	$r = -0.002$ P = 0.974 ^α
No, n (%)	172 (77)		73 (49)	46 (31)	30 (20)	

BMI Change Over Time Groups are defined as a change in BMI greater than 5% of their baseline BMI over three years. The statistical tests for the Total Sample were calculated using the average BMI over three years with the exceptions of using baseline BMI for the correlation between age at baseline and average duration of SCI.

Abbreviations and Definitions: BMI = Body mass index (kg/m²), AIS = American Spinal Injury Association (ASIA) Impairment Scale, High paraplegia is T2-T7, Low paraplegia is T8 and below, SD = standard deviation, IQ = interquartile range.

* with value in bold shows statistical significance > .05, [†] shows Man-Whitney test, ^α shows Spearman's Two-tailed test, [†] shows Kruskal-Wallis test, [±] shows Sign test, [¥] shows Bonferroni Correction.

Figure 3. The scatter plot shows the relationship between the BMI over three years relative to distance propelled per day. A trendline is shown indicating an inverse relationship between BMI and distance propelled. A lower BMI indicates a greater distance propelled and a greater BMI indicates a shorter distance propelled ($r = -0.179$, $P = 0.009$).

paraplegia ($z = -1.150$, $P = 0.250$), or between those with AIS scores of A, B, C or D ($P = 0.555$).

Community mobility and participation

Average BMI over three years was inversely correlated with distance propelled per day, ($r = -0.179$, $P = 0.009$), (Figure 3). Correlations between average BMI over three years and number of transfers or depression raises performed per day and average velocity of WCP were not statistically significant ($r = -0.123$, $P = 0.071$, $r = 0.007$, $P = 0.924$, and $r = -0.046$, $P = 0.511$ respectively). There were no significant differences in average BMI over three years between those who did and did not participate in a vocation ($z = -0.767$, $P = 0.443$) or sports on a regular basis ($z = -0.465$, $P = 0.642$).

BMI change over time groups (greater than 5%)

The majority of the participants maintained their weight within 5% of their baseline BMI over three years, 50% ($n = 95$), with a median BMI of 24.5 (21.8, 28.6) kg/m^2 . Weight gain of greater than 5% of baseline BMI was identified in 32% ($n = 61$) of participants, with a median BMI of 26.3 (20.7, 28.9) kg/m^2 . Weight loss greater than 5% of baseline BMI was identified in 18% ($n = 34$) of participants, with a median BMI of 22.2 (20.3, 26.3) kg/m^2 (Table 2).

Comparisons between BMI change over time groups

None of the demographic, SCI lesion characteristics, or community mobility and participation measures was significantly different between BMI change over time groups (Table 2).

Analyses within BMI change over time groups

Stable BMI over three years

No statistically significant differences were found between from the first to the last six months of participation in the study for daily number of transfers or depression raises ($z = -1.756$, $P = 0.079$ and $z = -1.901$, $P = 0.057$ respectively), or average daily velocity or distance of WCP ($z = -1.032$, $P = 0.302$ and $z = -0.574$, $P = 0.566$ respectively). Average BMI over three years was significantly lower in participants who engaged in a vocation compared to those who did not ($z = -2.040$, $P = 0.041$). In contrast, average BMI was not different between those who did and did not participate in sports on a regular basis ($z = -1.614$, $P = 0.106$).

Increased BMI over three years

There were no differences from the first to the last six months of the study in number of transfers or depression raises per day ($z = -1.374$, $P = 0.170$ and $z = -0.549$, $P = 0.583$ respectively). Velocity of daily WCP decreased from the first to the last six months of the study ($z = -2.626$, $P = 0.009$), but daily distance of WCP was unchanged over time ($z = -1.714$, $P = 0.086$), (Figure 4). Average BMI over three years was greater in persons who did not engage in a vocation ($z = -2.485$, $P = 0.013$) or sport activity ($z = -1.960$, $P = 0.050$) compared to those who did.

Decreased BMI over three years

There were no statistically significant differences from the first to the last six months in number of transfers or depression raises per day ($z = -1.701$, $P = 0.089$

Figure 4. The scatter plot shows the relationship between the average BMI over three years for the group of those who demonstrated an increase in BMI greater than 5% of their baseline BMI relative to velocity propelled. A trendline is shown indicating an inverse relationship between BMI and velocity. A lower BMI indicates a faster velocity and a greater BMI indicates a slower velocity ($z = -2.626$, $P = 0.009$).

and $z = -0.189$, $P = 0.850$ respectively), or in average daily velocity or distance of WCP ($P = 0.424$ and $P = 1.000$). Moreover, there were no significant differences in average BMI over three years between those who did and did not participate in a vocation ($z = -1.365$, $P = 0.172$), or sports on a regular basis ($z = -0.748$, $P = 0.454$).

Discussion

This study measured BMI and community mobility of persons with chronic SCI over a three year time period. The prevalence of persons who were overweight and obese was presented using both the WHO BMI classification and SCI adjusted BMI classification.^{21,22} We used the WHO BMI classification to enable comparison of our results to other relevant research findings. The SCI adjusted BMI classification corrects for the underestimation of percentage body fat following the body mass changes that occur following SCI and is believed to be a more accurate measure of identifying those at risk for health problems.^{4,5,7,9,20,22,25} This study demonstrated a shift in the distribution of obesity dependent on the BMI classification used. The WHO BMI classification identified 44% of our population as overweight or obese at baseline, whereas the SCI adjusted BMI classification identified that 67% were in those categories. Potentially 23% of our population may be at risk for health, mobility or function problems, but would not have been identified by the WHO BMI classification for educational or medical intervention.

We compared the BMI distribution of persons with chronic SCI in this study population to U.S. population data from 2009–2012 (Figure 1).²⁴ We expected our study sample of 222 persons with chronic SCI to have BMIs that were greater than the distribution of BMI in the U.S. population due to their higher percentage of fat mass,²⁰ predisposition for weight gain and limited physical activity.²⁶ Baseline median BMI of our study sample was significantly lower compared to the U.S. population¹ however the prevalence of obesity according to the SCI adjusted BMI classification was slightly greater in our study sample compared to the U.S. population, 44.1% and 35.7% respectively. The WHO BMI classification presents a different picture, with merely 13.5% of our study participants in the obese category. In our study sample, the SCI adjusted BMI classification more closely matched the U.S. population data in identifying the distribution of body weight into normal/recommended, overweight, and obese categories compared with the WHO BMI classification.

Our study is unique in that it measured body weight over time for persons with a chronic SCI. Previous research documented increases in weight over time from onset of SCI up to a mean of five years post SCI.^{3–6} Three distinct trajectories of changes in BMI were identified for persons with SCI during and up to five years after rehabilitation: (1) a favorable stable BMI during and after rehabilitation (54%); (2) a higher but stable BMI during inpatient rehabilitation and an increase after discharge (38%); and (3) an increase in BMI during inpatient rehabilitation and

leveling off after discharge (8%).²⁷ Based on previous research involving acute SCI, we expected that persons with chronic SCI would show an increase in BMI over the three year longitudinal study. Our study found that the BMI of persons having a SCI greater than two years and with a median duration of SCI of 8.7 years did increase over a three year period. The median change in BMI was 0.46 kg/m², and median change in weight was 1.4 kg. The rate of change in BMI was 0.15 kg/m²/yr or 0.47 kg/yr. The yearly increase may not appear clinically meaningful, yet given a longer period of time this steady gain would result in an increase in weight over five years of 2.33 kg or slightly more than 5 pounds. In this study, 32% of our participants increased more than 5% of their baseline BMI, and 5% of our participants had an increase in BMI large enough to shift them into the obese category (SCI adjusted BMI classification). This is clinically significant because obesity is a determinant of clustering for cardiovascular risk factors.¹⁵ In contrast, 18% of our participants demonstrated a decrease in BMI greater than 5% of their baseline BMI which is also clinically meaningful because of the health and cardiovascular benefits associated with a modest weight loss of as low as 5%.^{13–15, 28}

One purpose for identifying groups of persons whose BMI remained stable, increased or decreased over three years was to identify unique demographic and SCI lesion characteristics that could aid in targeting interventions for health and mobility concerns. Unfortunately, this study did not identify any differences in demographic or SCI lesion characteristics *between* the groups. As well, gender, duration of SCI, level of injury, and completeness of injury for the total sample were not related to BMI. Only age and race/ethnicity for the total sample was related to BMI. Our results are consistent with previous findings in that age was the only demographic or lesion characteristic related to BMI.^{5,6} Our results showed that BMI for the total sample increased with age for persons with a chronic SCI. Weight management becomes increasingly challenging as one ages with and without a disability. The U.S. National Survey states that overall, adults greater than 60 years of age were more likely than younger adults to be obese.² Individuals with SCI live for an average of more than 40 years after injury. In addition, persons with SCI appear to experience premature and accelerated adverse body composition changes similar to those seen with aging, (slowing metabolism, weight gain, less lean body mass and greater adiposity).²⁰ Our results showed that along with age, those who were Hispanic (83%) had a greater BMI followed by those

who were African American (13%). However, a health report by the CDC identified that between the years 2009–2012 the greatest prevalence of adult obesity in the United States was found in those who were African American (male = 39%, female = 58%), followed by those who were Hispanic (male = 41%, female = 48%).²⁴ In designing weight management intervention guidelines, it is important to take into account the effects of aging, the special considerations of aging with a disability, and the influences of culture and race/ethnicity.

This study adds to the body of knowledge regarding body weight and its impact on community mobility. A retrospective study of 1524 inpatients with new traumatic SCI reported that obesity presents a barrier to meeting mobility and self-care functional goals.¹⁶ Those patients with complete paraplegia and obesity had significantly lower FIM mobility and self-care score gains compared to those with complete paraplegia and a normal weight. We hypothesized that body weight would have an effect on community mobility. We expected daily frequency of transfers to decrease with an increase in BMI because transfers require lifting body weight on the arms and would be more difficult for those who are overweight or obese.^{6,18} However, the median number of transfers (12 per day), and depression raises (9 per day) were not significantly correlated to BMI. In addition, number of transfers and depression raises performed per day did not change from the first to the last six months of the study *between* or *within* the groups of those whose BMI was stable, increased or decreased over three years. We also expected to find a decrease in average WCP velocity with heavier persons pushing slower, but there was no correlation between BMI and propulsion speed for the total sample or for the *between* groups comparison. Only *within* the group that increased in weight by at least 5% did we find that velocity slowed when participants became heavier (last six months of participation in the study). We found that for the total sample, obesity did have a significant negative impact on average daily distance propelled in a manual WC, an important aspect of community mobility. WCP is a physically demanding activity and persons with a greater BMI did not push as far as those with lower BMIs. Persons with obesity (as defined by the SCI adjusted BMI classification) pushed 19% less than those who were not obese, or 0.30 mile less per day. Community participation for the total sample as measured by vocational status or participation on a sports team was not affected by body weight. *Within* the group of those who increased more than 5% of

baseline BMI, those who did not participate in vocation or sports team had greater BMIs than those who did. To summarize, persons who are obese complete the same average number of transfers and depression raises as persons categorized as having a normal/recommended weight or overweight. Average velocity decreased *within* the group who increased weight (more than 5%), in that as participants gained weight they propelled more slowly. Average distance propelled per day decreased as average BMI over the three years increased for the total sample.

An unintended side effect of performing equal amounts of community mobility and participation activities by persons who are obese is overloading the shoulder joint and thereby increasing the risk for shoulder injury and pain. The prevalence of shoulder pain in those with SCI is between 36% to 71%.^{29–33} Because obese persons with SCI place greater loads on their arms and shoulders than their counterparts with lower body weight, consideration should be given to optimizing both transfer and WCP technique to minimize risk of shoulder injury. For example, a person who is overweight or obese should consider using a sliding board during transfers to minimize upper extremity load and risk for shoulder injury. Additionally, consideration should be given to performing a strength training program focusing on the shoulder musculature to support the excess loads placed on the upper extremities and reduce the risk for injury and pain.³⁴

Limitations

Obesity is difficult to measure in the SCI population. BMI is a guiding tool and it is important to take into account both its advantages and limitations. An advantage is that BMI is easy to calculate and does not require specialized equipment. Among the disadvantages is that error is introduced when the persons' body frame and composition is not average. Furthermore, error is introduced by using self-reported height because recalled height and measured height have been found to disagree.⁴ Measurement of waist circumference is gaining support as a better measure of visceral adipose tissue and better predictor of coronary heart disease risk for persons with SCI.^{3,4,9}

Objective assessment tools of physical activity, such as an odometer, are more precise and accurate than subjective self-report.³⁵ This study used an odometer to measure distance travelled per day, and self-report to collect the number of transfers and depression raises performed in the previous 24 hours. These two self-reported community mobility measures are a limitation to the study because of a tendency for under or over

reporting self-reported physical activity.³⁶ However, vigorous activities tend to be more reliably reported than lower intensity daily activities often done in several short bouts within a day.³⁷ While transfers and depression raises are not vigorous, they are deliberate actions and "events". This study attempted to minimize the limitation of using self-reported data by averaging the number of transfers and depression raises over three years from multiple self-reports collected every one to two months, choosing a deliberate action to recall, and limiting the recall time to the previous 24 hours.

Community participation was measured at entry into the study by self-reported participation in a vocation or a sports team on a regular basis. However community participation was not reassessed. Both participation in a vocation (employed work, volunteer work or student) and participation on a sports team are not static and the absence of reporting change in participation status is a limitation to the study. That said, in this study of persons with a median time since injury of 8.7 (3.2, 15.1) years, 59% reported participation in a vocation and of these 21% were employed. This rate of employment is just below the prevalence reported in the National SCI Database in which 28% of persons with SCI are employed by year ten.³⁸ This suggests that while community participation is not static, the prevalence of employment documented in the current study is similar to the national average.

There were no significant differences in either average BMI over three years or baseline BMI (not reported) between those who did and did not participate in a vocation or a sports team. There were no significant differences between BMI change over time groups and the participation measures using average BMI and baseline BMI (not reported). We used average BMI versus baseline BMI for the within group analyses because it characterizes their weight more accurately over the three years.

Data from this study were a subset of a parent longitudinal study investigating predictors of shoulder pain. Because of this, 80 persons were excluded because of having shoulder pain or shoulder pathology. Due to the high prevalence of shoulder pain, limiting participation to only those without shoulder pain likely introduced a sampling bias and limits the generalizability of the results. The parent study measured upper extremity biomechanics during WCP on a WC ergometer that had a maximum weight limit of 250 pounds. Because of this limitation we excluded three persons weighing over 250 pounds. Consequently, our measured prevalence of persons who are obese may be slightly reduced.

Conclusions

Obesity is a modifiable risk factor for health and mobility problems. Correctly identifying persons who are overweight or obese allows for directed and timely educational and medical intervention. The SCI adjusted BMI classification demonstrated that the majority of our study sample with chronic SCI was obese (44%). Body weight increased over a three year time period at a rate of 0.47 kg/yr. According to the SCI adjusted BMI classification, 13% of our participants moved into a higher weight category over the three years while only 8% shifted to a lower weight category. Of those who gained weight, 5% moved into the obese weight category.

There were no differences in demographic or SCI lesion characteristics *between* the groups of those whose BMI changed more than 5% of their baseline making it difficult to target interventions. Overall, we found that those who were older were heavier.

We found that those who were heavier did not push their wheelchairs as far in the home and community. However other mobility and participation measures for the total sample were not significantly related to body weight in that persons who are obese complete the same average number of transfers and depression raises, and propel at the same average velocity as persons categorized as having a normal/recommended weight or overweight. Only the group that gained weight (more than 5% of baseline) over three years demonstrated a decrease in velocity with the increase in weight. Continued high levels of upper extremity weight bearing mobility activities, especially with increased body weight, can increase the risk for shoulder injury and pain.

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