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REVIEW ARTICLE
Clinical Assessment and Management of Obesity in Individuals With Spinal Cord Injury: A Review

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Received September 24, 2007; accepted March 10, 2008

Abstract

Background: Diagnosing and managing obesity in individuals with spinal cord injury (SCI) remain challenging.

Methods: Literature on the epidemiology, impact, and management of obesity in individuals with SCI was reviewed.

Findings: Although nearly 66% of individuals with SCI are either overweight or obese, little guidance is available to measure and monitor obesity in the clinical setting. The use of anthropometric indices and specific cut points available for able-bodied persons is limited by the body composition changes that follow SCI. Indices of upper body obesity warrant examination in SCI because they provide an index of central obesity, which is more closely linked to some obesity-related conditions than is overall obesity. Investigations into the sequelae of excess body fat and its distribution are also needed in SCI because past research in this area has been inconclusive. Although limited, evidence regarding obesity interventions in SCI may be promising.

Conclusions: The best anthropometric tool to define obesity in the clinical setting remains unknown. SCI-specific assessment tools and a better understanding of the sequelae of excess body weight will lead to better targeting of prevention and treatment efforts. More research is needed on the individual components of a weight management program unique to SCI. Until then, providers are urged to use a team approach and draw on existing resources and applicable research in able-bodied individuals to facilitate weight management in individuals with SCI.

J Spinal Cord Med. 2008;31:361–372

Key Words: Spinal cord injuries; Obesity; Weight control; Body composition; Paraplegia; Tetraplegia; Actigraphy; Bariatric surgery; Orlistat; Sibutramine

INTRODUCTION

Obesity (defined as an excess accumulation of body fat) is a complex multifactorial condition that has reached epidemic proportions (1–5). In epidemiological studies, obesity is usually defined using body mass index (BMI), a surrogate measure for body fat selected due to its high correlation ($r = 0.7–0.9$) with fat mass (1). Body mass index is estimated by dividing an individual's weight (in kg) by his or her height (in m^2) (1). Individuals with BMI values from 25 kg/m^2 to 29.9 kg/m^2 are considered overweight, and those with BMI values of 30 kg/m^2 or higher are categorized as obese. According to National Health and Nutrition Examination Survey data, the rates of overweight and obesity have continued to increase in the US since the late 1970s (2–4). During 1976 to 1980, 46% of US adults were overweight or obese. In 2003–04, nearly 66% of adults were considered either overweight or obese, which reflects an absolute prevalence increase of 20% in just the last 25 years (3).

Accumulation of excess body fat is associated with a wide range of diseases and metabolic abnormalities that affect many organ systems in the body (6). The adverse health consequences of obesity can be attributed to either the increased mass of fat or the increased release of pathogenic products from enlarged fat cells (6). A progressive increase in the prevalence of obesity-related comorbidities has been observed with increasing severity of overweight and obesity in the general population (7). It is well known that obesity is associated with increased risk of conditions, such as cardiovascular disease (CVD), hypertension, type 2 diabetes mellitus, dyslipidemia (decreased high-density lipoprotein cholesterol, high

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triglycerides, and increased small, low-density lipoprotein cholesterol), certain forms of cancers, sleep apnea, osteoarthritis, gallstones, and higher risk of mortality (6–12). The disproportionate accumulation of body fat on the torso (measured by waist-hip ratio, waist circumference [WaC], or truncal skinfold thickness) is referred to as a central obesity pattern. Central obesity is a stronger risk factor for metabolic complications, such as dyslipidemia, hypertension, glucose intolerance, and hyperinsulinemia, than measures of overall body fatness, such as BMI (13–15). Body fat is located both under the skin (subcutaneous fat) and inside the abdomen (intra-abdominal or visceral fat) (16). Visceral fat appears to have more adverse metabolic effects than subcutaneous fat, which seems to explain why the central obesity pattern is more strongly associated with metabolic disorders than obesity in general (16). In addition to medical conditions, obesity has been shown to have profound negative effects on quality of life, self-esteem, body image, and satisfaction with life (17–20).

OBESITY IN SCI

The obesity epidemic affects nearly every subgroup of the population, including individuals with disabling health conditions. Results from the National Health Interview Survey showed that obesity was more prevalent among individuals with disabilities than among the general population (21). Individuals with SCI live with their disabling conditions for an average of more than 40 years after injury; therefore, they are prone to the same chronic conditions that affect able-bodied individuals with advancing age (22). The changes in body composition that follow SCI (reduction in muscle and bone mass), resultant changes in metabolic rate, and mobility limitation may contribute to the development of weight gain. Although there are scant data on the rate of weight gain, available data come from one study of 13 overweight and obese individuals with SCI participating in a weight-loss intervention program, who gained weight at the rate of 2.0 kg/year after injury (23).

Prevalence estimates of overweight and obesity in SCI vary among studies (40–66%) and are similar in magnitude to able-bodied individuals (24–28). A retrospective chart review showed that nearly 66% of veterans with SCI were either overweight or obese and 30% fell in the obese category (24). Similarly, in a sample of urban community dwelling men with paraplegia, nearly 57% fell in the overweight category and 20% in the obese category (25). The largest study to date (N = 7,959), which used information obtained from Veterans Affairs (VA) databases, reported that nearly 33% of veterans with SCI are overweight and an additional 20% are obese (28). When the cutpoints were lowered to account for lower muscle and bone mass in SCI, the prevalence of overweight (23–27 kg/m^2) was 37% and the prevalence of obesity ($\geq$28 kg/m^2) was 31%. These "best" estimates, based on BMI, may be underestimates of the true prevalence rates. The use of BMI-based obesity definitions developed for able-bodied individuals does not account for the lower muscle and bone mass and higher percentage body fat that accompanies SCI (29). Furthermore, BMI is based on measured heights and weights, and using a combination of self-reported and measured heights and weights, as was done in these studies, may result in misclassification and underestimation of the true prevalence of obesity (30,31).

In a study of 7,959 veterans with SCI (98% male) aged 50 to 64 years treated at a VA medical center (VAMC) during fiscal year 2001, obesity was more common in those with paraplegia than with tetraplegia (28). In the same study, whites were at a higher risk for being overweight than were African Americans. In a separate study of 387 veterans (98% male) with SCI from a single VA facility, prevalence of overweight and obesity was lower in those less than 39 years of age compared with individuals aged 40 years or more; however, there were only 33 study subjects in the younger age group (24). Additionally, there was a suggestion of a trend toward increasing obesity prevalence from ASIA class A to C in individuals with paraplegia. The trend across ASIA class was, however, not as clear in individuals with tetraplegia. Although data on average BMI across duration of injury categories were presented in this paper, statistical comparisons were not performed (24).

One of the most striking findings from epidemiological data was a higher prevalence of obesity in individuals with paraplegia compared with those with tetraplegia (24,28). Although the reasons for this observation are not fully understood, one possible explanation for this, as pointed out by Gupta and others, is that individuals with paraplegia can more readily feed themselves and, thus, may eat more than individuals with tetraplegia, who may only be able to eat with the assistance of a caregiver (24). Another possible explanation for these results is that BMI measures total body weight (which includes lean mass and fat mass) adjusted for height. Lean body tissues (muscle and bone) have higher density (greater weight per volume) than fat tissue. It is possible that individuals with paraplegia may have a higher percent lean mass than individuals with tetraplegia have. Thus, BMI may underestimate obesity (defined as percent body fat) to a greater extent in individuals with tetraplegia than in paraplegia. It also remains unclear whether these results may be generalized to nonveterans. Further study using better measurements of body fat is needed to clarify risk factors for obesity in the SCI population.

Medical Consequences

The increasing prevalence of obesity, which results in negative health effects and can exacerbate existing health conditions (32), is of particular concern in a vulnerable population, such as those with SCI, in which individuals already present with multiple comorbidities. Case study reports suggest that compared with other individuals with similar levels of injury, obese individuals with SCI have more difficulties with transfers, have poorer functional outcomes, and require special equipment and additional staff time for transfers and personal care (33). Obesity in SCI has also been implicated in carpel tunnel syndrome, pulmonary embolism, and obstructive sleep apnea (34–39). In people with SCI, obesity is commonly cited as one of the major risk factors for the higher prevalence of CVD in this population (40). Studies in SCI have shown relationships between total and/or regional measures of adiposity and CVD risk factors, such as abnormalities in carbohydrate metabolism and serum lipid levels and hypertension (41–47). For example, BMI or upper body obesity is positively correlated with serum triglycerides, insulin, glucose, and C-reactive protein levels (41–47). Recently, using a combination of self-reported and measured heights and weights to determine BMI and a blood pressure level of $<$120/80 mmHg as the reference, Weaver and colleagues showed that borderline and high blood pressure levels were positively related to being overweight or obese in veterans with SCI (28). However, data on smoking, a variable related to both BMI and blood pressure, were lacking in this study. Findings from these studies on obesity and health outcomes must be interpreted cautiously, keeping in mind that cross-sectional associations do not prove causality.

Data on the health effects of obesity have not yielded consistent results in individuals with SCI. For example, the link between obesity and CVD risk factors and sleep apnea has been variable (48–51). Akin to the general population, obesity may be a leading risk factor for sleep apnea in individuals with paraplegia, but it may not be strongest or the most common risk factor in individuals with tetraplegia (38). Because obesity predisposes individuals to sleep apnea by excessive fat deposition in the upper pharyngeal area, Burns and colleagues suggest that total body fat may be a better marker of sleep apnea in individuals with SCI (38). In the case of CVD risk factors and obesity, Buchholz and colleagues in a comprehensive review on this topic suggest that measurement error and insensitivity of body weight and BMI to measure actual fat mass and fat distribution in people with SCI may account for inconsistencies in this relationship (49).

Despite overweight and obesity prevalence rates of nearly 66% in individuals with SCI, the clinical complications and health effects of overall obesity and body fat distribution have not been well examined in this population. Both the magnitude and direction of the impact of excess body weight on specific comorbid conditions need investigation in SCI. Studies have primarily examined the impact of obesity on CVD risk factors and laboratory values (eg, plasma insulin, glucose, C-reactive protein levels). In addition to these intermediate outcomes, the influence of obesity on hard health outcomes, such as diagnosed diabetes, CVD, and mortality across all BMI weight categories, needs to be examined. Individuals with SCI have many health problems directly related to their SCI that may be affected by obesity. Also, the impact of weight on function and views about quality of life in individuals with SCI has received limited attention (52). The relationship between obesity and health implications needs to be examined in prospective studies with adequate power and a well-represented sample of individuals with SCI. Studies should take into account potential confounding factors, such as age, race, gender, smoking status, and SCI characteristics.

Successful management of overweight or obesity involves both accurate assessment and effective treatment (1). Assessment involves determining the degree of overweight or obesity and associated disease risks. Management involves weight-loss interventions. Therefore, the primary goal of this review is to provide an update of field assessment techniques and limitations in SCI. A secondary goal of this review is to provide an overview of the available literature on the treatment of obesity in SCI.

ASSESSMENT

A number of studies have examined body composition in individuals with SCI using laboratory and field techniques. Keeping in alignment with the focus of this review, in this section we review the common measures used to measure body composition in clinical settings. A review of the various laboratory techniques for measuring obesity in individuals with SCI and its strengths and limitations are beyond the scope of this review. Readers are referred to a comprehensive review recently published on this topic (53).

Body Mass Index

Studies have shown that SCI is followed by changes in both regional and total body lean and fat mass (54–59). Overall, these studies suggest that compared with control subjects, individuals with SCI have lower lean tissue mass and higher fat mass. Considering that a reduction in muscle mass is expected to lower metabolic rate and that injury to the spinal cord limits physical activity, it is not surprising that individuals with SCI accumulate body fat.

Body mass index is frequently used to define obesity in the clinical setting and, for research purposes, in individuals with SCI. Spungen and colleagues (55) showed that the correlation between BMI and percent fat mass was 0.81 in able-bodied men and 0.6 in men with SCI. For any given BMI, individuals with SCI on average had 13% higher percent fat as measured by dual-energy X-ray absorptiometry compared with non-SCI controls. Studies in individuals with SCI have cited the limitations of using National Heart Lung and Blood Institute cutpoints for BMI and the need for SCI-specific cutpoints to define overweight and obesity in this population (29). Using receiver operating characteristics curve methodology, Buchholz and colleagues suggested lowering the National Heart Lung and Blood Institute cutpoints for obesity from 30 to 25 kg/m^2 in subjects with SCI. This would provide a sensitivity of 60% and specificity of 100% for detecting obesity defined as excess body fat measured by deuterium dilution, as was used in this study (29). However, this study included only 31 individuals with paraplegia. The applicability of these cutoff values to all persons with SCI is unknown. The relationship between body fat and BMI warrants additional investigation in a representative sample of individuals with SCI.

Lack of accurate and reliable measurement of height has been suggested as another possible reason for the underestimation of obesity using BMI in individuals with SCI (49). Although weight is typically obtained using a wheelchair scale, assessing stature in individuals with SCI is complicated by their inability to stand, postural deformities, and contractures. To calculate BMI, SCI researchers have relied on height that was ascertained from self-reports, values recorded in hospital charts, or height measured in the supine position (28,29,55,57,58). Theoretically, height could be measured in the lying position, but the accuracy of such measures is suspect because it is impossible for many patients with SCI to lay flat because of joint contractures, scoliosis, spine deformities, and contractures. Furthermore, it takes additional clinical resources to get patients into a supine position in the clinic, including an adjustable height table, an appropriate measurement tool, lifting equipment, additional staff to lift the patient, and a considerable amount of time. Finally, use of recalled adult height prior to SCI is problematic because unreliability in self-reported height and subsequent misclassification has also been shown to occur in specific population groups, such as men, older adults, individuals with disabilities, and those who are short (60–64). Although height obtained from self-reports has the appeal of simplicity and practicality, failure to measure height and weight in clinical settings can result in misclassification of overweight status (63).

An alternative to measured height is the use of proxy measures of height, such as knee height, arm length, and lower leg length. These segmental lengths have been used as alternative measures of stature in the elderly, individuals with disabilities, and children with cerebral palsy (65–68). These measures are also used by forensic pathologists and anthropologists to estimate height from skeletal remains (69,70). The aging process does not affect the long bones in the leg and arm (71), whereas aging does affect the length of the spine due to dessication of the vertebral disks. With the exception of one study that examined arm span measurements (72), there are no published data on the use of surrogate measures to predict stature in individuals with SCI.

Although BMI has replaced ideal body weight (IBW), an older clinical tool for obesity screening and treatment, IBW standards provided in the Metropolitan Life Insurance table are still used in many clinical settings for individuals with SCI. A few papers in the SCI literature recommend lowering the recommended guidelines in the Metropolitan Life Insurance IBW by 10 to 15 lb for a given height and frame size for individuals with paraplegia and lowering the IBW by 15 to 20 lb for individuals with tetraplegia (73,74). It appears that this recommendation is empirically derived based on the weight management experiences with patients with SCI at the East Orange VAMC (73). The use of the Metropolitan Life Insurance tables has limitations in that they are height based and have the same inherent problems as BMI. Furthermore, these tables were derived to predict mortality and not morbidity (30).

Other Anthropometric Measures

An increase in central fat (trunk region) has been shown in persons with SCI compared with able-bodied controls (57). Waist circumference, a measure of central adiposity and a surrogate measure of visceral fat, has been specifically measured in 5 different studies in individuals with SCI (23,25,46,75,76). In 3 of these studies, WaC was measured in the supine position and in the seated position in one study (23,25,46,75). Nearly 35% of the study participants in one study had a WaC greater than 102 cm (National Heart Lung and Blood Institute cutoff for central obesity in males) (25). The appropriateness of using WaC cutpoints established for the general population in patients with SCI is not known. To our knowledge, the accuracy of the supine or seated WaC measurements to predict visceral fat has not been validated against reference imaging techniques in individuals with SCI. This is an important deficit because decreased abdominal muscle tone in individuals with SCI and modifications for measurement techniques may affect the strength of the association between WaC and body fat in individuals with SCI. In a recent review, Buchholz and colleagues outlined several potential problems health professionals could encounter when measuring WaC in SCI (49). However, none of the studies in individuals with SCI has systematically evaluated these potential problems. Waist circumference has the potential to be a very useful tool for determining obesity in individuals with SCI because it is relatively simple to obtain, can be monitored over time, and does not require estimation of height. However, routine use of WaC in individuals with SCI has not been well studied and requires validation of a standardized measuring protocol. Neck circumference and sagittal abdominal diameter are 2 additional measures that have been shown to be useful for measuring upper body obesity in the general population (77,78) but have not been evaluated in individuals with SCI. Anthropometric indices of obesity, such as WaC, sagittal abdominal diameter, and neck circumference, warrant further examination in the SCI population because they provide an index of central obesity, which is more closely linked to some obesity-related conditions, such as metabolic syndrome, than is overall obesity.

Despite the inherent problems associated with using BMI in specific populations, federal agencies have continued to recommend its use alone or in combination with WaC for assessing and treating overweight and obesity in adults (79). Body mass index continues to be a simple, convenient, and inexpensive way for health care providers to assess body fat and guide obesity treatment in the clinical setting (79). Body mass index is correlated with body fat, morbidity, and mortality and is the favored measure to estimate disease relative risk (1). There is an urgent need to develop SCI-specific cutpoints for BMI to guide the assessment and management of obesity in individuals with SCI. The best anthropometric tool to measure abdominal and upper body fat and the efficacy of these indices to predict disease risk and health effects in individuals with SCI remain unknown.

MANAGEMENT

Treatment

Managing obesity in individuals with SCI is important, yet evidence-based information on management of obesity is lacking. The primary focus of the remainder of this review is to synthesize the current state of evidence in the area of obesity management.

National Institutes of Health guidelines recommend using lowered caloric intake and increased physical activity in conjunction with behavior modification support for obesity management (1). Able-bodied individuals who have been successful in losing and maintaining a 13.6-kg (30-lb) weight loss for 1 year have reported eating a diet low in fat and high in carbohydrates, engaging in high levels of physical activity (close to 1 hour per day), regularly self-monitoring body weight and food intake, eating breakfast regularly, and maintaining the same eating patterns 7 days per week (80,81). These strategies may also be directly applicable to individuals with SCI. Interventions designed to reduce fat in the diet and modify the proportions of various types of fat in the diet could be one potential area of intervention. Analysis of the macronutrient composition of the diet has shown that individuals with SCI typically consume a diet that provides more than 30% of their total daily energy intake from fat (25,82,83). Although there is no consensus on the optimal macronutrient composition of the diet for weight loss or the role of dietary fat in the development of obesity (84,85), consumption of a diet low in fat can help with weight loss because it can be part of a lower caloric density diet, which encourages the consumption of high fiber foods that foster satiety and are compatible with diets advised for overall health (86–88). In the only published weight loss intervention study, caloric-restricted diets of 1,400 calories for men and 1,200 calories for women were used, but information on the macronutrient composition of the prescribed regimen was not provided (23).

Although weight loss has been extensively investigated in the able-bodied population, there is very little work focusing on people with disabilities, such as individuals with SCI. Evidence in this area is only lately emerging. Recently, Chen and others reported on the effectiveness of a weight-loss intervention for individuals with SCI (23). A total of 16 overweight or obese individuals participated in a 12-week program that combined diet prescription (1,400 calories for men and 1,200 calories for women), a single weekly supervised 30-minute exercise session, and behavior change strategies. Investigators examined the effects on weight loss and a number of other parameters at 12 weeks and then again at 24 weeks. At the end of the intervention, participants achieved an average weight loss of 3.5 kg (approximately 3.8% of initial body weight). Mean weight loss at 24 weeks was 2.9 kg. Three subjects withdrew from the study for health reasons before their 24-week follow-up visit. Of the remaining 13 subjects, 6 continued to lose weight after the 12-week intervention period, 4 kept their weight off, and 3 gained weight. A total of 10 subjects had net weight loss that was below their baseline value. Benefits of the weight loss included significant improvements in total fat mass, WaC, dietary intake of saturated fat, and improvements in metabolic profile. Improvements in psychosocial well being and physical functioning were also noted. This study showed for the first time that weight-loss interventions can be safely used in individuals with SCI without adverse effects on lean body mass and overall health. However, the methodological limitations of this study (short duration of intervention and follow up, lack of a comparison group, study sample selection criteria, and the failure to provide information on the adherence to prescribed regimen) point to the need for well-designed, long-term studies in the area of weight loss and weight maintenance. As pointed out by Chen and colleagues, their study design, which involved the participants' making multiple trips to the study site, could be impractical for people with SCI, for whom difficulties with transportation are common (23). Future studies could also potentially use the internet-based Telehealth service to enable home-based weight-loss programs.

Addressing exercise and physical activity in weight-loss interventions for people with SCI is essential because of known low levels of physical activity. Low levels of habitual physical activity are documented in people with mobility-limiting conditions in general (89–91) and specifically in SCI (92). Physical deconditioning exacerbates metabolic abnormalities and functional limitations related to SCI, increases perceived difficulty of exercise, and contributes to low motivation for physical activity, all of which create a reinforcing cycle of inactivity (93). Inactivity coupled with low metabolic rate, common after SCI, significantly reduces energy expenditure (EE). Research on EE in people with SCI has demonstrated lower daily EE compared with ambulatory individuals that is partially explained by injury level and smaller proportion of active muscle mass (40,94,95) but also by lower levels of spontaneous physical activity (95,96).

Physical activity aids in weight loss and plays a role in maintaining body weight after successful weight loss (81). Successful weight-loss maintainers reported changing both their diet and their physical activity to lose and maintain the weight loss (81). Regular physical activity is an important part of a weight-loss program because it improves the metabolic rate slowing that typically occurs with calorie restriction; it improves mood and reduces depressive symptoms and anxiety, which may be associated with calorie restriction; and it establishes the habit of regular physical activity so that it is easier to continue during maintenance, when exercise is even more important for preventing weight regain (97).

Although additional work in this area is needed, the benefits of exercise in SCI include reversing body fat accumulation, lipid abnormalities, and carbohydrate metabolism abnormalities, including glucose tolerance, insulin sensitivity, and insulin levels (47,98–105). Although 79.2% of respondents with SCI in one survey acknowledged that an exercise program would be beneficial to them, only 45% reported that they currently exercise (106). This study identified barriers to exercising or practicing sport cited by individuals with SCI, including lack of motivation, lack of energy, cost of an exercise program, not knowing where to exercise, lack of interest, dislike of "traditional disabled sports," and fear of further injury. A higher percentage of individuals with tetraplegia than paraplegia cited heath conditions and that the exercise was too difficult. A study examining correlates of physical activity in wheelchair users (50% of sample was SCI) identified BMI, age, self-reported health, health care providers' discussions about exercise, and social support for exercise as significant correlates (89). The role of health care providers and supportive family and friends in interventions for this population is likely to be more important than in populations without visible disabling health conditions. Identification of effective interventions to surmount barriers and emphasize predictors is essential to help increase physical activity levels in this population.

Physical activity for persons with SCI may be primarily upper extremity movement, trunk movement, or a combination of upper and lower extremity movements. In a recent review, Jacobs and Nash highlighted the sports and exercise options available for individuals after SCI with various levels of injury (107). In addition to volitional exercise of innervated muscle groups, electrical stimulation of denervated muscles can produce muscle contractions for lower extremity training for appropriate candidates, especially those with tetraplegia. Electrical stimulation exercise may be a useful option for endurance training and muscle strengthening to enhance weight-loss efforts (107). Although many benefits of exercise have been documented in individuals with SCI (108), more research is needed to determine the type, duration, and level of exercise intensity for both health promotion and weight loss. Although there are documented alterations in the physiologic response to exercise in SCI that are dependent on injury level and completeness (attenuated heart rate response due to decreased sympathetic drive and decreased cardiac stroke volume and cardiac output caused by decreased sympathetic tone and decreased venous return from the lower extremities) (109), the risks of exercise for people with SCI can usually be prevented or managed with foreknowledge of their possibility. These risks include autonomic dysreflexia, musculoskeletal injury, hypotension, and thermal dysregulation and should be considered when designing physical activity interventions for individuals with SCI (107,109).

Risks of physical activity are more likely with strenuous effort than with mild to moderate effort. One previous study in SCI demonstrated that lifestyle physical activity (accumulation over the course of a day of 30 minutes or more of self-selected moderate intensity activity on bouts of at least 10 minutes in duration) is a feasible, acceptable, and potentially effective approach for promoting activity in people with SCI (110,111). In a single-group, prepost pilot study ($n = 16$), 81% of the participants progressed in stage of change (ie, actually beginning physical activity rather than just thinking about it) and 60% increased in overall physical activity as measured by actigraphy (112). Although more research is needed to elucidate the risks of exercise for people with SCI, it is more likely that SCI providers will continue to recommend exercise as a major component of a weight-loss program. Given the lack of data, a reasonable approach is to recommend lifestyle physical activity or mild- to moderate-intensity exercise beginning with short sessions and gradually working up to longer sessions.

The previously reported pilot obesity intervention for people with SCI included a 30-minute observed exercise session beginning the sixth week of the 12-week intervention (23). There was no reported measurement of adherence nor was there a measure of overall physical activity level, both important variables in understanding the efficacy of the piloted intervention. Research on physical activity and exercise in obesity interventions for people with SCI requires much more work on determination of EE for various physical activities and how EE is affected by level and completeness of injury. A self-report measure of physical activity suitable for use in multisite intervention studies has been developed (113) and initially validated. Actigraphy shows some promise as an objective measure of physical activity or movement (112,114) but is limited by its lack of specificity for the type of activity being performed. Issues to be resolved include the best measure or combination of measures to assess physical activity type, frequency, intensity, and duration and determination of reliable predictors of EE in SCI possibly incorporating the ASIA motor score with age, gender, and body weight. In the absence of established guidelines, physical activity recommendations for weight loss in SCI should be based on guidelines for the general population (30 minutes of moderate-intensity activity most days for health benefits and 60 to 90 minutes for weight loss and maintenance of weight loss), with programs developed for individuals based on injury level and completeness, individual preferences, and fitness level and options available. Physical therapists should be consulted for advice on establishing a program, and health care providers should monitor progress and give encouragement.

The use of surgery and medications is recommended for obese individuals who have failed to achieve sufficient weight loss using conventional therapies (115). Weight-loss surgical procedures (bariatric surgery) are reserved as a treatment option for individuals with morbid obesity (ie, having a BMI $\geq$40 kg/m^2) or a BMI $\geq$35 kg/m^2 with serious obesity-related comorbidities (1). Available evidence in able-bodied individuals suggests that surgery is more effective than conventional weight loss treatments for individuals with morbid obesity (116). A single published case study of Roux-en-Y gastric bypass surgery in an individual with paraplegia and BMI of 48 kg/m^2 and pre-existing comorbid conditions, such as sleep apnea, diabetes, and hypertension, suggests that surgery may be an option in this population (117). The patient had lost more than 52 kg at 12 months after surgery and experienced amelioration or improvements in his comorbid conditions, quality of life, and overall health. No adverse outcomes or postoperative complications were reported at 21 weeks after surgery. There are no published data regarding the frequency of morbid obesity in a population-based sample of subjects with SCI. Although bariatric surgery may have a role for weight loss in individuals with morbid obesity in the setting of SCI, risks include perioperative mortality, surgical complications, chronic postprandial discomfort and loose stools (eg, dumping syndrome), gallstones, and nutritional deficiencies (116,118,119). Also, weight-loss surgery may pose unique risks in the SCI population, particularly for individuals without abdominal sensations and those who have trouble coping with loose stools. Thus, although the feasibility of using bariatric surgery for morbid obesity and benefits of surgically induced weight loss have been reported in one individual with SCI, the efficacy, safety, and complications of a surgical option for weight loss need to be studied before weight-loss surgery is extensively used in this population.

Antiobesity drugs are offered as an adjunctive therapy to diet and physical activity for weight-loss treatment for individuals with BMI $\geq$30 kg/m^2 and in patients with BMI $>$27 kg/m^2 with obesity-related comorbid conditions. To our knowledge, there are no published reports on the use of pharmaceutical agents for weight-loss treatments in individuals with SCI. Sibutramine and Orlistat are the 2 most studied antiobesity medications in the US (120). Recently, these 2 medications were approved for use in the VA's Managing Obesity in Veterans Everywhere (MOVE!) Program, a clinical intervention program developed by the VA to address overweight and obesity issues among veterans. The VA is the largest provider of care to individuals with SCI, and an average of 26,000 veterans with SCI each year receive their health care through the VHA. The deleterious side effects of pharmacological agents, such as modest increases in blood pressure, heart rate, and gastrointestinal symptoms (including fecal incontinence and diarrhea), (120) may prove especially problematic for some individuals with SCI.

Poor diet and physical activity, 2 modifiable health behaviors that predispose individuals to overweight and obesity, are leading causes of preventable deaths in the US (12). Interestingly, in one study diet and exercise both ranked high on the list of things individuals with SCI wanted to discuss with their physicians (121). Rates of such counseling by SCI providers to overweight/obese individuals are, however, low (26). Both SCI providers and patients need to be aware of the changes that occur after injury, including the likelihood of weight gain. Revising diet and/or physical activity recommendations is crucial to guide patients in making optimal choices. Importantly, although there is a need to focus on weight gain during the early days after SCI, the emphasis should shift to maintenance of healthy weight and weight-loss issues after the acute stage. Barriers to obesity prevention and management cited by VA primary care providers include insufficient time and knowledge about weight-management services and lack of obesity training during medical school and residency (122). In the case of SCI, it is possible that the limited guidance in the literature on how to manage obesity and lack of SCI-specific weight management guidelines or programs could account for the low rates of counseling. Despite this and the need for much more research to address SCI-specific issues in obesity and weight management, we urge SCI clinicians to utilize guidelines for the general population, focus on health promotion strategies, and utilize the expertise of health care professionals in their teams to manage obesity (Table 1).

CONCLUSIONS

In this literature review, we have raised several issues relevant to the management of obesity in individuals with SCI (Table 2). Much research remains to be performed to assess and treat obesity in individuals with SCI. Given the prevalence of obesity in individuals with SCI, there is an urgent need to develop practical guidelines and measures to monitor obesity in the clinical setting. Weight-loss programs for individuals with SCI should be designed that take into consideration the barriers to dietary and physical activity unique to this population. Preliminary efforts in SCI have already documented that weight loss can be promoted in individuals with both paraplegia and

Table 1. Recommendations for Clinicians

Measure	Check weight at each clinic visit. Provide a wheelchair scale and variable height examination table. Weigh patient in the chair and then weigh the chair with cushion with the person out of the chair. Calculate patient weight by subtracting chair weight from total weight of patient and chair. Or, weigh the patient using a reliable lifting device that includes a calibrated scale.
Track trends	Discuss body weight trends over time, personal goals, and plan of action if needed.
Advise	Learn about exercise options for people with spinal cord injury at various levels and completeness of injury. Advise participation in moderate physical activity or exercise regularly. Refer to physical therapy or recreational therapy if guidance or recommendations for a regular program are needed. Discuss current eating habits. Offer advice for healthy eating patterns and food choices. Refer to a nutritionist as needed.
Reward	Verbally reward efforts toward weight management. Do not ignore this issue or convey the message that weight loss is impossible.

tetraplegia without adverse outcomes. There is a need for well-designed, long-term studies to evaluate the sustainability of weight loss and maintenance after SCI. Efforts to gain insights from individuals with SCI about their weight-control practices and a better understanding of the barriers and facilitators to weight change from a system, provider, and patient perspective will be relevant to in the design of effective weight-loss programs in this population. In the meantime, SCI providers should inform patients about the resources available within and outside the place of care. Practitioners are urged to talk with patients about weight concerns and problems associated with excess weight gain and to use a team approach utilizing community and hospital resources (such as support services with expertise in weight management) to facilitate weight management.

Table 2. Recommendations for Future Research

1. Develop and validate a spinal cord injury–specific measure for obesity assessment
2. Investigate clinical complications and health effects of obesity and body fat distribution
3. Determine optimal time after injury to target obesity prevention
4. Characterization of barriers to physical activity
5. Determine type, duration, and level of exercise intensity for weight loss and health promotion, including assessment of risk of autonomic dysreflexia
6. Evaluate interventions for tailored obesity treatment using diet, physical activity, and behavior modification
7. Examine prevalence, safety, and efficacy of antiobesity medications
8. Examine prevalence, safety, and efficacy of bariatric surgery

ACKNOWLEDGMENT

This material is the result of work supported by resources from the VA Puget Sound Health Care System, Seattle Washington.

REFERENCES

1. National Heart, Lung, and Blood Institute. *Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults.* Bethesda, MD: National Institute for Health, 1998. NIH publication No. 98-4083.
2. Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among US adults, 1999–2000. *JAMA.* 2002;288:1723–1727.
3. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999–2004. *JAMA.* 2006;295:1549–1555.
4. Hedley AA, Ogden CL, Johnson CL, Carroll MD, Curtil LR, Flegal KM. Overweight and obesity among US children, adolescents, and adults, 1999–2002. *JAMA.* 2004;291: 2847–2850.
5. Mokdad A, Bowman BA, Ford ES, Vinicor F, Marks JS, Koplan JP. The continuing epidemics of obesity and diabetes in the United States. *JAMA.* 2001;286:1195–1200.
6. Bray GA. Medical consequences of obesity. *J Clin Endocrinol Metab.* 2004;89:2583–2589.
7. Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH. The disease burden associated with overweight and obesity. *JAMA.* 1999;282:1523–1529.
8. Ashton WD, Nanchahal K, Wood DA. Body mass index and metabolic risk factors for coronary heart disease in women. *Eur Heart J.* 2001;22:46–55.
9. Duncan BB, Schmidt MI, Chambless LE, Folsom AR, Carpenter M, Heiss G. fibrinogen, other putative markers of inflammation, and weight gain in middle-aged adults: The ARIC Study. *Obes Res.* 2000;8:279–286.
10. Colditz GA, Willett WC, Rotnitzky A, Manson JE. Weight gain as a risk factor for clinical diabetes mellitus in women. *Ann Intern Med.* 1995;122:481–486.
11. Kissebah AH, Krakower GR. Regional adiposity and morbidity. *Physiol Rev.* 1994;74:761–811.
12. Mokdad AH, Marks JS, Stroup DF, Gerberding JL. Actual causes of death in the United States, 2000. *JAMA.* 2004; 291:1238–1245.
13. Janssen I, Katzmarzyk PT, Ross R. Body mass index, waist circumference, and health risk: evidence in support of current national institutes of health guidelines. *Arch Intern Med.* 2002;162:2074–2079.
14. Hayashi T, Boyko EJ, Leonetti DL, et al. Visceral adiposity and the risk of impaired glucose tolerance. *Diabetes Care.* 2003;26:650–655.

15. Snijder MB, Dekker JM, Visser M, et al. Associations of hip and thigh circumferences independent of waist circumference with the incidence of type 2 diabetes: the Hoorn Study. *Am J Clin Nutr.* 2003;77:1192–1197.
16. Aronne LJ, Segal KR. Adiposity and fat distribution outcome measures: assessment and clinical implications. *Obes Res.* 2002;10(suppl 1):14s–21s.
17. Yancy WS Jr, Olsen MK, Westman EC, Bosworth HB, Edelman D. Relationship between obesity and health-related quality of life in men. *Obes Res.* 2002;10:1057–1064.
18. Ford ES, Moriarty DG, Zack MM, Mokdad AH, Chapman DP. Self reported body mass index and health related quality of life: findings from the behavioral risk factor surveillance system. *Obes Res.* 2001;9:21–31.
19. Devlin MJ, Zhu AJ. Body image in the balance. *JAMA.* 2001;286:2159.
20. Sullivan M, Karlsson J, Sjostrom L, et al. Swedish obese subjects (SOS): an intervention study of obesity. Baseline evaluation of health and psychosocial functioning in the first 1743 subjects examined. *Int J Obes.* 1993;17:503–512.
21. Weil E, Wachterman M, McCarthy EP, et al. Obesity among adults with disabling conditions. *JAMA.* 2002;288:1265–1268.
22. De Vivo MJ, Black KJ, Stover SL. Causes of death during the first 12 years after spinal cord injury. *Arch Phys Med Rehabil.* 1993;74:248–254.
23. Chen Y, Henson S, Jackson AB, Richards JS. Obesity intervention in persons with spinal cord injury. *Spinal Cord.* 2006;44:82–91.
24. Gupta N, White KT, Sandford PR. Body mass index in spinal cord injury: a retrospective study. *Spinal Cord.* 2006;44:92–94.
25. Tomey KM, Chen DM, Wang X, Braunschweig CL. Dietary intake and nutritional status of urban community-dwelling men with paraplegia. *Arch Phys Med Rehabil.* 2005;86:664–671.
26. Johnston MV, Diab ME, Chu BC, Kirshblum S. Preventive services and health behaviors among people with spinal cord injury. *J Spinal Cord Med.* 2005;28:43–54.
27. Anson CA, Shepherd C. Incidence of secondary complications in spinal cord injury. *Int J Rehabil Res.* 1996;19:55–66.
28. Weaver FM, Collins EG, Kurichi J, et al. Prevalence of obesity and high blood pressure in veterans with spinal cord injuries and disorders: a retrospective review. *Am J Phys Med Rehabil.* 2007;86:22–29.
29. Buchholz AC, McGillivray CF, Pencharz PB. The use of bioelectric impedance analysis to measure fluid compartments in subjects with chronic paraplegia. *Arch Phys Med Rehabil.* 2003;84:854–861.
30. Kuczmarski RJ, Flegal KM. Criteria for definition of overweight in transition: background and recommendations for the United States. *Am J Clin Nutr.* 2000;72:1074–1081.
31. McAdams MA, Van Dam RM, Hu FB. Comparison of self-reported and measured BMI as correlates of disease markers in US adults. *Obesity (Silver Spring).* 2007;15:188–196.
32. Kopelman PG. Obesity as a medical condition. *Nature.* 2000;404:635–643.
33. Blackmer J, Marshall S. Obesity and spinal cord injury: an observational study. *Spinal Cord.* 1997;35:245–247.
34. Green D, Twardowski P, Wei R, Rademaker AW. Fatal pulmonary embolism in spinal cord injury. *Chest.* 1994;105:853–855.
35. Boninger ML, Cooper RA, Baldwin MA, Shimada SD, Koontz A. Wheelchair pushrim kinetics: body weight and median nerve function. *Arch Phys Med Rehabil.* 1999;80:910–915.
36. Leduc BE, Dagher JH, Mayer P, Bellemare F, Lepage Y. Estimated prevalence of obstructive sleep apnea-hypopnea syndrome after cervical cord injury. *Arch Phys Med Rehabil.* 2007;88:333–337.
37. Ayas NT, Epstein LJ, Lieberman SL, et al. Predictors of loud snoring in persons with spinal cord injury. *J Spinal Cord Med.* 2001;24:30–34.
38. Burns SP, Kapur V, Buhrer R. Factors associated with sleep apnea in men with spinal cord injury: a population-based case-control study. *Spinal Cord.* 2001;39:15–22.
39. Stockhammer E, Tobon A, Eser M, et al. Characteristics of sleep apnea syndrome in tetraplegic patients. *Spinal Cord.* 2002;40:286–294.
40. Myers J, Lee M, Kirati J. Cardiovascular disease in spinal cord injury: an overview of prevalence, risk, evaluation and management. *Am J Phys Med Rehabil.* 2007;86:142–152.
41. Bauman WA, Adkins RH, Spungen AM, Waters RL. The effect of residual neurological deficit on serum lipoproteins in individuals with chronic spinal cord injury. *Spinal Cord.* 1998;36:13–17.
42. Bauman WA, Adkins RH, Spungen AM, et al. Is immobilization associated with an abnormal lipoprotein profile? Observations from a diverse cohort. *Spinal Cord.* 1999;37:485–493.
43. Bauman WA, Adkins RH, Spungen AM, Waters RL. The effect of residual neurological deficit on oral glucose tolerance in persons with chronic spinal cord injury. *Spinal Cord.* 1999;37:765–771.
44. Janssen TW, Oers Van Kamp, TenVoorde B, Woudie, Hollander P. Coronary heart disease risk indicators, aerobic power, and physical activity in men with spinal cord injuries. *Arch Phys Med Rehabil.* 1997;78:697–705.
45. Dallmeijer AJ, Hopman M, Van der Woude L. Lipid, lipoprotein, and apolipoprotein profiles in active and sedentary men with tetraplegia. *Arch Phys Med Rehabil.* 1997;78:1173–1176.
46. Maki KC, Briones ER, Langbein WE, et al. Associations between serum lipids and indicators of adiposity in men with spinal cord injury. *Paraplegia.* 1995;33:102–109.
47. Manns PJ, McCubbin J, Williams DP. Fitness, inflammation, and the metabolic syndrome in men with paraplegia. *Arch Phys Med Rehabil.* 2005;86:1176–1181.
48. Zlotolow SP, Levy E, Bauman WA. The serum lipoprotein profile in veterans with paraplegia: the relationship to nutritional factors and body mass index. *J Am Paraplegia Soc.* 1992;15:158–162.
49. Buchholz AC, Bugaresti JM. A review of body mass index and waist circumference as markers of obesity and

coronary heart disease risk in persons with chronic spinal cord injury. *Spinal Cord.* 2005;12:1–6.

50. Burns SP, Little JW, Hussey DJ, Lyman P, Lakshminarayanan S. Sleep apnea syndrome in chronic spinal cord injury associated factors and treatment. *Arch Phys Med Rehabil.* 2000;81:1334–1339.
51. Klefbeck B, Sternhag M, Weinberg J, Levi R, Hultling C, Borg J. Obstructive sleep apneas in relation to severity of cervical spinal cord injury. *Spinal Cord.* 1998;36:621–628.
52. Price GL, Kendall M, Amsters DI, Pershouse KJ. Perceived causes of change in function and quality of life for people with long duration spinal cord injury. *Clin Rehabil.* 2004;18:164–171.
53. Clasey JL, Gater DR. Body composition assessment in adults with spinal cord injury. *Top Spinal Cord Inj Rehabil.* 2007;12:8–19.
54. Maggioni M, Bertoli S, Margonato V, Merati G, Veicsteinas A, Testolin G. Body composition assessment in spinal cord injury subjects. *Acta Diabetol.* 2003;40(suppl 1):S183–S186.
55. Spungen AM, Adkins RH, Stewart CA, et al. Factors influencing body composition in persons with spinal cord injury: a cross-sectional study. *J Appl Physiol.* 2003;95:2398–2407.
56. Bauman WA, Spungen AM, Wang J, Pierson RN. The relationship between energy expenditure and lean tissue in monozygotic twins discordant for spinal cord injury. *J Rehabil Res Dev.* 2004;41:1–8.
57. Jones LM, Legge M, Goulding A. Healthy body mass index values often underestimate body fat in men with spinal cord injury. *Arch Phys Med Rehabil.* 2003;84:1068–1071.
58. Nuhlicek DN, Spurr GB, Barboriak JJ, Rooney CB, el Ghatit AZ, Bongard RD. Body composition of patients with spinal cord injury. *Eur J Clin Nutr.* 1988;42:765–773.
59. Buchholz AC, McGillivray CF, Pencharz PB. Differences in resting metabolic rate between paraplegic and able-bodies subjects are explained by differences in body composition. *Am J Clin Nutr.* 2003;77:371–378.
60. Palta M, Prineas RJ, Berman R, Hannan P. Comparison of self-reported and measured height and weight. *Am J Epidemiol.* 1982;115:223–230.
61. DelPrete LR, Caldwell M, English C, Banspach SW, Lefebvre C. Self-reported and measured weights and heights of participants in community based weight loss programs. *J Am Diet Assoc.* 1992;12:1483–1486.
62. Stevens J, Keil JE, Waid R, Gazes PC. Accuracy of current 4-year, and 28-year self reported body weight in an elderly population. *Am J Epidemiol.* 1990;132:1156–1163.
63. Kuczmarski MF, Kuczmarski RJ, Najjar M. Effects of age on validity of self-reported height, weight, and body mass index: findings from the Third National Health and Nutrition Examination Survey, 1988–1994. *J Am Diet Assoc.* 2001;101:28–34.
64. Nawaz H, Chan W, Abdulrahaman M, Larson D, Katz DL. Self-reported weight and height: implications for obesity research. *Am J Prev Med.* 2001;20:294–298.
65. Chumlea WC, Steinbaugh ML, Roche AF, Mukherjee D, Gopalswamy N. Nutritional anthropometric assessment in elderly persons 65 to 90 years of age. *J Nutr Elderly.* 1985;4:39–51.
66. Mitchell CO, Lipschitz DA. Arm length measurement as an alternative to height in nutritional assessment of the elderly. *JPEN J Parenter Enteral Nutr.* 1982;6:226–229.
67. Stevenson RD. Use of segmental measures to estimate stature in children with cerebral palsy. *Arch Pediatr Adolesc Med.* 1995;149:658–662.
68. Han TS, Lean ME. Lower leg length as an index of stature in adults. *Int J Obes Relat Metab Disord.* 1996;20:21–27.
69. Jantz RL. Modification of the Trotter and Gleser female stature estimation formulae. *J Forensic Sci.* 1992;37:1230–1235.
70. Munoz JI, Linares-Iglesias M, Suarez-Penaranda JM, et al. Stature estimation from radiographically determined long bone length in a Spanish population sample. *J Forensic Sci.* 2001;46:363–366.
71. Mitchell CO, Lipschitz DA. The effect of age and sex on the routinely used measurements to assess the nutritional status of hospitalized patients. *Am J Clin Nutr.* 1982;36:340–349.
72. Garshick E, Ashba J, Tun CG, Lieberman SL, Brown R. Assessment of stature in spinal cord injury. *J Spinal Cord Med.* 1997;20:36–42.
73. Peiffer SC, Blust P, Leyson JF. Nutritional assessment of the spinal cord injured patient. *J Am Diet Assoc.* 1981;78:501–505.
74. Blissitt PA. Nutrition in acute spinal cord injury. *Crit Care Nurs Clin North Am.* 1990;2:375–384.
75. Demirel S, Demirel G, Tukek T, Erk O, Yilmaz H. Risk factors for coronary heart disease in patients with spinal cord injury in Turkey. *Spinal Cord.* 2001;39:134–138.
76. Jeon JY, Steadward RD, Wheeler GD, Bell G, McCargar L, Harber V. Intact sympathetic nervous system is required for leptin effects on resting metabolic rate in people with spinal cord injury. *J Clin Endocrinol Metab.* 2005;88:402–407.
77. Ben-Noun L, Sohar E, Laor A. Neck circumference as a simple screening measure for identifying overweight and obesity patients. *Obes Res.* 2001;9:470–477.
78. Valsamakis G, Chetty R, Anwar A, Banerjee A, Kumar S. Associations of simple anthropometric measures of obesity with visceral fat and metabolic syndrome in male Caucasian and Indo-Asian subjects. *Diabet Med.* 2004;21:1339–1345.
79. Seidell JC, Kahn HS, Williamson DF, Lissner L, Valdez R. Report from a Centers for Disease Control and prevention workshop on the use of adult anthropometry for public health and primary health care. *Am J Clin Nutr.* 2001;73:123–126.
80. Wing RR, Phelan S. Long-term weight maintenance. *Am J Clin Nutr.* 2005;82(suppl 1):222S–225S.
81. Hill JO, Wyatt H, Phelan S, Wing R. The national weight control registry: is it useful in helping deal with our obesity epidemic. *J Nutr Educ Behav.* 2005;37:206–210.
82. Levine AM, Nash MS, Green BA, Shea JD, Aronica MJ. An examination of dietary intakes and nutritional status of chronic healthy spinal cord injured individuals. *Paraplegia.* 1992;30:880–889.
83. Moussavi RM, Ribas-Cardus F, Rintala DH, Rodriguez GP. Dietary and serum lipids in individuals with spinal cord injury living in the community. *J Rehabil Res Dev.* 2001;38:225–233.

84. Malik VS, Hu FB. Popular weight-loss diets: from evidence to practice. *Nat Clin Pract Cardiovasc Med.* 2007;4:34–41.
85. Bray GA, Popkin BM. Dietary fat intake does affect obesity. *Am J Clin Nutr.* 1998;68:1157–1173.
86. US Department of Health and Human Services and US Department of Agriculture. Dietary Guidelines for Americans 2005. Available at: http://www.healthierus.gov/dietaryguidelines/. Accessed January 2007.
87. Adam-Perrot A, Clifton P, Brouns F. Low-carbohydrate diets: nutritional and physiological aspects. *Obes Rev.* 2006;7:49–58.
88. Lindstrom J, Peltonen M, Eriksson JG, et al. High-fiber low fat diet predicts long-term weight loss and decreased type 2 diabetes risk: the Finnish Diabetes Prevention Study. *Diabetologia.* 2006;49:912–920.
89. Warms CA, Whitney JD, Belza BL. Measurement and description of physical activity in adult manual wheelchair users [abstract #135]. *Association of Rehabilitation Nurses 33rd Annual Educational Conference Program Book.* Glenview, IL: Association of Rehabilitation Nurses; 2007.
90. Heath GW, Fentem PH. Physical activity among persons with disabilities: a public health perspective. *Exerc Sport Sci Rev.* 1997;25:195–234.
91. Cooper R, Quatrano L, Axelson P, et al. Research on physical activity and health among people with disabilities: a consensus statement. *J Rehabil Res Dev.* 1999;36: 142–154.
92. Buchholz AC, McGillivray CF, Pencharz PB. Physical activity levels are low in free-living adults with chronic paraplegia. *Obes Res.* 2003;11:563–570.
93. Washburn RA, Figoni SF. Physical activity and chronic cardiovascular disease prevention in spinal cord injury: a comprehensive literature review. *Top Spinal Cord Inj Rehabil.* 1998;23:16–32.
94. Mollinger LA, Spurr GB, Elghatit AZ, et al. Daily energy expenditure and basal metabolic rates of patients with spinal cord injury. *Arch Phys Med Rehabil.* 1985;66:420–426.
95. Buchholz AC, Pencharz PB. Energy expenditure in chronic spinal cord injury. *Curr Opin Clin Nutr Metab Care.* 2004;7: 635–639.
96. Monroe MB, Tataranni PA, Pratley R, Manore MM, Skinner JS, Ravussin E. Lower daily energy expenditure as measured by a respiratory chamber in subjects with spinal cord injury compared with control subjects. *Am J Clin Nutr.* 1998;68:1223–1227.
97. Hill JO, Wyatt HR. Role of physical activity in preventing and treating obesity. *J Appl Physiol.* 2005;99:765–770.
98. Hjeltnes N, Aksnes AK, Birkeland KI, et al. Improved body composition after 8 weeks of electrically stimulated leg cycling in tetraplegic patients. *Am J Physiol.* 1997;273: R1072–R1079.
99. Kocina P. Body composition of spinal cord injured adults. *Sports Med.* 1997;23:48–60.
100. Midha M, Schmitt JK, Sclater M. Exercise effect with the wheelchair aerobic fitness trainer on conditioning and metabolic function in disabled persons: a pilot study. *Arch Phys Med Rehabil.* 1999;80:258–261.
101. Bostom AG, Toner MM, McArdle WD, Montelione T, Brown CD, Stein RA. Lipid and lipoprotein profiles relate to peak aerobic power in spinal cord injured men. *Med Sci Sports Exerc.* 1991;23:409–414.
102. Nash MS, Jacobs PL, Mendez AL, Goldberg RB. Circuit resistance training improves the atherogenic lipid profiles of persons with chronic paraplegia. *J Spinal Cord Med.* 2001;24:2–9.
103. Hjeltnes N, Galuska D, Björnholm M, et al. Exercise-induced over expression of key regulatory proteins involved in glucose uptake and metabolism in tetraplegic persons: molecular mechanism for improved glucose homeostasis. *FASEB J.* 1998;12:1701–1712.
104. Mohr T, Dela F, Handberg A, Biering-Sorensen F, Galbo H, Kjaer M. Insulin action and long-term electrically induced training in individuals with spinal cord injuries. *Arch Phys Med Rehabil.* 2001;33:1247–1252.
105. Jeon JY, Weiss CB, Steadward RD, et al. Improved glucose tolerance and insulin sensitivity after electrical stimulation-assisted cycling in people with spinal cord injury. *Spinal Cord.* 2002;40:110–117.
106. Scelza WM, Kalpakjian CZ, Zemper ED, Tate DG. Perceived barriers to exercise in people with spinal cord injury. *Am J Phys Med Rehabil.* 2005;84:576–583.
107. Jacobs PL, Nash MS. Exercise recommendations for individuals with spinal cord injury. *Sports Med.* 2004;34: 727–751.
108. Duran FS, Lugo L, Ramirez L, Eusse E. Effects of an exercise program on the rehabilitation of patients with spinal cord injury. *Arch Phys Med Rehabil.* 2001;82:1349–1354.
109. Gater D, Ugalde V. Physiologic foundations for exercise prescription in tetraplegia. In: Shankar K, ed. *Exercise Prescription.* Philadelphia, PA: Hanley & Belfus Inc; 1998: 199–246.
110. Dunn AL, Anderson RE, Jakicic JM. Lifestyle physical activity interventions: history, short- and long-term effects and recommendations. *Am J Prev Med.* 1998;15:398–412.
111. Warms CA, Belza BL, Whitney JD, Mitchell PH, Stiens SA. Lifestyle physical activity for individuals with spinal cord injury: a pilot study. *Am J Health Promotion.* 2004;18:288–291.
112. Warms CA, Belza BL. Actigraphy as a measure of physical activity for wheelchair users with spinal cord injury. *Nurs Res.* 2004;53:136–143.
113. Ginis KA, Latimer AE, Hicks AL, Craven BC. Development and evaluation of an activity measure for people with spinal cord injury. *Med Sci Sports Exerc.* 2005;37:1099–1111.
114. Washburn RA, Copay AG. Assessing physical activity during wheelchair pushing: validity of a portable accelerometer. *Adapted Phys Activity Q.* 1999;16:290–299.
115. Fujioka K. Management of obesity as a chronic disease: nonpharmacologic, pharmacologic, and surgical options. *Obes Res.* 2002;10:116S–123S.
116. Colquitt J, Clegg A, Loveman J, Royle P, Sidhu MK. Surgery for morbid obesity. *Cochrane Database Syst Rev.* 2005;4:CD003641.
117. Alaedeen D, Jasper J. Gastric bypass surgery in a paraplegic morbidly obese patient. *Obes Surg.* 2006;16: 1107–1108.
118. Flum DR, Salem L, Elrod JA, Dellinger EP, Cheadle A, Chan L. Early mortality among Medicare beneficiaries under-

going bariatric surgical procedures. *JAMA.* 2005;294: 1903–1908.
119. Flum DR. Impact of gastric bypass operation on survival: a population-based analysis. *J Am Coll Surg.* 2004;199:543–551.
120. Li Z, Maglione M, Tu W, et al. Meta-analysis: pharmacologic treatment of obesity. *Ann Intern Med.* 2005;142: 532–546.
121. Collins EG, Langbein WE, Smith B, Hendricks R, Hammond M, Weaver F. Patients' perspective on the comprehensive preventive health evaluation in veterans with spinal cord injury. *Spinal Cord.* 2005;43:366–374.
122. Forman-Hoffman V, Little A, Wahls T. Barriers to obesity management: a pilot study of primary care clinicians. *BMC Fam Pract.* 2006;7:35.