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Comparison of body composition between physically active and inactive wheelchair users

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COMPARISON OF BODY COMPOSITION BETWEEN PHYSICALLY ACTIVE AND INACTIVE WHEELCHAIR USERS

by

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ABSTRACT

Comparison of Body Composition Between Physically Active and Inactive Wheelchair Users

by

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The purpose of this study was to examine the association between regular physical activity and body composition in individuals with physical disabilities. The study was designed to compare body composition parameters between wheelchair users participating in adapted sports programs and those being physically inactive. Male wheelchair users were recruited and classified based on physical activity level (active or inactive) and disability type (paraplegic or quadriplegic). Regional and whole-body percent body fat (%BF), lean body mass (LBM), and bone mineral density (BMD) were assessed by dual-energy X-ray absorptiometry. These variables were then compared among the groups using a two-way between-groups multivariate analysis of covariance with age, body mass index, and time since injury/disease as covariates. The physically active, paraplegic and quadriplegic men had a significantly higher BMD in the arms than did their physically inactive counterparts. Furthermore, arm BMD tended to be higher in the paraplegic group than in the quadriplegic group. The paraplegic men had a significantly lower %BF and a higher LBM in the arms than did the quadriplegic men. Any regional and whole-body %BF or LBM were not associated with physical activity level. In conclusion, playing adapted sports is associated with an increased BMD in the arms among wheelchair users. On the other hand, engaging in regular physical activity is not likely to influence BMD in the trunk, lower limbs, and the whole body among these individuals. A higher functional capacity is related to favorable %BF, LBM, and, to some extent, BMD in the upper limbs among wheelchair users, whereas playing wheelchair sports at recreational levels may not be sufficient to positively affect %BF or LBM in this population.

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CHAPTER 1

INTRODUCTION

Body composition is one of the five components of health-related physical fitness (Caspersen, Powell, & Christenson, 1985). Body mass index (BMI), body weight relative to height, is widely used to estimate body fatness and health risks associated with overweight and obesity (Expert Panel on the Identification Evaluation and Treatment of Overweight and Obesity in Adults, 1998). The World Health Organization (2000) defines BMI between 25.00 kg/m^2 and 29.99 kg/m^2 as overweight and of 30.00 kg/m^2 or higher as obesity. BMI does not distinguish between fat mass (FM) and fat-free mass (FFM), therefore other measures of body composition are used to evaluate various characteristics or components of the human body. These measures include percent body fat (%BF; body fat relative to body mass), lean body mass (LBM; amount of fat-free tissues and essential lipids), and bone mineral density (BMD; relative mineral content in the bone).

Assessment of body composition is important for detecting the risk of various diseases and maintaining one’s quality of life. According to research, excess body fat is associated with an increased risk of chronic diseases, such as coronary heart disease, stroke, and type 2 diabetes mellitus (National Task Force on the Prevention and Treatment of Obesity, 2000). Excessively low body fat may also indicate health hazards, as it is frequently linked with disordered eating (e.g., anorexia and bulimia nervosa) (Lear, Pauly, & Birmingham, 1999; Mathiak et al., 1999). A decrease in LBM is associated with reduced quality of life, an increased risk of disability and morbidity, and increased mortality (Kell, Bell, & Quinney, 2001; Roubenoff & Hughes, 2000; Wannamethee, Shaper, Lennon, & Whincup, 2007). Furthermore, low levels of BMD can lead to osteoporosis, which will increase the risk of bone fractures (Kanis & Glüer, 2000). Body composition measurement can be used to develop exercise prescriptions and dietary recommendations in order to reduce %BF and increase LBM and BMD.

It has been suggested that people with physical disabilities tend to have higher BMI and %BF, increased FM, decreased FFM or LBM, and lower BMD (Gater Jr & Clasey, 2006; Kocina, 1997; Liou, Pi-Sunyer, & Laferrere, 2005). Because of limited mobility, physical activity levels and total energy expenditure of those with disabilities are generally low (Buchholz, McGillivray, & Pencharz, 2003; Monroe et al., 1998), increasing the likelihood of the accumulation of excess body fat and the loss of muscle mass and bone mineral content. In particular, physical inactivity is a major concern for this population, as Healthy People 2010 reported that 56% of people with disabilities engage in no leisure-time physical activity compared to 36% of those without disabilities (U.S. Department of Health and Human Services, 2000b). Consequently, the risk of obesity-related chronic diseases and osteoporosis is higher in people with disabilities than in the general population (Gater Jr & Clasey, 2006; Kocina, 1997; Liou et al., 2005).

It is estimated that 22.0% of adults living in the U.S. have a disability (Centers for Disease Control and Prevention, 2001). Those with disabilities include: 452,000 people with head or spinal cord injury, 1,160,000 people with stroke, 299,000 people with missing limbs, and 250,000–350,000 people with multiple sclerosis (Anderson et al., 1992; Centers for Disease Control and Prevention, 2001). These numbers are growing each year (Centers for Disease Control and Prevention, 1994, 2001), probably as a result of the advancement of medical technologies and thus better survival rates from accidents and diseases. Hence, improving qualify of life in clinical populations is becoming an urgent health-related issue.

Physical activity is important for achieving and maintaining optimal body composition. Physical activity helps to reduce body fatness by increasing energy expenditure, stimulating fat loss, and promoting gains in muscle mass (Donnelly et al., 2009; Physical Activity Guidelines Advisory Committee, 2008). In addition, bone mineral content can be increased by regular physical activity (Physical Activity Guidelines Advisory Committee, 2008), especially by engaging in weight-bearing activities (Kohrt, Bloomfield, Little, Nelson, & Yingling, 2004). Physical activity programs for people with disabilities are offered mainly through community agencies, and typical programs include wheelchair basketball, wheelchair/quad rugby, wheelchair tennis, and track and field (City of Las Vegas Adaptive Recreation, n.d.). The rules of these activities are adapted and individuals are classified based on their disability levels, so that people with various disabilities can enjoy and compete with and against each other (Clark, 1980).

Although the benefits of physical activity on improving body composition have been well documented in the general population (Physical Activity Guidelines Advisory Committee, 2008), there is a paucity of research on the effects of physical activity on body composition in people with physical disabilities. The lack of body composition research for this population is believed to be due to the difficulty in assessing their body composition. Traditionally, hydrostatic weighing (HW) has been a choice for estimating %BF (Clasey & Gater Jr, 2005; Lohman, Houtkooper, & Going, 1997). However, because of the presence of disability, HW would be challenging to conduct for those with physical disabilities (e.g., difficulty in moving a person into and out of a tank; potential bowel and bladder accidents during testing). Recently, dual-energy X-ray absorptiometry (DXA) has emerged as a new technique for body composition measurement (Lohman & Chen, 2005). DXA requires minimal subject compliance and can take into account the changes in the FFM components typically experienced by persons with disabilities (Gater Jr & Clasey, 2006; Kocina, 1997; Liou et al., 2005). Therefore, the development of DXA provides researchers with a practical method for assessing body composition of individuals with physical disabilities.

Research Question

Is regular physical activity associated with lower %BF, higher LBM, and increased BMD in people with physical disabilities?

Purpose of the Study

The purpose of this study was to examine whether regular physical activity is associated with lower %BF, higher LBM, and increased BMD in individuals with physical disabilities. Body composition parameters were compared between paraplegic and quadriplegic wheelchair users who participated in adapted sports programs and those who were physically inactive.

Research Hypothesis

Wheelchair users participating in adapted sports programs have lower %BF, higher LBM, and increased BMD compared with their inactive counterparts.

Significance of the Study

If the benefits of physical activity on body composition for people with physical disabilities are fully understood, it will help to raise awareness of the importance of active lifestyles for maintaining quality of life among them. In addition, the results of the study will be used to design randomized control trials in order to investigate the effects of regular physical activity on body composition (i.e., causation), which will eventually help to develop physical activity or exercise recommendations specifically for clinical populations.

Definition of Terms

1. Body mass index (BMI): body weight relative to height; calculated weight in kilograms divided by the square of height in meters
2. Fat mass (FM): Lipids from adipose and other tissues in the body
3. Fat-free mass (FFM): Lipid-free tissues including water, muscle, bone, connective tissue, and internal organs
4. Percent body fat (%BF): Body fat relative to body mass
5. Lean body mass (LBM): Fat-free tissues and essential lipids
6. Bone mineral content (BMC): Amount of mineralized tissue in the bone
7. Bone mineral density (BMD): Amount of mineralized tissue normalized to the area of the bone (i.e., relative mineral content in the bone)
8. Dual-energy X-ray absorptiometry (DXA): Body composition equipment that estimates bone mineral content, lean tissue mass, fat mass, and fat-free mass using an X-ray tube

9. Spinal cord injury: Fractured or dislocated vertebrae caused by traumatic blow to the spine or damage to the spinal cord caused by infectious diseases
10. Spina bifida: Congenital birth defect of the vertebral column resulting from a failure of the vertebral arches to fuse
11. Cerebral palsy: Neurological disorder characterized by a lack of muscular coordination and partial paralysis caused by damage to the motor areas of the brain
12. Muscular dystrophy: Genetic disease characterized by progressive weakness and degeneration of skeletal muscles
13. Friedreich's ataxia: Genetic disease characterized by progressive damage to the nervous system resulting in symptoms, such as gait disturbance and speech problems
14. Paraplegia: Paralysis of trunk and lower limbs
15. Quadriplegia: Paralysis of trunk and all four extremities

Assumptions

1. The validity and reliability of the results relied on the equipment used to assess body composition. It was assumed that DXA was valid and reliable for measuring %BF, LBM, and BMD of the participants in this study.
2. The participants were male adults who used a manual wheelchair for daily activities due to physical disabilities from injuries and diseases.
3. The participants were either paraplegic or quadriplegic.
4. The active individuals participated in adapted sports programs for an average of 1.5 hr per day twice a week during the season (lasting 8–9 months depending on sports)

and once a week during the off-season. The inactive individuals did not participate in any adapted sports or structured exercise programs at the time of the study.

Limitations

1. Actual energy expenditure for sports play by the wheelchair users was not measured in this study. In addition, variability in exercise energy expenditure existed among the physically active individuals.
2. The current study included wheelchair users with various types of injuries and diseases (spinal cord injury, spina bifida, cerebral palsy, muscular dystrophy, and Friedreich's ataxia). Besides physical activity level (active vs. inactive) and disability type (paraplegia vs. quadriplegia), type of injury/disease could influence body composition (Liou et al., 2005).
3. The current study employed a cross-sectional study design, therefore it was not possible to establish causation between sports participation and body composition parameters in people with physical disabilities.

CHAPTER 2

REVIEW OF LITERATURE

Measures of Body Fatness

Body mass index (BMI; weight in kilograms divided by the square of height in meters) is a common measure to estimate body fatness and health risks associated with overweight and obesity (Expert Panel on the Identification Evaluation and Treatment of Overweight and Obesity in Adults, 1998). The World Health Organization (2000) defines BMI between 25.00 kg/m^2 and 29.99 kg/m^2 as overweight and of 30.00 kg/m^2 or higher as obesity. Evidence suggests that higher BMI values are associated with an increased risk of developing a number of diseases, including coronary/ischaemic heart disease (McGee, 2005; Ni Mhurchu, Rodgers, Pan, Gu, & Woodward, 2004), stroke (Ni Mhurchu et al., 2004; Rexrode et al., 1997), hypertension (Davy & Hall, 2004; Pi-Sunyer, 2009), type 2 diabetes mellitus (Hu et al., 2001; Wang, Rimm, Stampfer, Willett, & Hu, 2005), and certain types of cancer (Bianchini, Kaaks, & Vainio, 2002; Calle & Kaaks, 2004; Calle, Rodriguez, Walker-Thurmond, & Thun, 2003). BMI is easy to obtain, practical, and suitable for large epidemiological studies. On the other hand, a major disadvantage of using BMI to assess body fatness is that it does not account for the composition of body mass. For example, a person with a high BMI value may have a large amount of either body fat or lean body tissue. Therefore, obesity "may be better defined as an excessive amount of body fat relative to body weight" (Heyward & Wagner, 2004).

Percent body fat (%BF; fat mass divided by body mass) can be used to classify levels of body fatness. Although there are no universal standards for %BF, experts recommend that male and female adults in the general population should have %BF of 8–25% and 20–38%, respectively, depending on age (Lohman et al., 1997). Research indicates that %BF of 26–31% or higher for men and 38–43% or higher for women correspond to BMI of 30 kg/m^2 or higher (i.e., classified as obesity), depending on age and ethnicity (Gallagher et al., 2000). Evidence has shown that people with high %BF have an increased risk of cardiovascular disease mortality (Lee, Blair, & Jackson, 1999).

Bone Mineral Density and Osteoporotic Fractures

Bone mineral density (BMD; relative mineral content in the bone) can be used to predict the development of osteoporosis and the risk for bone fractures (Kanis & Glüer, 2000). Research indicates that low levels of BMD lead to osteoporosis and increase the incidence of fractures (Kanis et al., 2000; Marshall, Johnell, & Wedel, 1996). Moreover, lower BMD values were shown to be linked with increased mortality in both men and women (Johansson, Black, Johnell, Oden, & Mellstrom, 1998). Osteoporosis is generally defined as BMD of more than 2.5 standard deviations below the mean value of young healthy females (Kanis, Melton, Christiansen, Johnston, & Khaltaev, 1994; World Health Organization, 1994). This threshold value is suggested for women; however, because of a similar relative risk for osteoporosis given by this value, it appears that the same cut-off value can also be used for men (de Laet, van der Klift, Hofman, & Pols, 2002; Melton, Atkinson, O'Connor, O'Fallon, & Riggs, 1998). It is estimated that the lifetime risk of any osteoporotic fracture ranges from 40% to 50% for women and from 13% to 22% for men (Johnell & Kanis, 2005). As a result of increased longevity in the world’s population, osteoporosis-related fractures are becoming a global socioeconomic issue (Dontas &

Yiannakopoulos, 2007). For example, the number of hip fractures worldwide in 2050 is projected to 6.3 million, a significant increase from 1.7 million in 1990, and the estimated cost of hip fractures will be $131.5 billion in 2050 (Johnell, 1997).

There are certain risk factors associated with osteoporotic fractures, including age, gender, and lifestyle (Dontas & Yiannakopoulos, 2007). The incidence of hip fracture increases exponentially with age in both men and women (Cummings & Melton, 2002; Melton & Cooper, 2001). Hui, Slemenda, and Johnston (1988) followed middle-aged to elderly women for an average of 6.5 years and found that age was a significant predictor of hip fractures. It has been proposed that an increased risk of osteoporotic fractures with age results mainly from a decrease in BMD or bone mass and an increase in falls related to age (Dontas & Yiannakopoulos, 2007; Hui et al., 1988). Women are more susceptible to osteoporotic fractures than are men (40–50% in women vs. 13–22% in men) (Johnell & Kanis, 2005). Melton (2000) estimated that the lifetime risk of hip fracture is 17.5% for women compared to 6.0% for men. It appears that this gender difference exists because women experience greater bone loss that is accelerated after menopause, women have a greater risk of falls than men, and women also live longer than men (Cummings & Melton, 2002; Dontas & Yiannakopoulos, 2007). Lifestyle is also related to the risk of osteoporotic factures, as physical activity during adolescents and throughout life and proper nutritional intake, including calcium and vitamin D, are important for reducing the risk of osteoporosis later in life (Gass & Dawson-Hughes, 2006; Karlsson, 2004). Disuse osteoporosis, resulting from the reduction of mechanical stress on bones (Takata & Yasui, 2001), can occur by prolonged bed rest (Arnaud, Sherrard, Maloney, Whalen, & Fung, 1992), localized/partial immobilization due to spinal cord injury or hemiplegia after stroke (Kiratli, Smith, Nauenberg, Kallfelz, & Perkash, 2000; Lazo et al., 2001; Takamoto et al., 1995), and the application of a cast to treat fractures (Kannus, Jarvinen, Sievanen, Oja, & Vuori, 1994).

Body Composition Models

It is essential to understand various theoretical models underlying the measurement of body composition. Basically, body composition models divide the human body into two or more components (Pietrobelli, Heymsfield, Wang, & Gallagher, 2001). Two-component (2-C) models, the simplest and most widely used for assessing body composition, divide the body into fat mass (FM) and fat-free mass (FFM) compartments. Body density (Db; body mass divided by body volume) is measured and compared to the reference body in order to estimate %BF using prediction equations. This process is referred to as densitometry. The two most popular 2-C model prediction equations are the Brozek et al. equation (4.57 / Db – 4.142) (Brozek, Grande, Anderson, & Keys, 1963) and the Siri equation (4.95 / Db – 4.50) (Siri, 1956). These two equations assume that the relative proportions of water, protein, and mineral in FFM are constant within and between individuals and are the same as the reference body (water = 73.8% or 0.9937 g/cc; protein = 19.4% or 1.34 g/cc; mineral = 6.8% or 3.038 g/cc) and that the densities of FM and FFM are 0.90 g/cc and 1.10 g/cc, respectively (Brozek et al., 1963; Siri, 1956). Therefore, according to 2-C models, any variation in Db and %BF is due to the amount of body fat, specifically triglyceride and adipose tissues.

In general, 2-C models can provide reasonable estimates of %BF as long as the assumptions described above are met (Heyward & Wagner, 2004). However, measurement errors can be greater if the assumptions are violated. It has been suggested that factors, such as age, gender, ethnicity, level of body fatness, physical activity level, and disease/injury status, affect the composition of FFM (Baumgartner, Heymsfield, Lichtman, Wang, & Pierson, 1991; Deurenberg, Leenen, Van der Kooy, & Hautvast, 1989; Formica, Cosman, Nieves, Herbert, & Lindsay, 1997; Mazariegos et al., 1994; Modlesky et al., 1996; Spungen et al., 2003; Wagner & Heyward, 2000), potentially resulting in an inaccurate estimate of %BF from Db. Hence, a number of population-specific equations for 2-C models have been developed to improve the accuracy of %BF prediction (Heyward & Wagner, 2004). Measurement techniques utilizing the concepts of 2-C models include hydrostatic weighing (HW), air displacement plethysmography (ADP), and skinfold (SKF) measurements.

In contrast to 2-C models, multi-component models, such as three-component (3-C) models, take into account the individual variability in FFM, which can provide a more accurate estimate of %BF. By measuring additional body compartments, including water, protein, and/or mineral content, multi-component models divide the human body into more than two components, thereby requiring fewer assumptions when estimating %BF. Siri (1961) developed a 3-C model that adjusts Db for the proportion of water in FFM. In this model, the body is divided into fat, water, and solids (mineral and protein), and total body water is measured by hydrometry in addition to Db measurement by densitometry. The Siri 3-C model yield more accurate estimates of %BF when assessing body composition of subgroups, such as children and obese adults, whose relative hydration of the body may deviate significantly from the assumed value (73.8% of FFM) in the 2-C models (Deurenberg et al., 1989; Fomon, Haschke, Ziegler, & Nelson, 1982; Hewitt, Going, Williams, & Lohman, 1993; Heyward & Wagner, 2004).

Lohman (1986) developed another 3-C model that divides the body into fat, mineral, and water and protein combined, which accounts for the individual variability in the mineral content of FFM. In this model, total body mineral is measured by dual-energy X-ray absorptiometry (DXA), along with Db measurement. The Lohman's 3-C model is more appropriate for assessing body composition of individuals, such as African Americans and Asians, whose relative mineral content may differ significantly from the reference value (6.8% of FFM) (Russell-Aulet, Wang, Thornton, Colt, & Pierson, 1991; Wagner & Heyward, 2000).

In addition to these 3-C models, using DXA alone can provide a 3-C tissue-level model that divides the body into FM, bone-free lean tissue mass or lean body mass (LBM), and total body bone mineral (Ellis, 2000). It appears that %BF estimated from DXA is within 1–3% of body fat from multi-component models (Lohman, Harris, Teixeira, & Weiss, 2000) with the minimal detectable change in FM of 2 kg (Ellis, 2001). DXA is particularly useful for assessing body composition of clinical populations, as it requires minimal subject compliance and can account for the changes in bone mineral content (BMC) and muscle mass experienced by persons with disabilities (Gater Jr & Clasey, 2006; Kocina, 1997; Liou et al., 2005). DXA has been recommended as the reference method for assessing body composition of individuals with spinal cord injury (Gater Jr & Clasey, 2006; Jones, Goulding, & Gerrard, 1998).

Factors Affecting Body Composition

Age

There are several factors that can affect body composition. In general, FM increases gradually with age during adulthood (Guo, Zeller, Chumlea, & Siervogel, 1999; Mott et al., 1999; Siervogel et al., 1998). Guo and colleagues (1999) estimated that men and women aged 40 to 66 years gained total body fat by 0.37 kg and 0.41 kg per year and %BF by 0.32% and 0.33% per year, respectively, during 20 years of follow-up. According to Siervogel et al. (1998), men, on average, gained total body fat by 0.57 kg/year and %BF by 0.55%/year between 18 and 45 years of age and by 0.37 kg/year (total body fat) and 0.34%/year (%BF) between 45 and 65 years of age. In women, the increases in total body fat and %BF were 0.44 kg/year and 0.41%/year between 18 and 45 years of age and 0.52 kg/year and 0.47%/year between 45 and 65 years of age, respectively. The results of this study indicated that the rate of gains in body fat slowed down in men after the age of 45 years, but no such trend was observed in women. Mott and coworkers (1999) found that FM increased with age and peaked at the age of 50–60 years old and then decreased after 60 years old in a curvilinear fashion among men and women of all ethnic groups (Asian, Black, Puerto Rican, and White) except Puerto Rican women whose FM continued to increase even after the age of 60 years.

In contrast to FM, FFM tends to change at much slower rates (–0.13 to +0.08 kg/year in men and –0.11 to +0.04 kg/year in women) over the years in the adulthood (Guo et al., 1999; Siervogel et al., 1998). Nevertheless, studies showed that LBM could decrease by 16% from 25 to 65–70 years old or by up to 19% in men and up to 12% in women between 18 and 85 years of age (Forbes & Reina, 1970; Kuczmarski, 1989; Novak, 1972).

Skeletal muscle mass declines with age, referred to as sarcopenia (Rosenberg, 1989; Roubenoff & Hughes, 2000). Janssen, Heymsfield, Wang, and Ross (2000) looked at skeletal muscle mass of 468 men and women aged 18 to 88 years using magnetic resonance imaging (MRI). The researchers found that a noticeable decrease in skeletal muscle mass began at 45 years of age in both genders with an estimated decrease of 1.9 kg/decade and 1.1 kg/decade in men and women, respectively. Baumgartner et al. (1998) examined the prevalence of sarcopenia among 883 elderly Hispanic and White men and women using DXA. In their study, sarcopenia was defined as appendicular skeletal muscle mass of less than 2.0 standard deviations below the mean of a young reference group. The study revealed that the prevalence of sarcopenia was more than 50% of those over 80 years old compared to 13–24% of those below 70 years old. A study by Iannuzzi-Sucich, Prestwood, and Kenny (2002) reported that the prevalence of sarcopenia was 26.8% in men and 22.6% in women over 65 years of age, but these numbers increased to 52.9% (men) and 31.0% (women) if people of only 80 years or older were included in the analysis.

BMD tends to decrease with age, as well (osteopenia), potentially leading to osteoporosis (Dontas & Yiannakopoulos, 2007; Kanis & Glüer, 2000; Kanis et al., 1994). Warming, Hassager, and Christiansen (2002) examined BMD of more than 600 men and women aged 20 to 89 years. The researchers found that BMD in the total body as well as the forearm, spine, and hip was negatively related with age in both genders. The study also looked at longitudinal changes in BMD among these people and observed the reductions in BMD by 0.1–0.9% (men) and 0.4–2.1% (women) at the hip over a 2-year period. Burger et al. (1994) calculated that men and women in their study lost BMD by

0.3–0.5% and 0.4–0.8% per year, respectively, at the femoral neck, Ward’s triangle (area in the femoral neck where bone density is the lowest), and trochanter after the age of 55 years.

Ethnicity

It has been well documented that certain ethnic groups have a higher risk for obesity than others (U.S. Department of Health and Human Services, 2000a). Recent data showed that in the U.S. (2003–2004) the prevalence of obesity in adults was approximately 30% for non-Hispanic White, 45% for non-Hispanic Black, and 36.8% for Mexican Americans (Ogden et al., 2006). These differences may be partly due to the disparities in physical activity levels among the ethnic groups. For example, African Americans and Hispanics are typically less physically active than are Whites (U.S. Department of Health and Human Services, 2000a). Furthermore, the proportions of adults engaging in no leisure-time physical activity were found to be 52% among Blacks/African Americans and 54% among Hispanics/Latinos compared to 38% among Whites (U.S. Department of Health and Human Services, 2000b).

Research also indicates that the relationship between BMI and %BF varies among ethnic groups (Deurenberg, Yap, & van Staveren, 1998). According to a meta-analysis by Deurenberg et al. (1998), American Blacks and Polynesians tend to have lower %BF than do Caucasians at the same BMI, age, and gender. In contrast, %BF of Indonesians, Thais, and Ethiopians is typically higher than that of Caucasians at the same BMI level. If a prediction equation for Caucasians is used to estimate %BF of Chinese from BMI, it tends to underestimate %BF at lower BMI levels and overestimate %BF at higher BMI levels. Deurenberg et al. (1998) therefore concluded that levels of body fatness could be different among populations of the same age, gender, and BMI and that BMI cut-off values for obesity would probably need to be population-specific.

The composition and densities of FFM could also vary among ethnic groups (Deurenberg & Deurenberg-Yap, 2003). For example, Blacks, in general, have higher body mineral and protein than do Whites, whereas a water content in FFM between the two groups does not appear to differ significantly (Wagner & Heyward, 2000). Asians, including Chinese, Malays, and Indians, tend to have a higher mineral fraction in FFM than do Caucasians (Deurenberg-Yap, Schmidt, van Staveren, Hautvast, & Deurenberg, 2001; Deurenberg & Deurenberg-Yap, 2003; Werkman, Deurenberg-Yap, Schmidt, & Deurenberg, 2000). Moreover, the hydration of FFM was shown to be different between Dutch Caucasians and the groups of Asians (Deurenberg-Yap et al., 2001; Werkman et al., 2000), though these differences are probably negligible for body composition measurement (Deurenberg & Deurenberg-Yap, 2003). Also, there seem to be variations in the proportion of protein in FFM across different ethnic groups; however, protein fractions may depend on gender as well as ethnicity (Deurenberg-Yap et al., 2001; Deurenberg & Deurenberg-Yap, 2003; Werkman et al., 2000).

Physical Activity

It is well established that regular physical activity helps to lose weight and prevent weight regain (Donnelly et al., 2009; Physical Activity Guidelines Advisory Committee, 2008). Research suggests that physical activity ranging 13 to 26 MET-hours per week (MET = metabolic equivalent) can result in modest weight loss (up to 1–3% decrease), as 13 MET-hours per week of physical activity is equivalent to walking at a 4-mph pace for 150 min per week or jogging at a 6-mph pace for 70 min per week (Physical Activity

Guidelines Advisory Committee, 2008). The American College of Sports Medicine recommends 150–250 min per week of moderate-intensity physical activity (expending 1,200–2,000 kcal/week) for preventing weight gain greater than 3% and for achieving modest weight loss (up to 2–3 kg decrease) (Donnelly et al., 2009).

There appears to be a dose-response relation between physical activity and weight loss (Donnelly et al., 2009; Physical Activity Guidelines Advisory Committee, 2008). In cross-sectional observations, groups of healthy men aged 40–75 years who engaged in 0.9, 4.8, 11.3, 22.6, and 46.8 MET-hours per week of physical activity had mean BMI values of 25.4, 25.3, 25.1, 24.7, and 24.4 kg/m^2, respectively (Giovannucci et al., 1995). Similarly, Larsson and colleagues (Larsson, Rutegard, Bergkvist, & Wolk, 2006) reported that 10 min or less, 10–59 min, and 60 min or more per day of leisure-time physical activity corresponded to mean BMI values of 26.7, 25.9, and 25.5 kg/m^2, respectively, among 45,906 Swedish male adults. In a randomized control trial, McTiernan and coworkers (2007) investigated the changes in body fatness parameters based on steps per day. According to the results of the study, both men and women showed greater reductions in weight as steps per day increased. Specifically, increasing up to 1,760 steps, 1760–3520 steps, and more than 3520 steps per day resulted in weight losses by 1.4%, 0.3%, and 3.9% in men and by 0.1%, 1.2%, and 2.3% in women, respectively.

Physical Activity Guidelines Advisory Committee Report (2008) summarized that the recommended amount of physical activity (i.e., 13–26 MET-hours per week) typically results in 1–3% of weight loss, and engaging in higher amounts of physical activity could result in greater weight losses (e.g., 4–6%). According to the American College of Sports

Medicine (Donnelly et al., 2009), less than 150 min/week of physical activity promotes minimal weight loss, greater than 150 min/week of physical activity can achieve modest weight loss (up to 2–3 kg), and 225–420 min/week of physical activity can achieve weight loss ranging from 5 kg to 7.5 kg.

Evidence also shows that regular physical activity even without caloric restriction helps to lose body weight and body fat, including total and abdominal adiposity, in overweight and obese individuals (Physical Activity Guidelines Advisory Committee, 2008). Ross et al. (2000) reported that aerobic exercise training alone (expending 700 kcal/day for 12 weeks) caused substantial reductions in body weight (–7.6 kg), total fat (–6.1 kg), abdominal fat (–1.9 kg), and visceral fat (–1.0 kg) among obese men. In particular, individuals with higher levels of initial body fat tend to attain greater body fat loss by exercise (Forbes, 2000). It appears that both endurance exercise and resistance exercise are effective in reducing FM (0.4–3.2 kg decrease by endurance exercise; 0.9–2.7 kg decrease by resistance exercise), while resistance exercise can induce an additional benefit of increasing FFM (Toth, Beckett, & Poehlman, 1999). The change in FM by endurance exercise seem to depend on the duration of exercise, whereas this does not seem to be the case for resistance exercise (Toth et al., 1999).

Regarding the dose-response relation between physical activity and body fat loss, Ross and Janssen (2001) reviewed studies investigating the effects of physical activity on body fatness and summarized that physical activity with greater energy expenditure can result in greater body fat loss (i.e., dose-response manner). Williams, Teixeira, and Going (2005) also analyzed exercise trials employing reliable body composition assessment techniques. They support the findings by Ross and Janssen (2001), suggesting the dose-response relation between physical activity and body fat loss (Williams et al., 2005). In a recent randomized control trial, Slentz and colleagues (2005) looked at the effects of different exercise volumes on the changes in body fatness parameters among overweight men and women. The study included the following four conditions: 1) high amount, vigorous intensity exercise (equivalent to jogging 20 miles/week); 2) low amount, vigorous intensity exercise (equivalent to jogging 12 miles/week); 3) low amount, moderate intensity exercise (equivalent to walking 12 miles/week); and 4) no exercise (control). After 8 months of the interventions, the high amount, vigorous intensity exercise group achieved the highest losses in visceral, subcutaneous, and total abdominal fat (6.8–7.0% decrease). On the other hand, the changes in body fat measures were statistically significant but minimal (up to 1.2% decrease) in the other two exercise groups and were not significant in the control group. It has been suggested that if more physical activity than the recommended amount is done (e.g., 42 MET-hours per week), a reduction in intra-abdominal adipose tissue can be 3–4 times as the level achieved with the recommended amount of physical activity (i.e., 13–26 MET-hours per week) (Physical Activity Guidelines Advisory Committee, 2008; Ross et al., 2004).

In addition to weight and body fat losses, regular physical activity has positive effects on FFM (Williams et al., 2005). It is well known that skeletal muscle mass can be maintained or increased by engaging in physical activity, especially in resistance training (Physical Activity Guidelines Advisory Committee, 2008). For example, resistance training with intensity of 70–85% of one repetition maximum with 8–12 repetitions per set, 1–3 sets per exercise, and 2–4 times per week of training sessions can maximize an increase in muscle mass for novice and intermediate individuals (Ratamess et al., 2009).

According to Toth et al. (1999), resistance training for 3–4 months can result in a 1.1 kg to 2.1 kg increase in FFM. BMD can also be increased by engaging in exercise and weight-bearing activities, in particular (Kohrt et al., 2004). The importance of mechanical loading for maintaining optimal bone density is well documented (Heaney et al., 2000). In general, athletes tend to have a higher BMD than do nonathletes (Evans, Prior, Arngrimsson, Modlesky, & Cureton, 2001). It is likely that BMD can be increased by 1% to 2% after up to 1 year of exercise training (Physical Activity Guidelines Advisory Committee, 2008). Regarding exercise programs with longer durations, Friedlander and colleagues (Friedlander, Genant, Sadowsky, Byl, & Gluer, 1995) demonstrated that a 2-year exercise program including both aerobics and weight training resulted in a 1.3–5.6% increase in BMD (depending on region) among young women aged 20–35 years. Furthermore, Cussler et al. (2005) showed that an increase in BMD accomplished during the first year of exercise training could be maintained up to 4 years by continuing exercise. The American College of Sports Medicine (Kohrt et al., 2004) recommends 30–60 min per day of weight-bearing activities 3–5 times per week or resistance exercise 2–3 times per week during adulthood for promoting bone health.

Physical Disability and Obesity

Literature indicates that people with physical disabilities have a 1.2- to 3.9-fold increase in obesity prevalence compared with the general population (Liou et al., 2005), as obesity is defined as BMI of 30 kg/m^2 or greater (World Health Organization, 2000). According to the data from the 1994–1995 National Health Interview Survey, the 1994–1995 Disability Supplement, and the 1995 Healthy People 2000 Supplement (total *N* =

25,626), people with extremity disabilities were 1.5 to 2.5 times as likely to be obese as those without such disabilities, and people with lower extremity disabilities had the highest risk of obesity (Weil et al., 2002). The Centers for Disease Control and Prevention (2002) reported that 27.4% of people with disabilities were classified as obese compared to 16.5% of those without disabilities, while 18.4% of a total sample (*N* = 52,037) were classified as obese. The Health and Retirement Study conducted in 1994, 1996, and 1998 (total *N* = 19,018) revealed that individuals who had functional impairment in performing daily activities had a higher percentage of obesity than did those who had no functional impairment (36.3% vs. 22.4%) (Jenkins, 2004). According to the 1997–1998 National Health Interview Survey (*N* = 30,526), 26.8% to 40.5% of women with mild to severe functional limitations were obese, whereas 14.1% of those without such limitations were obese (Jones & Bell, 2004). Havercamp, Scandlin, and Roth (2004) reported that, of the 6,902 study participants, the prevalence of either overweight or obese was 66.2% for people with disabilities and 56.8% for those without disabilities.

Physical Disability and Changes in Body Composition

Research shows that physical disability is associated with various changes in body composition (Liou et al., 2005). For example, people with spinal cord injury (SCI) tend to have increased FM, higher %BF, decreased FFM or LBM, and lower BMD or BMC compared with able-bodied counterparts (Kocina, 1997; Liou et al., 2005). Jones and colleagues in their earlier study (Jones et al., 1998) found that male adults with paraplegic SCI (*n* = 5; mean age = 32.6 years) showed 16% and 12% reductions in LBM and BMC and a 47% increase in total FM compared with 10 age- and height-matched able-bodied controls when they were tested by DXA. In their later study using DXA (Jones, Legge, & Goulding, 2003), men with paraplegic SCI (*n* = 19; mean age = 34 years) carried 8.9 kg less FFM and 7.1 kg more FM (9.4% more %BF) than did 19 age-, height-, and weight-matched able-bodied counterparts despite similar BMI values between the groups. Modlesky and coworkers (2004) examined body composition of eight men with paraplegic and quadriplegic SCI (mean age = 35 years) and eight able-bodied controls with similar age, height, and weight. The researchers reported that FFM (measured by DXA) and muscle mass (measured by MRI) of the SCI individuals were significantly lower than those of the able-bodied counterparts. In addition, the SCI group showed a significantly higher %BF than did the able-bodied group (33.8% vs. 16.2%).

Maggioni and colleagues (2003) compared body composition between 13 male paraplegic SCI patients (mean age = 33.8 years) and 13 age- and BMI-matched able-bodied males using DXA. According to the results of the study, there were a significantly higher total FM and a lower total FFM observed in the SCI group than in the able-bodied group, whereas total BMD did not significantly differ between the groups. In addition, the SCI patients carried a higher FM in the legs and trunk and showed a lower BMD in the legs than did the able-bodied controls. The authors noted that these results were potentially due to a lack of gravity load experienced by the SCI individuals. On the other hand, the SCI group had a significantly higher FFM in the arms than did the able-bodied group, indicating the importance of physical movement on preserving FFM.

Some studies examined body composition of people with SCI while accounting for the difference in disability type or functional capacity (Rasmann Nuhlicek et al., 1988;

Spungen et al., 2003; Tsuzuku, Ikegami, & Yabe, 1999). Rasmann Nuhlicek et al. (1988) classified 37 males with SCI (19–49 years old) based on residual motor function: low paraplegia (*n* = *3*; lesions = T10 or below; able to walk with difficulty using crutches and braces but completely independent in a manual wheelchair and in all other daily activities), high paraplegia (*n* = 15; lesions = T1–T10; completely independent in a manual wheelchair and in most daily activities), low quadriplegia (*n* = 11; lesions = C6–T1; able to manually propel a wheelchair and fairly independent with minimal assistance for some daily activities), and high quadriplegia (*n* = 8; lesions = C6 or higher; unable to manually propel a wheelchair and completely dependent on others for daily activities). The researchers then compared body composition using hydrometry (assessment of body water) among these groups in addition to a group of 10 able-bodied individuals. Age, height, weight, and BMI between the groups did not differ significantly. The results of the study showed that there were a significantly higher %BF and a lower LBM observed among the individuals with high paraplegia, low quadriplegia, and high quadriplegia compared with the able-bodied controls and those with low paraplegia. Furthermore, the high quadriplegia group showed the lowest FFM of the five groups. The authors indicate that residual motor function is a key to favorable body composition in people with SCI. However, it should be mentioned that the low paraplegia group had only 3 participants, which made it difficult to generalize the results of the study.

A cross-sectional study by Tsuzuku, Ikegami, and Yabe (1999) revealed that BMD (measured by DXA) in the lumbar spine, trochanter region, and upper extremities were significantly lower among 10 quadriplegic men with SCI (mean age = 44.1 years) than among 10 paraplegic counterparts (mean age = 30.2 years), whereas no significant group differences in BMD were observed in the femoral neck and head, Ward's triangle, pelvis, lower extremities, and whole body. A study by Garland et al. (1992) also reported that paraplegic and quadriplegic patients with SCI differed in arm and trunk BMD but were similar in pelvis and leg BMD. Spungen and associates (2003) conducted a body composition study with DXA that included SCI males with paraplegia (*n* = 67; mean age = 37 years) and quadriplegia (*n* = 66; mean age = 40 years), along with 100 able-bodied controls (mean age = 44 years). The researchers found that both paraplegic and quadriplegic groups showed a significantly higher total FM and a lower total LBM and BMC than did the control group. Moreover, these measures were significantly worse among the quadriplegic individuals than among the paraplegic individuals.

Research also suggests that people with SCI are subject to osteoporosis, which will increase the risk of bone fractures (Jiang, Dai, & Jiang, 2006). Kiratli and colleagues (2000) investigated the influence of immobilization on bone mineral properties in persons with SCI using DXA. The researchers found that men and women with paraplegic and quadriplegic SCI (*n* = 246; age = 19–81 years) showed a significant reduction in BMD in the various femoral regions (–27%, –25%, and –43% for the femoral neck, midshaft, and distal femur, respectively) compared with ambulatory male and female adults (*n* = 118; age = 19–83 years). According to Kaya and coworkers (Kaya, Aybay, Ozel, Kutay, & Gokkaya, 2006), BMD values at the lumber and hip, including the femoral neck, Ward's triangle, trochanter, and femoral shaft, were all significantly lower among males and females with paraplegic and quadriplegic SCI (*n* = 75; mean age = 33.0 years) than among healthy male and female controls (*n* = 39; mean age = 35.7 years). In another study, 25 out of 41 men (61.0%) with traumatic or ischemic SCI were found to have osteoporosis based on the World Health Organization criteria (Lazo et al., 2001).

Maimoun and colleagues (2002) looked at the changes in body composition during the acute phase of SCI. The researchers assessed body composition of seven males recently sustaining SCI (mean age = 31.3 years; average period since injury = 3 months) using DXA and compared their data to those of 10 able-bodied individuals. Age, height, weight, and BMI were not significantly different between the two groups. The study found that the individuals with SCI had a significantly higher %BF (23.9% vs. 18.2%) and a lower FFM (45.2 kg vs. 50.5 kg) than did the able-bodied controls. On the other hand, no significant between-groups differences in any regional or total BMD were observed except in the upper limbs. However, bone biochemical markers indicated a substantial demineralization process caused by immobilization.

Of the studies for individuals with injuries/diseases other than SCI, Takamoto et al. (1995) assessed BMD of 112 men and women with hemiplegia caused by stroke (mean age = 68.3 years) using DXA. The investigators found significantly lower BMD values in the paretic side among these individuals, including the femoral neck (–6.6%), total femur (–8.8%), trochanter (–10.4%), and Ward’s triangle (–10.3%). Jorgensen and Jacobsen (2001) used DXA and looked at the changes in body composition of 25 patients with hemiplegia aged 60 years or older during the first year after they had suffered from stroke. BMC significantly decreased 1 year after the stroke in both paretic and nonparetic legs, however the paretic side showed a greater BMC loss than did the nonparetic side. The reduction in LBM was observed only in the paretic leg. Ryan and coworkers (Ryan, Dobrovolny, Smith, Silver, & Macko, 2002) examined 60 patients with chronic hemiparetic stroke (47 men and 13 women; mean age = 65 years) using DXA and computed tomography. The results of the study showed that there were a significant decrease in LBM and an increase in intramuscular fat in the hemiparetic limb compared to the nonaffected limb.

McCrory and colleagues (1998) evaluated body composition of 15 men (mean age = 43.4 years) and 11 women (mean age = 48.1 years) with neuromuscular disease using ADP. The study then compared their body composition parameters to those of able-bodied men (*n* = 11) and women (*n* = 8) with similar age and body weight. The researchers found that both men and women with neuromuscular disease had a significantly higher %BF and a lower FFM than did the able-bodied controls. According to the study by Lambert, Lee Archer, and Evans (2002), there was no significant difference in %BF or FFM estimated by ADP between 17 women with multiple sclerosis and 12 able-bodied individuals. However, the authors pointed out a small sample size as a potential factor for no statistical between-groups differences in these measures.

Exercise and Obesity in People with Physical Disabilities

As discussed earlier, the effects of physical activity or exercise on reducing the risk of obesity are well known in the general population (Donnelly et al., 2009; Physical Activity Guidelines Advisory Committee, 2008). However, there are a limited number of related studies focusing on people with physical disabilities. Bostom and colleagues (1991) assessed anthropometric measures of nine males with paraplegic SCI (mean age = 30.6 years) who participated in leisure-time physical activity and recreational adapted sports programs (e.g., wheelchair tennis). According to the report, their average height and weight were 171.1 cm and 74.2 kg, respectively, resulting in a mean BMI of 25.3 kg/m^2 for these individuals. Slawta et al. (2002) examined the relationship between intensity of leisure-time physical activity and BMI among women with multiple sclerosis. The researchers classified the participants according to intensity of physical activity: light-intensity physical activity (n = 47; mean age = 50.7 years; intensity comparable to walking pace of 2–3 mph), moderate-intensity physical activity (n = 40; mean age = 48.9 years; intensity comparable to walking pace of 3–4 mph), heavy-intensity physical activity (n = 17; mean age = 45.8 years; intensity comparable to walking pace above 4 mph), and physical inactivity (n = 19; mean age = 53.4 years; not walking more than a few min each day). The study revealed that the light- and moderate-intensity physical activity groups both had a mean BMI of 26.0 kg/m^2, whereas BMI of those engaging in heavy-intensity physical activity was, on average, 23.1 kg/m^2. On the other hand, a mean BMI of the physically inactive women was found to be 30.4 kg/m^2.

Some studies looked at the association of structured exercise programs to the risk of obesity in people with physical disabilities (Bulbulian, Johnson, Gruber, & Darabos, 1987; Mojtahedi, Valentine, Arngrimsson, Wilund, & Evans, 2008; Mojtahedi, Valentine, & Evans, 2009). Bulbulian and associates (1987) examined 22 college-aged male athletes with paraplegic SCI (mean age = 27.5 years) who participated in a wide variety of sports (e.g., wheelchair basketball, racing) and were moderately trained to competitively conditioned. Calculated from height and weight data, a mean BMI value of these SCI athletes was 22.3 kg/m^2. Mojtahedi and colleagues (2008) reported a mean BMI of 22.2 kg/m^2 for 14 male and female college athletes with paraplegic SCI (mean age = 22.5 years) who engaged in 12 hr of sport-specific training and 3 hr of resistance training per week. Mojtahedi et al. (2009) in another study examined college-aged varsity athletes with SCI who had the similar injury level and training status. According to the results of the study, mean BMI values of eight male and eight female athletes were 22.5 kg/m^2 and 20.8 kg/m^2, respectively.

Ribeiro and coworkers (Ribeiro, da Silva, de Castro, & Tirapegui, 2005) investigated the relationship between sports participation and anthropometric measures in persons with paraplegic SCI (n = 28) and poliomyelitis (n = 32) aged 18–40 years. All participants practiced wheelchair basketball for at least 1 hr per day and 3 days per week. The authors reported that a mean BMI was 22.0 kg/m^2 for those with SCI and 23.0 kg/m^2 for those with poliomyelitis. Two studies examined males with paraplegic SCI (N = 25 and 28; mean age = 35.6 and 34.7 years) who participated in some types of adapted sports programs, including wheelchair basketball, track and field, and wheelchair tennis (Inukai, Takahashi, Wang, & Kira, 2006; Miyahara et al., 2008). In both studies, a mean period of their athletic careers was about 10 years, and the participants practiced their sports, on average, 3–4 days/week and 8–10 hr/week. The studies found mean BMI values of 22–24 kg/m^2 among these athletes. Ide and colleagues (Ide, Ogata, Kobayashi, Tajima, & Hatada, 1994) observed more than 800 wheelchair marathon racers with SCI in six different years for a 10-year period. From height and weight data, it was calculated that the racers' mean BMI ranged between 20 kg/m^2 and 23 kg/m^2 in those years.

There are a few studies that evaluated physical profiles of elite wheelchair athletes (Dwyer & Davis, 1997; Zwiren & Bar-Or, 1975). Zwiren and Bar-Or (1975) analyzed anthropometric measures of the following four groups of male individuals: 1) wheelchair-bound athletes with poliomyelitis or traumatic paraplegia (n = 11; mean age = 27.5 years) competing internationally in sports, including basketball, swimming, and javelin; 2) wheelchair-bound sedentary individuals with the same disabilities (*n* = 9; mean age = 29.1 years); 3) able-bodied athletes (*n* = 13; mean age = 26.7 years) competing internationally in sports, including basketball, swimming, discus, and wrestling; and 4) able-bodied sedentary individuals (*n* = 8; mean age = 31.0 years). From height and weight data, it was found that mean BMI values of the wheelchair-bound male athletes, the wheelchair-bound sedentary men, the able-bodied male athletes, and the able-bodied sedentary men were 21.0, 24.4, 24.2, and 23.5 kg/m^2, respectively. Dwyer and Davis (1997) examined 13 female wheelchair-bounded basketball players (mean age = 26.0 years) who were the members of the 1994 U.S. National Women's Wheelchair Basketball team and competed in the International Federation Games. The study found a mean BMI of 21.9 kg/m^2 among the players.

Based on the results of the studies reviewed, persons living with physical disabilities but staying physically active tend to have BMI values below the obesity criterion (i.e., less than 30 kg/m^2). This finding does not agree with the literature indicating that people with physical disabilities have a higher prevalence of obesity (Liou et al., 2005). However, it has been well documented that regular physical activity helps to achieve and maintain optimal weight and BMI for the general population (Donnelly et al., 2009; Physical Activity Guidelines Advisory Committee, 2008). In addition, Slawta et al. (2002) and Zwiren and Bar-Or (1975) showed that BMI of individuals with physical disabilities engaging in regular physical activity or exercise training was lower than that of sedentary or inactive individuals regardless of whether they had disabilities or not. Furthermore, the results of the study by Slawta et al. (2002) indicated an inverse relationship between intensity of physical activity and BMI among women with multiple sclerosis, as this relationship has been observed in the general population (Aadahl, Kjaer, & Jorgensen, 2007; Bernstein, Costanza, & Morabia, 2004). Therefore, physical inactivity, not physical disabilities, appears to be a major determinant of BMI and obesity among people with physical disabilities.

It should be noted that there are limitations associated with using BMI to determine whether individuals with physical disabilities are obese or not. As mentioned previously, BMI does not take into account the proportions of FM and FFM in the body, which does not allow for assessing obesity based on the amount of FM. In addition, recumbent length, often used instead of height when a person with a disability cannot stand and maintain straight posture, may not provide an accurate measure of BMI. Consequently, it is not clear whether the BMI standards for the general population are appropriate to be used for people with physical disabilities. For example, it has been suggested that the traditional BMI standards tend to underestimate obesity in people with SCI, and thus it is necessary to develop new BMI criteria for this population (Buchholz & Bugaresti, 2005; McDonald, Abresch-Meyer, Nelson, & Widman, 2007). However, BMI is practical and easy to obtain and therefore is suitable for large epidemiological studies. It will be ideal if future research is conducted and new BMI criteria are developed for clinical populations.

Exercise and Body Composition in People with Physical Disabilities

Several studies investigated the association between exercise or sports participation and body composition in people with physical disabilities. A majority of the studies examined male individuals with SCI, and the most common technique used for assessing body composition in these studies was DXA. Jones, Legge, and Goulding (2002) looked at the association of intensive exercise training to bone mass in persons with SCI using DXA. The study included 17 males with paraplegic and quadriplegic SCI (mean age = 32 years) and 17 able-bodied controls with similar age, height, weight, and BMI. The participants in both groups engaged in more than 60 min per week of physical activity (average of 442 min/week in SCI group and 367 min/week in able-bodied group). According to the results of the study, there were no significant differences in lumbar BMD and arm BMD and BMC between the two groups. In contrast, BMD values in the hip and total body were significantly lower among the SCI males than among the able-bodied controls. Moreover, the SCI group showed significantly lower BMD and BMC in the legs than did the able-bodied group. In their later study (Jones, Legge, & Goulding, 2004), body composition was compared between men with paraplegic and quadriplegic SCI (*n* = 20; mean age = 33.0 years) and age-, height-, and weight-matched able-bodied controls (*n* = 20) using DXA. The participants in both groups were highly active, as those in the SCI and able-bodied groups engaged in 376 min and 312 min per week of physical activity, respectively. The study revealed that the SCI group had %BF of 27.5% compared to 17.8% for the able-bodied group.

Ribeiro and colleagues (2005) used DXA and looked at body composition parameters of male wheelchair basketball players with paraplegic SCI and poliomyelitis who practiced for at least 1 hr/day and 3 days/week. The researchers found that %BF values of the SCI and poliomyelitis groups were 20.6% and 25.2%, respectively. In addition, high percentages (64.3–85.6%) of those with SCI and poliomyelitis had BMD z scores of less than –2.0 standard deviations relative to the reference population in the legs, indicating a significant bone loss in that region. Mojtahedi et al. (2008) reported a mean %BF of 22.2 % estimated by DXA among college-aged male and female varsity athletes with paraplegic SCI, while BMI-matched able-bodied controls who were sedentary had %BF of 26.5%. Furthermore, the SCI group showed a significantly lower LBM than did the able-bodied group. In another study by Mojtahedi and coworkers (2009), male and female college-aged varsity athletes with paraplegic SCI were found to have mean %BF values of 20.6% and 31.9%, respectively, when they were tested by DXA.

According to Inukai et al. (2006), male athletes with SCI who engaged in various adapted sports programs (wheelchair basketball, track and field, wheelchair tennis) had a mean %BF of 25.5%, as it was assessed by DXA. The researchers also found that %BF was significantly higher in the leg region (%BF ≈ 35%) than in other parts of the body (%BF ≤ 23%), among older individuals (40–55 years old; %BF = 28.6%) than among younger ones (20–39 years old; %BF = 23.0%), among those with 15 years or more since injury (%BF = 27.6%) than among those with less than 15 years since injury (%BF = 22.5%), and among those exercising less than 7 hr (%BF = 27.9%) than among those exercising 7 hr or more (%BF = 21.8%). In another study, a mean %BF of male wheelchair athletes with SCI who played various sports was found to be 24.0% (estimated by DXA), whereas their able-bodied counterparts who were triathletes, track and field athletes, and bicycle racers had a mean %BF of 12.8% despite their similar BMI values (22.6 kg/m^2 vs. 21.5 kg/m^2) (Miyahara et al., 2008). The significant between-groups differences in %BF were observed in the arms, legs, and body trunk, as well as the whole body. In addition, the wheelchair athletes showed a significantly lower LBM in each of the body parts than did the able-bodied athletes except for the arms in which the wheelchair athletes showed a significantly higher value, instead. Moreover, compared with the able-bodied athletes, BMD of the wheelchair athletes was significantly lower in the entire body (95.0% of able-bodied athletes; 1.153 g/cm^2 vs. 1.214 g/cm^2) and legs (76.5% of able-bodied athletes; 1.052 g/cm^2 vs. 1.373 g/cm^2). In contrast, the wheelchair athletes showed a significantly higher BMD in the arms than did the able-bodied counterparts (0.896 g/cm^2 vs. 0.856 g/cm^2). Furthermore, time since injury was negatively related to BMD in the legs, body trunk, and entire body (r = 0.414–0.549).

Besides using DXA, some studies employed other techniques to assess body composition of individuals with SCI. Bostom et al. (1991) looked at body composition of physically active men with paraplegic SCI using HW. The study showed that these individuals had %BF of 28.7% on average, while their mean BMI was 25.3 kg/m^2. Bulbulian and coworkers (1987) found that moderately trained to competitively conditioned college-aged male athletes with paraplegic SCI had a mean %BF of 22.3%, assessed by HW. On the other hand, two groups of able-bodied college-aged athletes (ectomorphs and mesomorphs) with the similar training status had mean %BF values of 8.3% and 11.3%, respectively. Olle and colleagues (Olle, Pivarnik, Klish, & Morrow, 1993) compared body composition among men with paraplegic and quadriplegic SCI (mean age = 32.4 years) based on their physical activity levels using total body electrical conductivity (TOBEC). The study reported that those who exercised 2 days per week and for 120 min per week at high/competitive intensity (n = 12) had a mean %BF of 15.6% compared to 23.3% of those who did not engage in any habitual physical activity (n = 5). Furthermore, the physically active group had a significantly higher percentage of FFM than did the sedentary group (84.4% vs. 76.7 %). Ide et al. (1994) evaluated body composition of wheelchair marathon racers with SCI using SKF measurements for a 10-year period. The researchers found that the racers' mean %BF was about 18% regardless of race performance.

Slawta et al. (2002) investigated the relationship between intensity of physical activity and %BF in women with multiple sclerosis using SKF measurements. The study revealed that those who engaged in heavy-intensity leisure-time physical activity (comparable to walking pace above 4 mph) had the lowest %BF (30.8%), whereas their physically inactive counterparts (i.e., no habitual leisure-time physical activity) showed the highest %BF (41.3%). %BF values of women who engaged in light- (comparable to walking pace of 2–3 mph) and moderate-intensity (comparable to walking pace of 3–4 mph) leisure-time physical activity were 37.6% and 37.2%, respectively.

A few studies examined body composition of elite wheelchair athletes who competed nationally and internationally (Dwyer & Davis, 1997; Zwiren & Bar-Or, 1975). Zwiren and Bar-Or (1975) used SKF measurements and compared %BF among wheelchair-bound male athletes and sedentary men and able-bodied male athletes and sedentary men. According to the results of the study, %BF values of the wheelchair-bound athletes (international caliber) and their sedentary counterparts were 17.4% and 21.9%, respectively, whereas the able-bodied athletes (national Israel teams) and their sedentary counterparts each had a mean %BF of 12.5% and 18.3%. Dwyer and Davis (1997) estimated %BF of the 1994 U.S. National Women's Wheelchair Basketball members using SKF measurements and reported that their mean %BF was 23.3%.

Compared to BMI, there is more variability of the data in %BF across the studies. The majority of the studies, however, have shown that individuals with physical disabilities who are physically active or athletes tend to have a lower %BF than do their inactive or sedentary counterparts. This finding may indicate that regular physical activity is effective in improving body composition in clinical populations as well as the general population. On the other hand, when compared with able-bodied individuals who are physically active or athletes, %BF of those with physical disabilities tend to be still higher even if they participate in regular exercise programs or sports activities. This may be because, despite engaging in exercise or playing sports, persons with physical disabilities have difficulty in maintaining muscle mass because of the limited ability to contract muscles, especially in the lower body. This assumption could explain the general trend seen in the studies reviewed that physically active individuals with disabilities had normal levels of BMI but higher %BF values. A person could lose weight and thus have a lower BMI by losing FFM, but he/she could also have a higher %BF with losing FFM or muscle mass.

CHAPTER 3

METHODOLOGY

Participants

Thirty six male adults with physical disabilities volunteered to participate in the study. All participants used a manual wheelchair for daily activities due to disabilities from various injuries and diseases, including spinal cord injury (*n* = 29), spina bifida (*n* = 3), cerebral palsy (*n* = 2), and muscular dystrophy (*n* = 1), and Friedreich's ataxia (*n* = 1). Some of the injuries and diseases were congenital, whereas others were acquired (e.g., automobile accident). Physical characteristics of the participants are presented in Table 1. Prior to the study, each participant read and signed an informed consent form approved by the University's Institutional Review Board.

The participants were classified according to physical activity level (active or inactive) and disability type (paraplegia or quadriplegia). In the current study, physically active individuals were defined as those participating in year-round adapted sports programs, including wheelchair basketball and wheelchair rugby, for at least the past 2 years. It was reported that they practiced their sports for an average of 1.5 hr per day twice a week during the season (lasting 8–9 months depending on sports) and once a week during the off-season. In contrast, those who were classified as physically inactive did not participate in any adapted sports or structured exercise programs. The participants with paraplegia had paralysis of trunk and lower limbs, whereas those with quadriplegia had paralysis of trunk and all four extremities. Therefore, each participant was classified into one of the following four groups: 1) active paraplegia, 2) active quadriplegia, 3) inactive paraplegia, and 4) inactive quadriplegia.

Table 1. Participants Characteristics

	Physically active		Physically inactive	
	Paraplegia	Quadriplegia	Paraplegia	Quadriplegia
Count (*n*)	15	9	7	5
Age (year)	38.9 ± 9.5	33.3 ± 5.8	39.6 ± 8.0	38.2 ± 1.9
Height (cm)	172.8 ± 12.3	181.4 ± 6.2	178.9 ± 4.8	183.0 ± 7.3
Weight (kg)	76.9 ± 16.4	70.7 ± 9.1	80.0 ± 16.0	70.4 ± 16.7
BMI (kg/m^2)	26.0 ± 6.7[a]	21.5 ± 2.2	24.8 ± 4.1[a]	20.8 ± 3.7
Time since injury/disease (year)	23.5 ± 14.5	17.7 ± 10.8	20.1 ± 13.6	12.2 ± 5.0

Note. Values are M ± SD. BMI = body mass index.
[a] Significant difference from quadriplegic group ($p < 0.05$).

Height and Weight Measurements

Recumbent length, used as the height of the participant, was measured (to the nearest 0.5 cm) from the top of the head to the extended limb with an anthropometric tape measure while he was lying supine. Body weight of the participant was measured (to the nearest 0.1 kg) while he was sitting on a standard physician scale placed on a box (see Figure 1). The scale was calibrated before the weight measurement. During the weight measurement, it was ensured that the participant’s feet were free from any support or did not touch the floor. Body mass index (BMI; kg/m^2) was calculated as weight (kg) divided by height (m) squared.

Figure 1. Body weight measurement

Body Composition Assessment

Regional and whole-body percent body fat (%BF; percentage), lean body mass (LBM; kg), and bone mineral density (BMD; g/cm^2) were measured by dual-energy X-ray absorptiometry (DXA; GE LUNAR Corporation, Madison, WI). Prior to testing, DXA was calibrated using a known marker provided by the manufacturer. After the height and weight measurements, the participant was asked to remove his shoes and anything metal. With minimal clothing, the participant was instructed to lie supine on the DXA scanner bed. Assistance was provided if needed, when the participant was moving from his wheelchair to the scanner bed. The participant was positioned properly according to the manufacturer's instructions. The participant's arms rested besides the body, and his legs were strapped around the knees and ankles (see Figure 2). After the participant data were entered (birth date, gender, ethnicity, height, weight), the scanning took place from the head to the toes. %BF, LBM, and BMD in the regional body parts (arms, legs, and trunk) and whole body were estimated using the DXA software.

Figure 2. Body composition assessment by dual-energy X-ray absorptiometry (DXA)

Data Analysis

The current study employed a 2 x 2 between-groups design. The independent variables were physical activity level (active and inactive) and disability type (paraplegia and quadriplegia). Because of relatively small sample sizes, particularly for the inactive, paraplegic and quadriplegic groups, as well as unequal sample sizes among the four groups, all measured variables were transformed into ranks in order to perform the following statistical tests in a nonparametric fashion (Conover & Iman, 1982; Milliken & Johnson, 2002). Nonparametric statistical tests are distribution-free tests and are appropriate to use when the assumptions of parametric tests, such as normality and equal variances, are not met or sample sizes are relatively small. Preliminary analyses compared age, height, weight, BMI, and time since injury/disease among the four groups using a two-way between-groups analysis of variance (ANOVA). Then, a two-way between-groups multivariate analysis of covariance (MANCOVA) with age, BMI, and time since injury/disease as covariates was performed on each set of the regional (i.e., arms, legs, and trunk) and whole-body %BF, LBM, and BMD in order to examine any between-groups differences. Adjusting the body composition measures by these covariates was necessary because age, BMI, and time since injury/disease have been shown be associated with body composition parameters (Dontas & Yiannakopoulos, 2007; Gallagher et al., 2000; Guo et al., 1999; Miyahara et al., 2008). There were three sets of the combined dependent variables: 1) regional and whole-body %BF, 2) regional and whole-body LBM, and 3) regional and whole-body BMD. In case of a significant result of a multivariate test, a separate follow-up analysis was conducted for each body part (e.g., %BF in the arms, legs, trunk, and whole body), while adjusting an alpha level using the Bonferroni adjustment to protect the inflation of type I error (new alpha = 0.05 / 4 = 0.0125).

CHAPTER 4

RESULTS

Preliminary Analyses

The two-way ANOVA showed that there was no significant difference in age, height, weight, or time since injury/disease among the groups ($p > 0.05$; see Table 1). On the other hand, BMI was significantly higher among the paraplegic individuals than among the quadriplegic ones ($p < 0.05$).

Comparison of Body Composition Measures

Table 2 shows the body composition measures (unadjusted raw values) of the participants. The two-way between-groups MANCOVA revealed that, after adjusting for age, BMI, and time since injury/disease, there was a significant difference in the combined %BF measures between the paraplegic and quadriplegic groups, $F(4, 26) = 5.20$, Wilks' $\Lambda = 0.56$, $p = 0.0032$, $\eta^2 = 0.45$. Therefore, the results for the %BF measures were analyzed separately using a Bonferroni adjusted alpha level of 0.0125. The follow-up analyses showed that %BF in the arms was significantly lower in the paraplegic group than in the quadriplegic group, $F(1, 29) = 8.07$, $p = 0.0081$, $\eta^2 = 0.22$, whereas the other %BF measures did not differ significantly between the two groups ($p > 0.05$; see Figures 3–6). The main effect for physical activity level [$F(4, 26) = 1.73$, Wilks' $\Lambda = 0.79$, $p = 0.1738$] and the interaction effect [$F(4, 26) = 0.49$, Wilks' $\Lambda = 0.93$, $p = 0.7466$] were not significant.

Table 2. Body Composition Measures Among Groups Based on Physical Activity Level and Disability Type (Unadjusted Raw Values)

		Active		Inactive	
		Paraplegia	Quadriplegia	Paraplegia	Quadriplegia
%BF (%)	Arms	18.3 ± 9.2	19.1 ± 6.7	22.5 ± 7.0	21.8 ± 7.9
	Legs	33.4 ± 10.8	26.1 ± 5.1	36.9 ± 6.9	27.5 ± 9.3
	Trunk	27.7 ± 13.9	18.6 ± 9.7	23.2 ± 7.8	17.5 ± 8.2
	Whole body	27.7 ± 10.0	20.8 ± 7.0	26.5 ± 5.0	20.9 ± 7.4
LBM (kg)	Arms	9.0 ± 1.9	6.5 ± 1.4	8.7 ± 2.0	5.6 ± 1.0
	Legs	14.6 ± 9.8	13.8 ± 2.3	12.4 ± 3.2	13.8 ± 1.2
	Trunk	25.1 ± 5.2	28.0 ± 2.4	30.0 ± 6.0	27.8 ± 5.2
	Whole body	50.2 ± 8.7	52.6 ± 4.6	55.3 ± 10.1	51.4 ± 7.5
BMD (g/cm^2)	Arms	1.11 ± 0.09	0.94 ± 0.11	0.97 ± 0.08	0.89 ± 0.09
	Legs	1.08 ± 0.20	0.97 ± 0.12	0.96 ± 0.10	0.95 ± 0.17
	Trunk	0.98 ± 0.16	0.78 ± 0.11	0.82 ± 0.12	0.79 ± 0.12
	Whole body	1.18 ± 0.12	1.03 ± 0.07	1.07 ± 0.07	1.02 ± 0.16

Note: Values are M ± SD. %BF = percent body fat; LBM = lean body mass; BMD = bone mineral density.

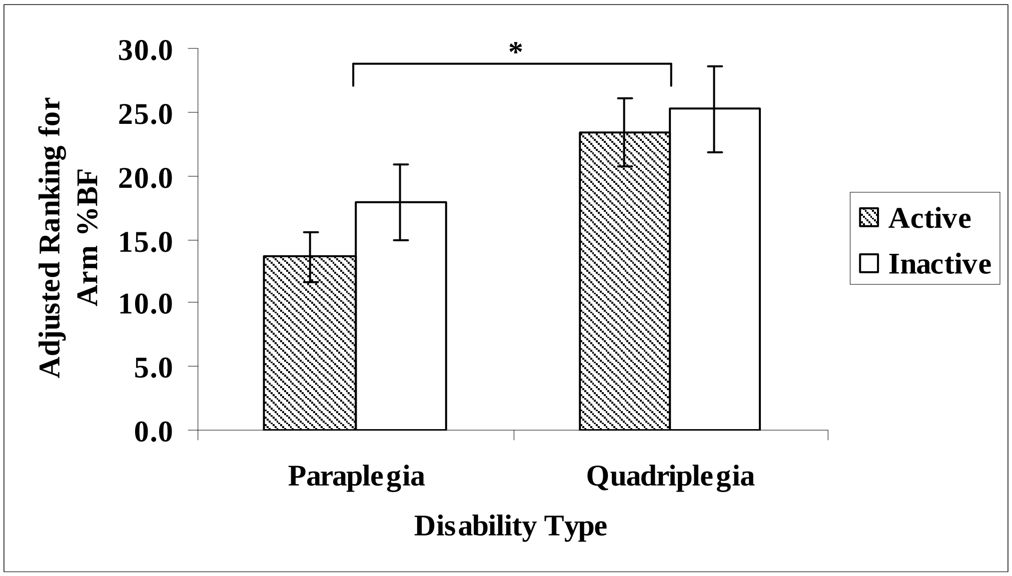


Figure 3. Differences in arm percent body fat (%BF) based on physical activity level and disability type after adjusting for age, body mass index, and time since injury/disease. [*]Significant difference between paraplegic and quadriplegic groups ($p < 0.01$).

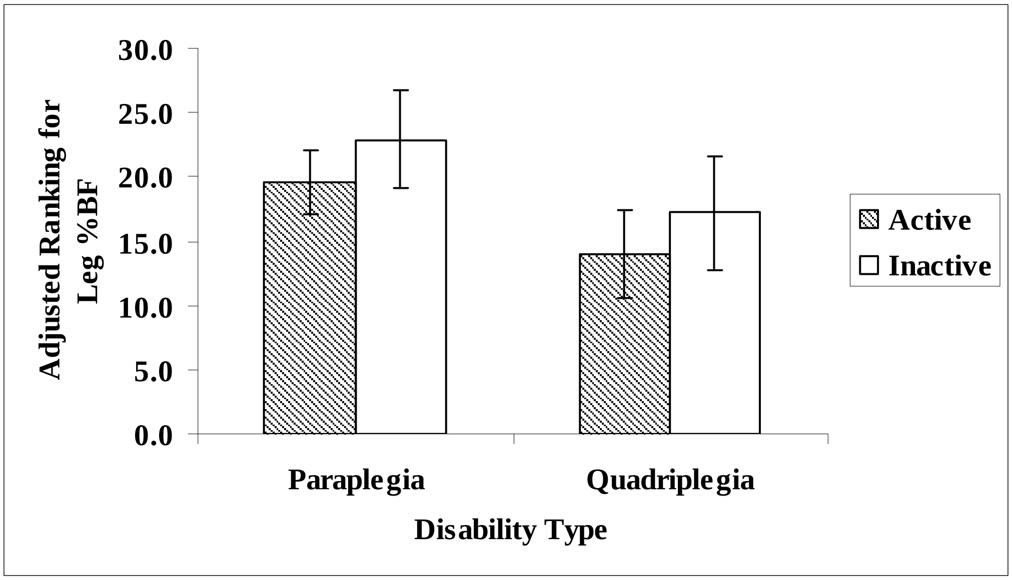


Figure 4. Differences in leg percent body fat (%BF) based on physical activity level and disability type after adjusting for age, body mass index, and time since injury/disease.

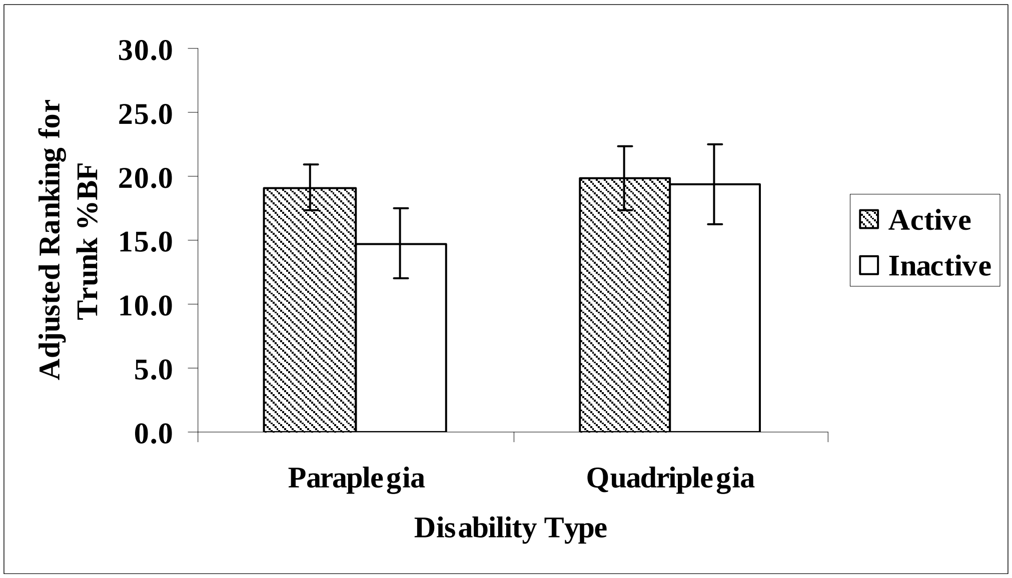


Figure 5. Differences in trunk percent body fat (%BF) based on physical activity level and disability type after adjusting for age, body mass index, and time since injury/disease.

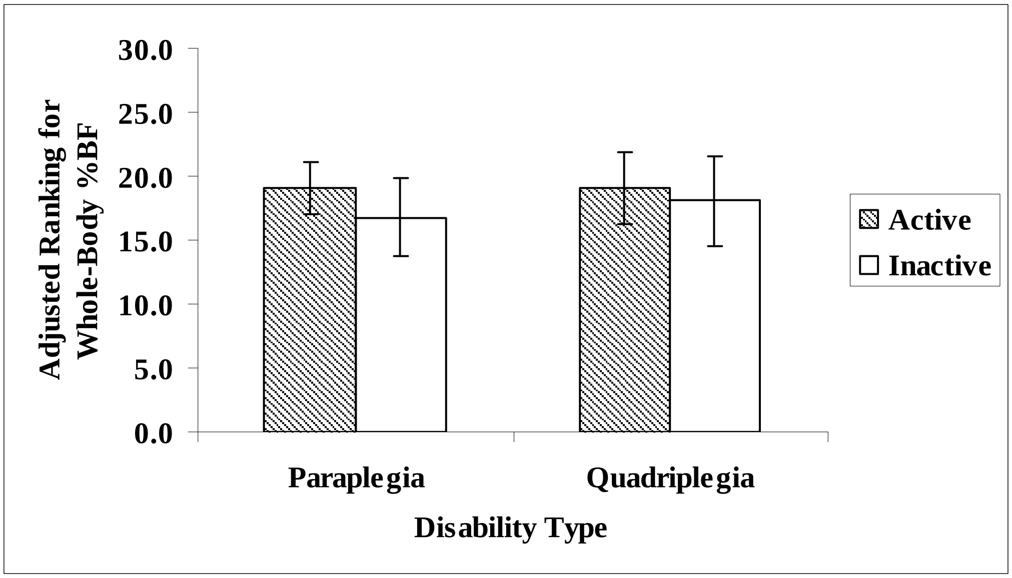


Figure 6. Differences in whole-body percent body fat (%BF) based on physical activity level and disability type after adjusting for age, body mass index, and time since injury/disease.

A significant difference was also observed between the paraplegic and quadriplegic groups on the combined LBM measures, *F*(4, 26) = 9.80, Wilks' Λ = 0.40, *p* = 0.0001, η^2 = 0.60, after adjusting for the same set of covariates. According to follow-up analyses, the only group difference to reach statistical significance was LBM in the arms that was significantly higher in the paraplegic group than in the quadriplegic group, *F*(1, 29) = 20.76, *p* = 0.0001, η^2 = 0.42 (see Figures 7–10). As was the case with the %BF analysis, there were no significant main effect for physical activity level [*F*(4, 26) = 0.66, Wilks' Λ = 0.91, *p* = 0.6256] and the interaction effect [*F*(4, 26) = 1.01, Wilks' Λ = 0.87, *p* = 0.4186].

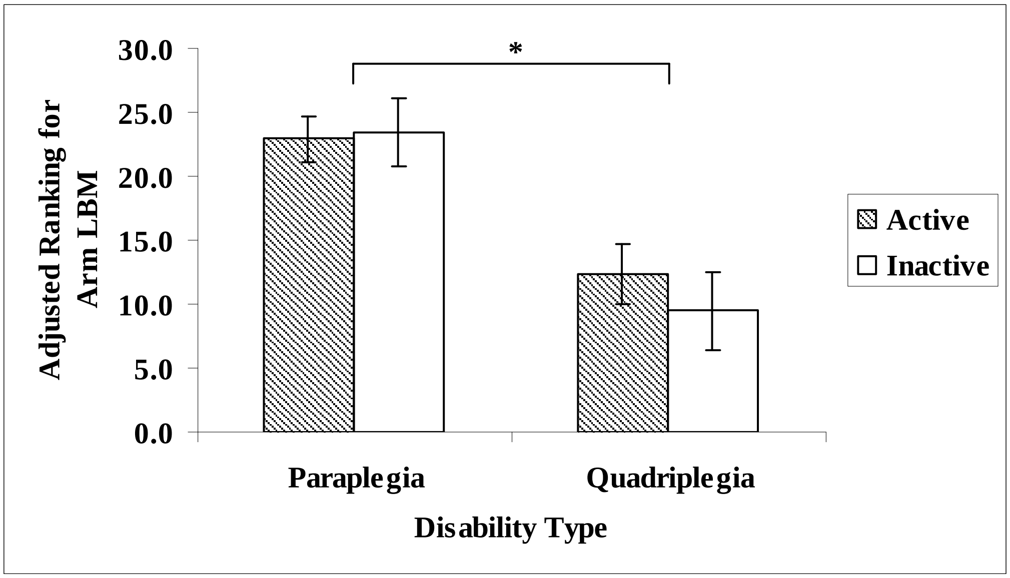


Figure 7. Differences in arm lean body mass (LBM) based on physical activity level and disability type after adjusting for age, body mass index, and time since injury/disease. *Significant difference between paraplegic and quadriplegic groups (*p* < 0.01).

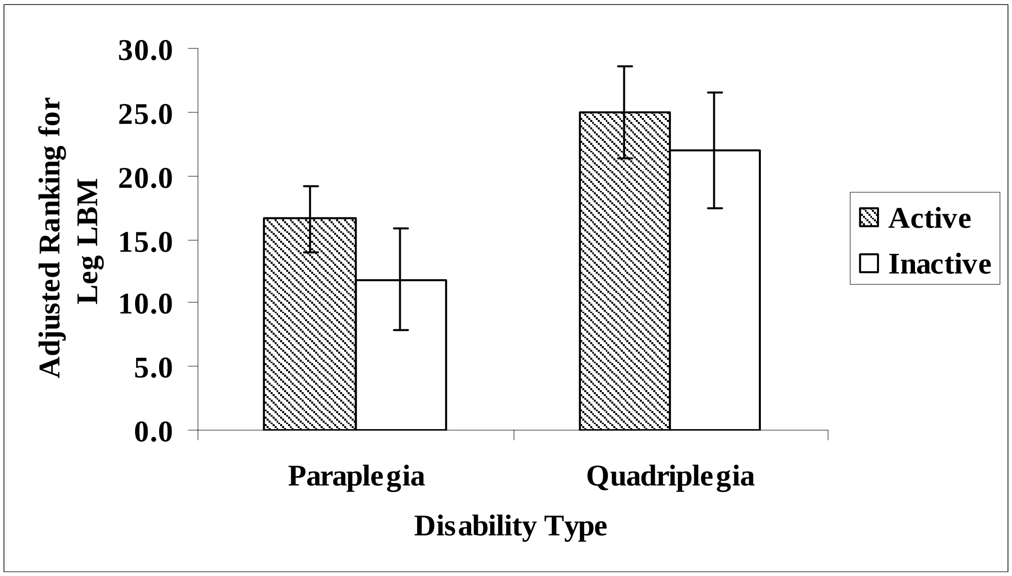


Figure 8. Differences in leg lean body mass (LBM) based on physical activity level and disability type after adjusting for age, body mass index, and time since injury/disease.

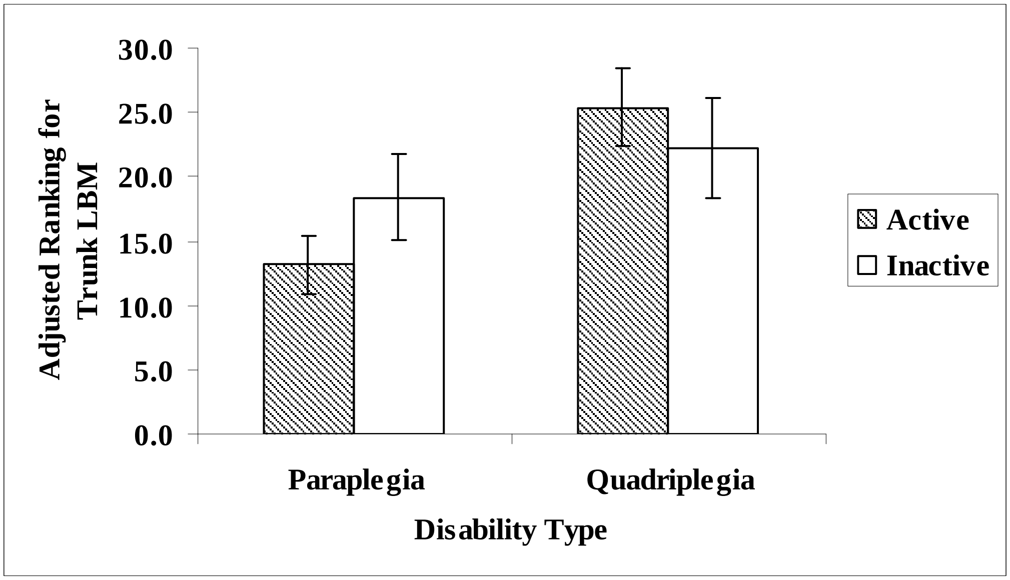


Figure 9. Differences in trunk lean body mass (LBM) based on physical activity level and disability type after adjusting for age, body mass index, and time since injury/disease.

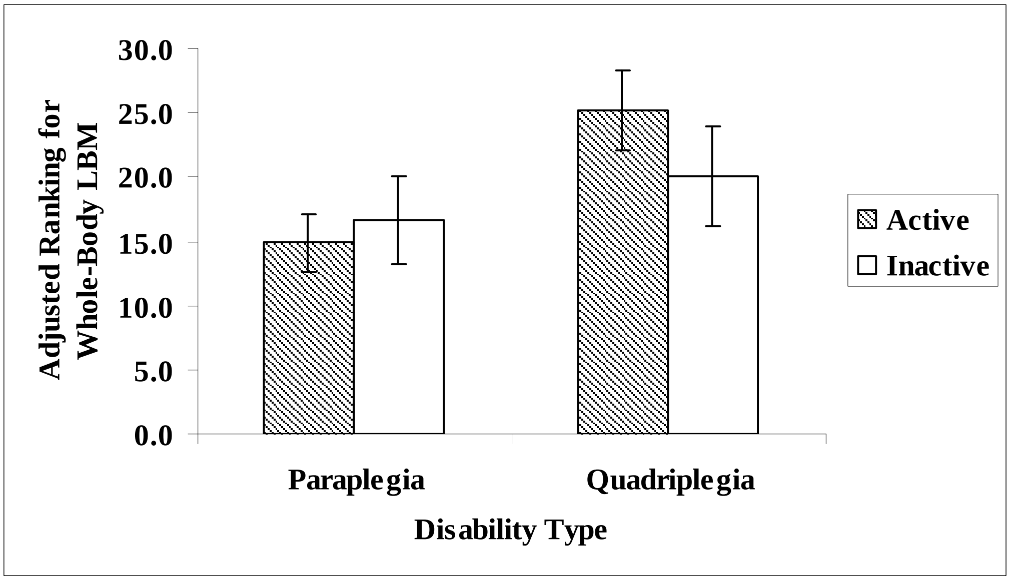


Figure 10. Differences in whole-body lean body mass (LBM) based on physical activity level and disability type after adjusting for age, body mass index, and time since injury/disease.

On the other hand, the combined BMD measures showed a significant main effect for physical activity level [$F(4, 26) = 5.17$, Wilks' $\Lambda = 0.56$, $p = 0.0033$, $\eta^2 = 0.44$] as well as disability type [$F(4, 26) = 3.63$, Wilks' $\Lambda = 0.64$, $p = 0.0177$, $\eta^2 = 0.36$]. Based on separate analyses of the BMD measures, the physically active individuals had a significantly higher arm BMD than did their physically inactive counterparts, $F(1, 29) = 16.64$, $p = 0.0003$, $\eta^2 = 0.37$, whereas no significant differences in leg, trunk, and whole-body BMD were observed between the two groups ($p > 0.05$; see Figures 11–14). Regarding disability type and the BMD measures, there was a trend that arm BMD was higher in the paraplegic group than in the quadriplegic group, $F(1, 29) = 6.79$, $p = 0.0143$, $\eta^2 = 0.19$; however, it did not reach statistically significance based on the adjusted alpha level of 0.0125. The interaction effect was not significant, $F(4, 26) = 1.95$, Wilks' $\Lambda = 0.77$, $p = 0.1316$.

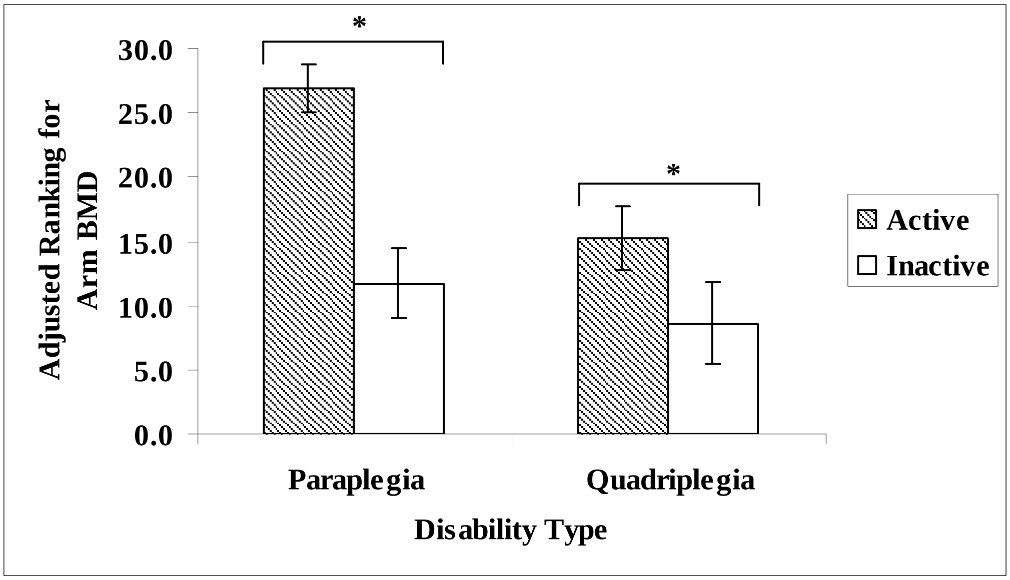


Figure 11. Differences in arm bone mineral density (BMD) based on physical activity level and disability type after adjusting for age, body mass index, and time since injury/disease.

[*]Significant difference between physically active and inactive groups ($p < 0.01$).

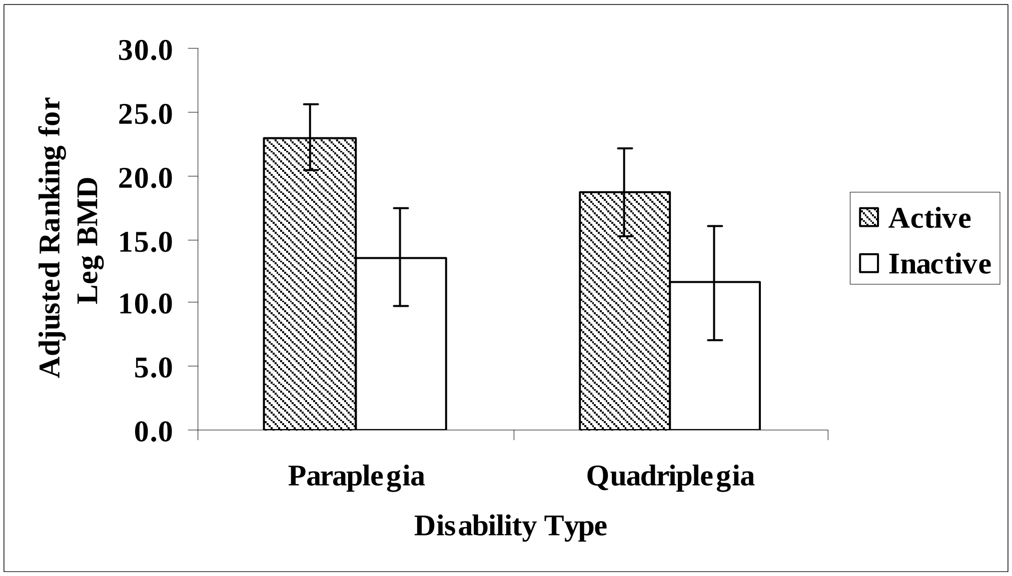


Figure 12. Differences in leg bone mineral density (BMD) based on physical activity level and disability type after adjusting for age, body mass index, and time since injury/disease.

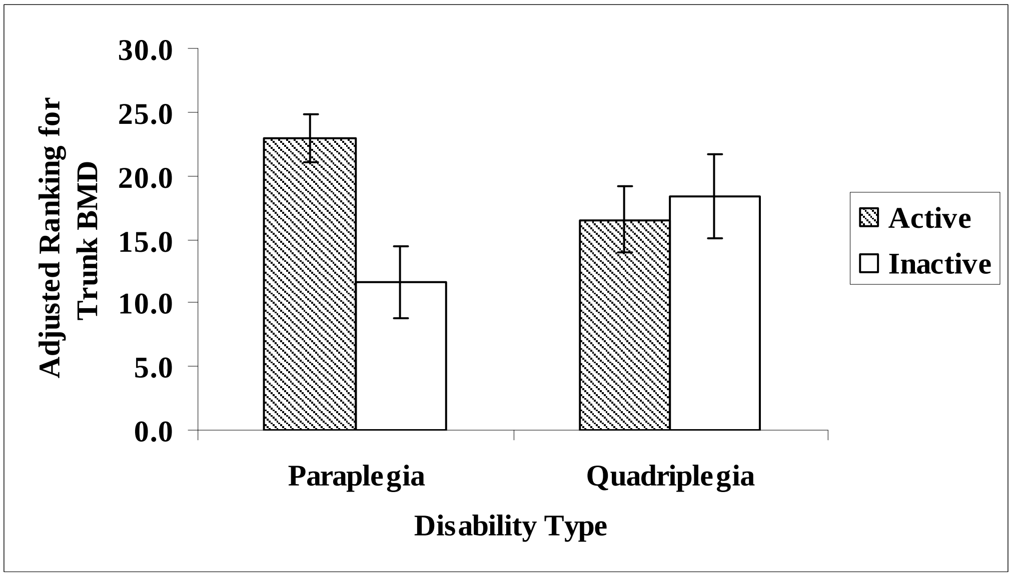


Figure 13. Differences in trunk bone mineral density (BMD) based on physical activity level and disability type after adjusting for age, body mass index, and time since injury/disease.

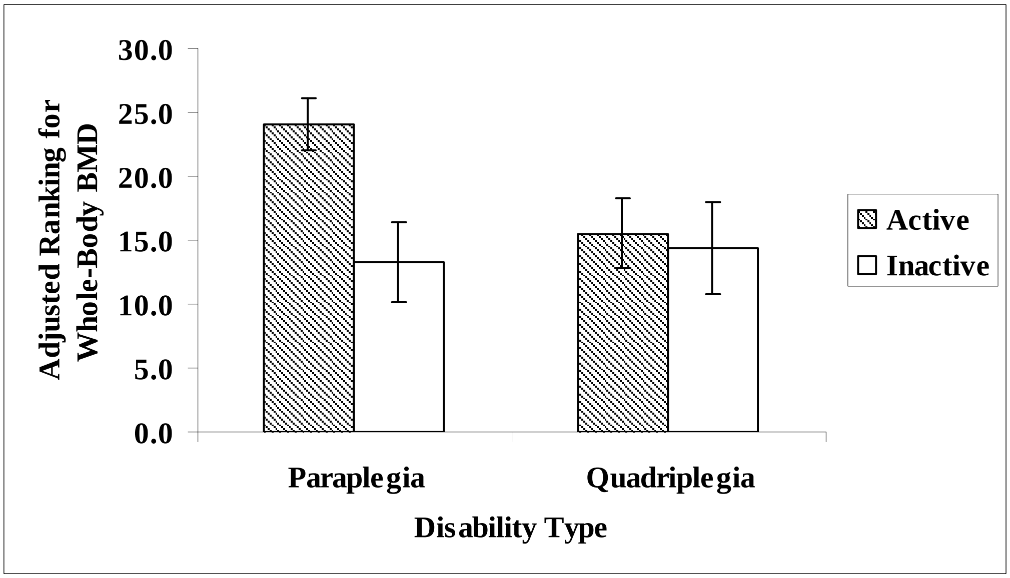


Figure 14. Differences in whole-body bone mineral density (BMD) based on physical activity level and disability type after adjusting for age, body mass index, and time since injury/disease.

CHAPTER 5

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Discussion

The purpose of this study was to examine the association of regular physical activity to body composition in individuals with physical disabilities. A comparison of percent body fat (%BF), lean body mass (LBM), and bone mineral density (BMD) was made between wheelchair users (paraplegic and quadriplegic men) who participated in adapted sports programs and those who were physically inactive. The results of the data analysis showed that the paraplegic men had a lower %BF and a higher LBM in the arms than did the quadriplegic men regardless of physical activity level. Any regional and whole-body %BF or LBM were not significantly associated with physical activity level. The physically active men, irrespective of disability type, had a higher BMD in the arms than did their physically inactive counterparts. Furthermore, arm BMD tended to be higher in the paraplegic group than in the quadriplegic group. On the other hand, neither physical activity level nor disability type was related to BMD in the legs, trunk, and whole body.

It was expected that the paraplegic men had a lower %BF and a higher LBM in the arms compared with the quadriplegic men. Due to the paralysis and thus the limited ability to contract muscles in the upper limbs, it can be speculated that quadriplegic persons are more likely to develop atrophy in the arms, leading to a decreased arm LBM and, as a result, an increased arm %BF. This is not the case with paraplegic individuals who have paralysis only in the trunk and lower limbs. Spungen and colleagues (2003) also found that paraplegic men had a significantly lower %BF and a higher LBM in the arms than did quadriplegic men. The results of the current study have confirmed that functional capacity seems to play an important role in maintaining favorable %BF and LBM in people with physical disabilities.

Physical activity level was not associated with any regional and whole-body %BF or LBM in this study. This does not agree with other studies indicating that individuals with physically disabilities can have a lower %BF and a higher FFM, if they engage in regular physical activity (Olle et al., 1993; Slawta et al., 2002; Zwiren & Bar-Or, 1975). This discrepancy in the findings could be because physical activity levels of the active wheelchair users in our study were not adequate to positively affect %BF and LBM. According to Abel and coworkers (Abel, Platen, Rojas Vega, Schneider, & Struder, 2008), energy expenditure for playing wheelchair basketball, rugby, and tennis by individuals with spinal cord injury who competed in the first and second national German league were, on average, 313.6 kcal/hr or 5.0 METs (MET = metabolic equivalent). If these values were used to estimate exercise energy expenditure of the active wheelchair users in our study, they were expected to expend 940.8 kcal or 15.0 MET-hours per week during the season (3 hr/week of practice; lasting 8–9 months depending on sports) and 470.4 kcal or 7.5 MET-hours during the off-season (1.5 hr/week of practice). This amount of physical activity may not be sufficient to induce significant changes in body composition parameters, including total body fat, abdominal fat, visceral fat, and muscle size (Physical Activity Guidelines Advisory Committee, 2008; Ross & Janssen, 2001). Furthermore, since the physically active wheelchair users in our study were all recreational athletes, their exercise energy expenditure was probably lower than that suggested by Abel et al. (2008) who examined players competing in the national league.

These factors may have been the reasons for the nonsignificant relationship of physical activity level to %BF or LBM in the current study.

On the other hand, physical activity level was found to be positively related to BMD in the arms. According to the results of this study, the wheelchair users participating in the adapted sports programs had a significantly higher arm BMD than did those not participating in any sports programs. This is in accordance with the previous findings suggesting the benefit of engaging in regular physical activity on preserving BMD in the arms for persons with disabilities (Jones et al., 2002; Miyahara et al., 2008; Ribeiro et al., 2005). Because wheelchair users rely on the upper body to provide movement during exercise, the results of the current and past studies could indicate that playing wheelchair sports accomplishes greater site-specific (i.e., upper limbs) mechanical loading, leading to an increased BMD in the arms. The site-specific effects of mechanical loading on promoting bone mineral accrual has been observed in able-bodied individuals (Haapasalo et al., 1994; Kannus, Haapasalo, Sievanen, Oja, & Vuori, 1994; Morel, Combe, Francisco, & Bernard, 2001). For example, sportsmen involved in a great deal of muscle activities of the upper body, such as climbing, body building, and fighting sports, were shown to have the highest arm BMD (Morel et al., 2001). Furthermore, studies reported an increased BMD in the dominant arm among tennis and squash players (Haapasalo et al., 1994; Kannus, Haapasalo et al., 1994). Morel et al. (2001) point out that in the upper limbs mechanical loading is often more important than impact loading for maintaining optimal BMD. The results of our study indicates that the site-specific effects of mechanical loading on promoting bone mineral accrual can be applied to persons with physical disabilities as well as those in the general population.

Although it did not reach statistical significance, there was a tendency that disability type was also linked with BMD in the arms. The paraplegic men tended to have a higher arm BMD than did the quadriplegic men ($p = 0.0143$, $\eta^2 = 0.19$, adjusted alpha = 0.0125). Other studies also observed a greater bone loss in the upper limbs among quadriplegic individuals compared with paraplegic ones (Garland et al., 1992; Spungen et al., 2003; Tsuzuku et al., 1999). As discussed above, people with quadriplegia generally have less ability to contract muscles of the upper limbs than those with paraplegia. Consequently, quadriplegic persons are prone to disuse arm muscles, leading to a lower mechanical stress on the arms and thus a decreased arm BMD [i.e., disuse osteoporosis (Takata & Yasui, 2001)], as mechanical loading plays an important role in maintaining optimal bone health (Heaney et al., 2000).

In contrast, BMD in the legs, trunk, and whole body had no apparent relationship with physical activity level or disability type. Similar findings were reported in the past (Jones et al., 2002; Spungen et al., 2003; Tsuzuku et al., 1999). Because wheelchair locomotion only involves working muscles of the upper limbs, it is logical to assume that playing wheelchair sports does not have significant impact on preserving bone health in the regions other than the upper body. In addition, both paraplegic and quadriplegic individuals have paralysis in the trunk and lower limbs; therefore, the influence of type of disability (i.e., paraplegia or quadriplegia) on bone mineral accrual in the legs and trunk is probably minimal. Moreover, because the area of the arms among the wheelchair users in our study was less than 25 % of the total body area, the differences in arm BMD by physical activity level or disability type did not necessarily result in statistical significance for whole-body BMD.

It should be mentioned that there are limitations associated with the present study. First, actual energy expenditure for sports play by the wheelchair users was not measured in this study. As discussed previously, using 313.6 kcal/hr or 5.0 METs for playing wheelchair sports reported by Abel et al. (2008) would probably overestimate exercise energy expenditure of the participants in our study due to the differences in competition and fitness levels of the individuals between the studies. In addition, there was a possibility that a great variability in exercise energy expenditure existed among the physically active wheelchair users. These factors made it not possible to examine the relationship between the volume of exercise and body composition parameters (i.e., dose-response relation) among the wheelchair users. Second, the study included wheelchair users with various types of injuries and diseases (spinal cord injury, spina bifida, cerebral palsy, muscular dystrophy, and Friedreich’s ataxia). Besides physical activity level (active vs. inactive) and disability type (paraplegia vs. quadriplegia), type of injury/disease could influence body composition (Liou et al., 2005). Third, the current study employed a cross-sectional study design, therefore it was not possible to establish causation between sports participation and body composition parameters in people with physical disabilities. Lastly, sample sizes in this study were relatively small, especially for the physically inactive, paraplegic ($n = 7$) and quadriplegic ($n = 5$) groups. Furthermore, sample sizes among the groups were unequal. As a result, a nonparametric statistical approach (i.e., using the rank transformation) instead of a parametric statistical approach was used in this study. It is generally agreed that a nonparametric statistical test can have more statistical power than do a corresponding parametric statistical test, when the assumptions of a parametric statistical test are violated (Field, 2009). Nevertheless, having more participants, regardless of the type of statistical test used, could help to detect significant group differences that were not found in the current data analysis. Moreover, increasing sample sizes would enable us to generalize the results of the study with more confidence.

Recruiting those who participated in adapted sports programs as physically active individuals is an important aspect of this study. Wheelchair users may have difficulty in finding opportunities to be physically active, in that they normally need assistance (e.g., equipment, transportation) to exercise or play sports, which often is not readily available. Hence, participating in adapted sports programs seems to be a primary avenue for people with physical disabilities in order to be physically active. The results of the study can be used to promote active lifestyles for maintaining quality of life among in clinical populations.

Conclusions

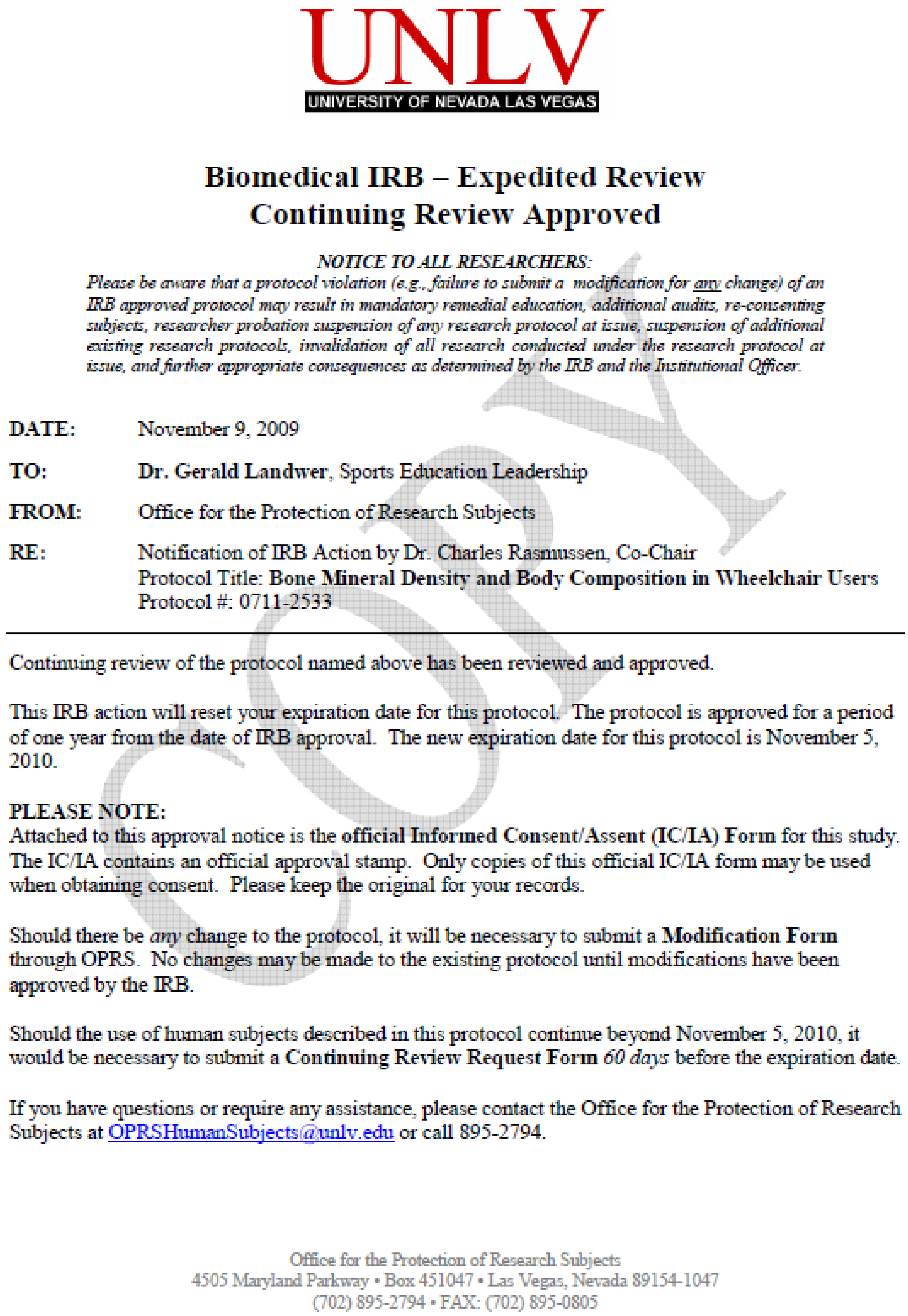
The present study shows that playing adapted sports is associated with an increased BMD in the arms among wheelchair users. In contrast, regular physical activity does not seem to influence BMD in other regions of the body among these individuals. Paraplegic persons can have favorable %BF, LBM, and, to some extent, BMD in the upper limbs compared with quadriplegic persons, indicating the relationship of functional capacity to these body composition parameters. On the other hand, it does not appear that %BF, LBM, and BMD in the trunk, lower limbs, or whole body are significantly influenced by whether persons are paraplegic or quadriplegic. Playing wheelchair basketball or rugby at recreational levels (e.g., 3 hr/week) may not be sufficient to significantly affect the regional and whole-body %BF or LBM among wheelchair users.

Recommendations

1. It will be necessary to determine energy expenditure for playing wheelchair sports based on intensity level (e.g., recreational, competitive). The development of portable metabolic carts (e.g., COSMED K4 b^2) makes it possible to measure energy expenditure during actual sports play (McLaughlin, King, Howley, Bassett, & Ainsworth, 2001). The knowledge of energy expenditure for playing various wheelchair sports at different intensities will allow researchers to investigate a dose-response relation between volume of exercise and body composition in people with physical disabilities.
2. Future research should look at body composition parameters of individuals with a specific injury/disease. This will enable researchers to determine the difference in relationships between regular physical activity and body composition among people with different types of injuries and diseases.
3. Randomized control trials should be conducted in the future to investigate the effects of playing adapted sports on body composition for people with physical disabilities. The results of randomized control trials will help researchers develop physical activity or exercise recommendations specifically for clinical populations.

APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVALS



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Continuing Review Approved

NOTICE TO ALL RESEARCHERS:

Please be aware that a protocol violation (e.g., failure to submit a modification for <u>any</u> change) of an IRB approved protocol may result in mandatory remedial education, additional audits, re-consenting subjects, researcher probation suspension of any research protocol at issue, suspension of additional existing research protocols, invalidation of all research conducted under the research protocol at issue, and further appropriate consequences as determined by the IRB and the Institutional Officer.

DATE: November 9, 2009

TO: **Dr. Gerald Landwer**, Sports Education Leadership

FROM: Office for the Protection of Research Subjects

RE: Notification of IRB Action by Dr. Charles Rasmussen, Co-Chair
Protocol Title: **Bone Mineral Density and Body Composition in Wheelchair Users**
Protocol #: 0711-2533

Continuing review of the protocol named above has been reviewed and approved.

This IRB action will reset your expiration date for this protocol. The protocol is approved for a period of one year from the date of IRB approval. The new expiration date for this protocol is November 5, 2010.

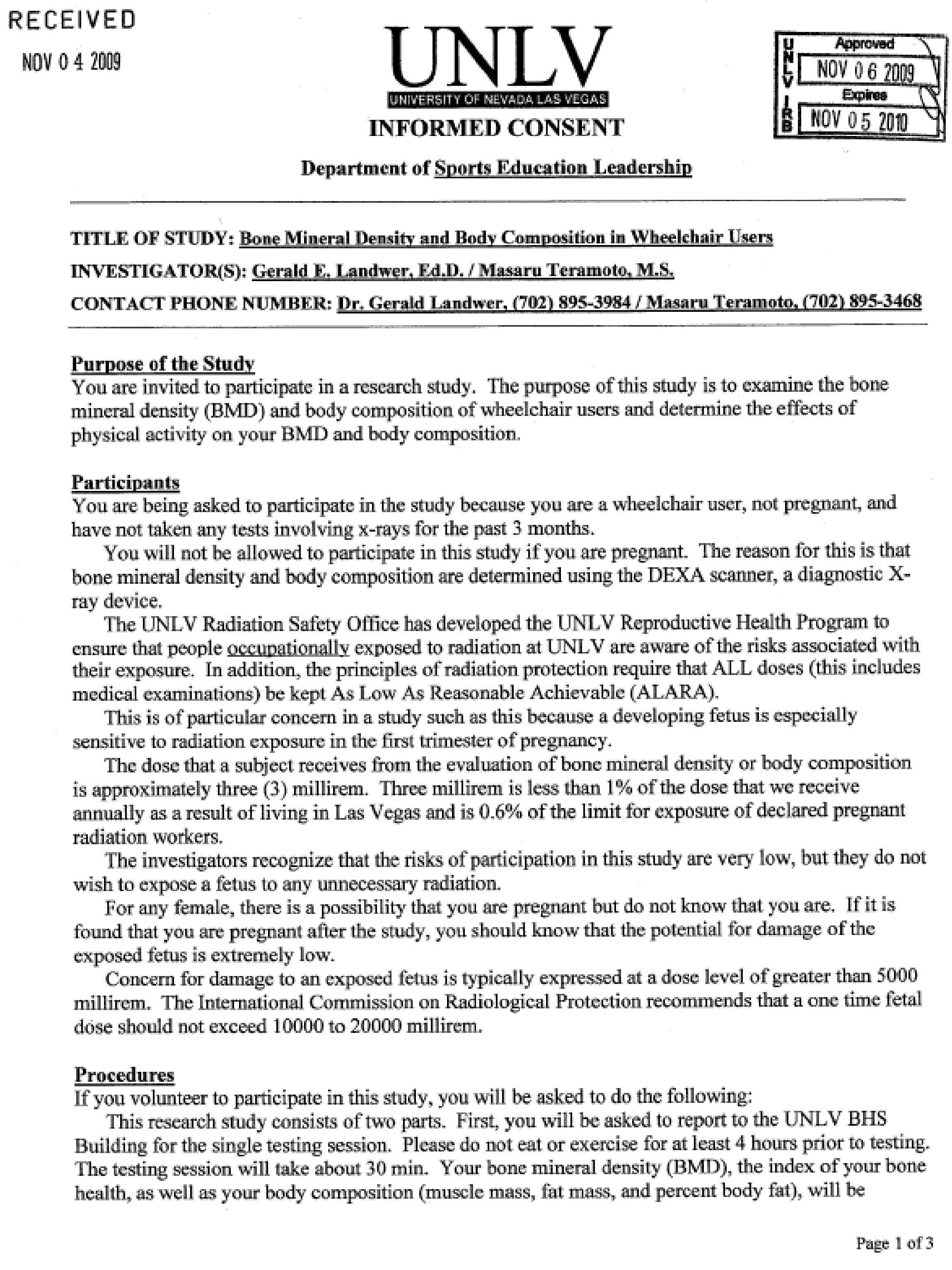
PLEASE NOTE:
Attached to this approval notice is the **official Informed Consent/Assent (IC/IA) Form** for this study. The IC/IA contains an official approval stamp. Only copies of this official IC/IA form may be used when obtaining consent. Please keep the original for your records.

Should there be *any* change to the protocol, it will be necessary to submit a **Modification Form** through OPRS. No changes may be made to the existing protocol until modifications have been approved by the IRB.

Should the use of human subjects described in this protocol continue beyond November 5, 2010, it would be necessary to submit a **Continuing Review Request Form** *60 days* before the expiration date.

If you have questions or require any assistance, please contact the Office for the Protection of Research Subjects at OPRSHumanSubjects@unlv.edu or call 895-2794.

Office for the Protection of Research Subjects
4505 Maryland Parkway • Box 451047 • Las Vegas, Nevada 89154-1047
(702) 895-2794 • FAX: (702) 895-0805



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UNLV IRB
Approved
NOV 06 2009
Expires
NOV 05 2010

INFORMED CONSENT

Department of Sports Education Leadership

TITLE OF STUDY: **Bone Mineral Density and Body Composition in Wheelchair Users**

INVESTIGATOR(S): **Gerald E. Landwer, Ed.D. / Masaru Teramoto, M.S.**

CONTACT PHONE NUMBER: **Dr. Gerald Landwer, (702) 895-3984 / Masaru Teramoto, (702) 895-3468**

Purpose of the Study

You are invited to participate in a research study. The purpose of this study is to examine the bone mineral density (BMD) and body composition of wheelchair users and determine the effects of physical activity on your BMD and body composition.

Participants

You are being asked to participate in the study because you are a wheelchair user, not pregnant, and have not taken any tests involving x-rays for the past 3 months.

You will not be allowed to participate in this study if you are pregnant. The reason for this is that bone mineral density and body composition are determined using the DEXA scanner, a diagnostic X-ray device.

The UNLV Radiation Safety Office has developed the UNLV Reproductive Health Program to ensure that people occupationally exposed to radiation at UNLV are aware of the risks associated with their exposure. In addition, the principles of radiation protection require that ALL doses (this includes medical examinations) be kept As Low As Reasonable Achievable (ALARA).

This is of particular concern in a study such as this because a developing fetus is especially sensitive to radiation exposure in the first trimester of pregnancy.

The dose that a subject receives from the evaluation of bone mineral density or body composition is approximately three (3) millirem. Three millirem is less than 1% of the dose that we receive annually as a result of living in Las Vegas and is 0.6% of the limit for exposure of declared pregnant radiation workers.

The investigators recognize that the risks of participation in this study are very low, but they do not wish to expose a fetus to any unnecessary radiation.

For any female, there is a possibility that you are pregnant but do not know that you are. If it is found that you are pregnant after the study, you should know that the potential for damage of the exposed fetus is extremely low.

Concern for damage to an exposed fetus is typically expressed at a dose level of greater than 5000 millirem. The International Commission on Radiological Protection recommends that a one time fetal dose should not exceed 10000 to 20000 millirem.

Procedures

If you volunteer to participate in this study, you will be asked to do the following:

This research study consists of two parts. First, you will be asked to report to the UNLV BHS Building for the single testing session. Please do not eat or exercise for at least 4 hours prior to testing. The testing session will take about 30 min. Your bone mineral density (BMD), the index of your bone health, as well as your body composition (muscle mass, fat mass, and percent body fat), will be

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health, as well as your body composition (muscle mass, fat mass, and percent body fat), will be measured using the DEXA scanner. Before the BMD and body composition measurements, you will be asked to complete the questionnaire called Physical Activity Scale for Individuals with Physical Disabilities (PASIPD) in order to assess your current physical activity level. After that, your weight will be measured while you are sitting on the chair that is placed on the scale. After that, you will be asked to lie down on the padded table of the DEXA scanner. Help will be provided based on your condition when you are trying to move from the wheelchair to the DEXA table. Specifically, Masa Teramoto (student investigator) and/or a licensed Physical Therapist (also a faculty member at Department of Physical Therapy) will provide you help, if necessary. In addition, if you are quadriplegic (impairment of both arms and legs), your caregiver will be asked to help transfer you from the wheelchair to the DEXA table. After lying down on the table and your height is measured by a tape measure, your legs will be strapped around the knees. While you are lying on the table with minimum body movements, the DEXA detector arm will move to scan you from the head to toe. The scan will take about 10-15 minutes. After the scan is completed, the strap around your knees will be taken off and the test will be finished.

In addition to the above experiment, you will also be asked to record your physical activity for 7 consecutive days. Specifically, you will use a bicycle odometer to measure a distance of pushing the wheelchair per day. A bicycle odometer will be provided to you. To measure the distance, you will need to attach a bicycle odometer to the spokes of your wheelchair in the morning when you first use the wheelchair that day. At the end of the day, you will need to read the odometer and record the total distance traveled by the wheelchair in the activity log sheet that will also be provided to you. Again, you will be asked to record the daily distance of pushing the wheelchair for 7 consecutive days. After the completion of this 7-day distance measurement, you will be contacted by the student investigator (Masa Teramoto) to return the activity log sheet and the bicycle odometer. Using your activity log, an average daily distance of wheelchair ambulation will be calculated.

Benefits of Participation

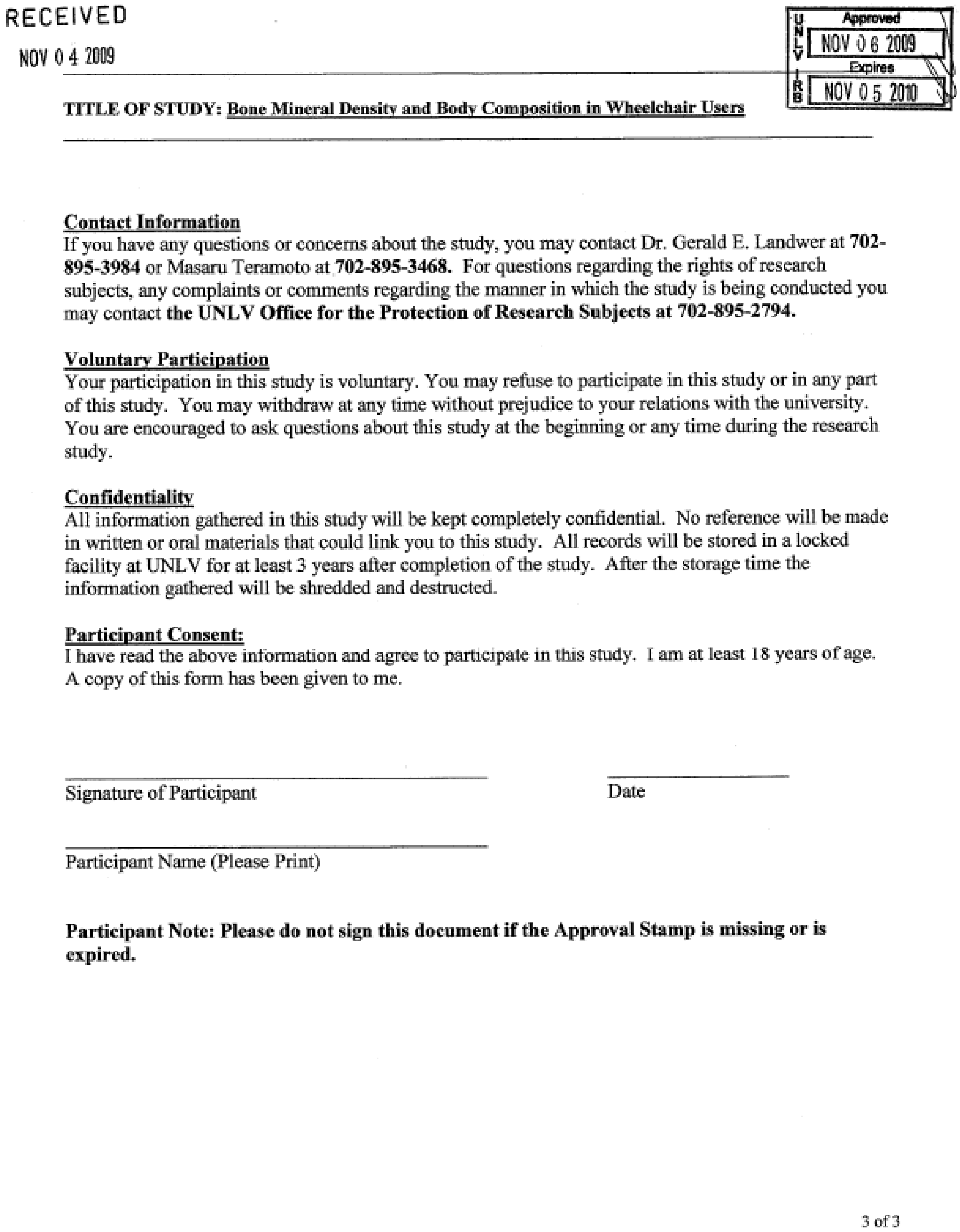
There may be direct benefits to you as a participant in this study. You will know your BMD, muscle mass, fat mass, and percent body fat for your own record. We hope to learn about the risk of osteoporosis (bone disease) and the relationship between BMD and physical activity levels in wheelchair users. We also hope to learn the association between physical activity levels and body composition in wheelchair users.

Risks of Participation

There are risks involved in all research studies. This study may include only minimal risks. The DEXA scans will provide a small amount of exposure to radiation. The scan provides approximately the same amount of radiation you receive from living in Nevada for less than 8 days. The risk associated with this exposure is minimal.

Cost /Compensation

There will not be financial cost to you to participate in this study. The study will take about a total of 30 minutes for the BMD and body composition measurements and filling out the PASIPD. In addition, the study will take about 30 minutes/day for a total of 7 days of your time for the measurement of a daily distance of wheelchair pushing. You will not be compensated for your time. The University of Nevada, Las Vegas may not provide compensation or free medical care for an unanticipated injury sustained as a result of participating in this research study.



UNLV IRB
Approved
NOV 06 2009
Expires
NOV 05 2010

TITLE OF STUDY: **Bone Mineral Density and Body Composition in Wheelchair Users**

Contact Information

If you have any questions or concerns about the study, you may contact Dr. Gerald E. Landwer at **702-895-3984** or Masaru Teramoto at **702-895-3468.** For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted you may contact **the UNLV Office for the Protection of Research Subjects at 702-895-2794.**

Voluntary Participation

Your participation in this study is voluntary. You may refuse to participate in this study or in any part of this study. You may withdraw at any time without prejudice to your relations with the university. You are encouraged to ask questions about this study at the beginning or any time during the research study.

Confidentiality

All information gathered in this study will be kept completely confidential. No reference will be made in written or oral materials that could link you to this study. All records will be stored in a locked facility at UNLV for at least 3 years after completion of the study. After the storage time the information gathered will be shredded and destructed.

Participant Consent:

I have read the above information and agree to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

Signature of Participant ____________________ Date ____________

Participant Name (Please Print) ____________________

Participant Note: Please do not sign this document if the Approval Stamp is missing or is expired.

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APPENDIX B

RAW DATA

Physical Characteristics of Physically Active, Paraplegic Men

Participant	Injury/disease	Ethnicity	Age (year)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Time since injury/disease
1	SCI (T12)	White	30	180.0	82.0	25.3	4.0
2	SCI (L1)	Black	42	169.0	107.4	37.6	27.5
3	SCI (T12-L1)	Black	38	175.5	69.9	22.7	27.0
4	SCI (T10)	White	28	156.0	74.4	30.6	22.5
5	SCI (T3-T4)	White	49	177.5	78.0	24.8	29.0
6	SCI (T12-L1)	White	50	185.5	83.5	24.3	36.5
7	SCI (T7)	White	59	159.0	112.5	44.5	41.0
8	Spina bifida	White	27	144.5	50.4	24.1	27.0
9	SCI (T10-T11)	White	29	185.5	88.5	25.7	11.0
10	Spina bifida	White	39	178.0	69.9	22.1	39.0
11	Spina bifida	White	50	175.5	74.4	24.2	50.0
12	SCI (T10)	White	32	167.5	61.7	22.0	5.0
13	SCI (T12)	Asian	35	167.5	61.2	21.8	6.0
14	SCI (T10-T11)	White	38	188.0	69.9	19.8	20.0
15	SCI (T10-T12)	White	37	183.0	70.3	21.0	7.0
	Mean		38.9	172.8	76.9	26.0	23.5
	SD		9.5	12.3	16.4	6.7	14.5

Note: SCI = spinal cord injury.

Physical Characteristics of Physically Active, Quadriplegic Men

Participant	Injury/disease	Ethnicity	Age (year)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Time since injury/disease
1	SCI (C6-C7)	Black	38	189.0	84.0	23.5	17.5
2	SCI (C6-C7)	White	28	178.0	58.1	18.3	7.0
3	SCI (C6-C7)	White	30	180.5	72.6	22.3	12.0
4	Muscular dystrophy	White	25	172.5	61.2	20.6	25.0
5	Cerebral palsy	White	29	178.0	81.6	25.8	29.0
6	Friedreich's ataxia	White	37	178.0	63.5	20.0	37.0
7	SCI (C5-C6)	White	43	193.0	77.1	20.7	17.0
8	SCI (C5-C6)	White	33	183.0	72.6	21.7	4.0
9	SCI (C6-C7)	White	37	180.5	65.8	20.2	11.0
	Mean		33.3	181.4	70.7	21.5	17.7
	SD		5.8	6.2	9.1	2.2	10.8

Note: SCI = spinal cord injury.

Physical Characteristics of Physically Inactive, Paraplegic Men

Participant	Injury/disease	Ethnicity	Age (year)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Time since injury/disease
1	SCI (T12-L1)	Black	40	172.5	77.6	26.1	27.5
2	SCI (T11-T12)	White	30	177.5	68.0	21.6	4.5
3	SCI (T3-T4)	White	30	183.0	90.7	27.1	9.5
4	Cerebral palsy	White	38	183.0	89.8	26.8	38.0
5	SCI (T10)	White	40	172.5	52.2	17.5	4.5
6	SCI (T12-L1)	White	49	183.0	99.8	29.8	28.0
7	SCI (T3)	White	50	180.5	81.6	25.0	28.5
	Mean		39.6	178.9	80.0	24.8	20.1
	SD		8.0	4.8	16.0	4.1	13.6

Note: SCI = spinal cord injury.

Physical Characteristics of Physically Inactive, Quadriplegic Men

Participant	Injury/disease	Ethnicity	Age (year)	Height (cm)	Weight (kg)	BMI (kg/m^2)	Time since injury/disease
1	SCI (C5-C6)	White	39	173.0	54.0	18.0	18.0
2	SCI (C5-C6)	Black	41	185.5	72.6	21.1	6.1
3	SCI (C5-C6)	White	36	193.0	90.7	24.3	15.7
4	SCI (C4-C5)	White	37	183.0	81.6	24.4	8.2
5	SCI (C5-C6)	White	38	180.5	53.1	16.3	13.0
	Mean		38.2	183.0	70.4	20.8	12.2
	SD		1.9	7.3	16.7	3.7	5.0

Note: SCI = spinal cord injury.

Percent Body Fat of Physically Active, Paraplegic Men

Participant	Percent body fat (%)			
	Arms	Legs	Trunk	Total
1	12.8	25.6	30.5	25.6
2	29.0	39.4	41.8	37.7
3	9.6	27.8	16.3	17.0
4	18.6	41.6	46.7	38.6
5	23.4	24.0	35.4	29.7
6	25.2	40.8	47.2	40.9
7	39.0	41.5	46.5	42.8
8	14.9	46.0	15.8	27.6
9	26.0	38.9	33.2	33.1
10	5.2	14.2	12.2	11.3
11	17.4	43.8	29.8	30.7
12	7.1	23.5	7.7	12.3
13	9.9	38.1	12.9	18.9
14	15.5	41.7	14.9	21.6
15	21.1	13.7	24.6	28.4
Mean	18.3	33.4	27.7	27.7
SD	9.2	10.8	13.9	10.0

Percent Body Fat of Physically Active, Quadriplegic Men

Participant	Percent body fat (%)			
	Arms	Legs	Trunk	Total
1	24.6	35.0	38.2	33.9
2	10.0	23.0	8.3	13.3
3	17.5	25.7	21.8	22.1
4	21.3	26.1	14.6	19.2
5	32.2	33.0	30.0	30.3
6	12.6	25.9	12.7	16.7
7	21.8	25.0	15.3	19.2
8	17.3	23.8	14.7	17.8
9	14.9	17.8	11.5	14.3
Mean	19.1	26.1	18.6	20.8
SD	6.7	5.1	9.7	7.0

Percent Body Fat of Physically Inactive, Paraplegic Men

Participant	Percent body fat (%)			
	Arms	Legs	Trunk	Total
1	18.5	35.8	36.2	31.3
2	23.5	51.4	20.5	30.2
3	22.9	32.5	19.6	23.9
4	27.0	33.8	29.7	29.7
5	8.7	32.7	11.7	16.9
6	28.6	39.6	23.6	28.2
7	28.0	32.7	21.3	25.0
Mean	22.5	36.9	23.2	26.5
SD	7.0	6.9	7.8	5.0

Percent Body Fat of Physically Inactive, Quadriplegic Men

Participant	Percent body fat (%)			
	Arms	Legs	Trunk	Total
1	14.3	20.2	17.7	17.6
2	17.9	31.5	14.9	20.1
3	27.9	37.4	22.4	27.1
4	32.3	33.2	27.1	28.9
5	16.5	15.3	5.3	10.7
Mean	21.8	27.5	17.5	20.9
SD	7.9	9.3	8.2	7.4

Lean Body Mass of Physically Active, Paraplegic Men

Participant	Lean body mass (kg)			
	Arms	Legs	Trunk	Total
1	8.9	16.0	28.0	56.8
2	11.0	16.6	30.9	63.4
3	13.8	10.8	26.0	55.0
4	10.0	7.7	19.4	40.6
5	7.8	13.6	27.9	53.1
6	7.8	10.2	23.4	45.2
7	7.3	18.1	31.1	60.6
8	10.0	10.3	10.7	34.5
9	9.9	18.2	27.7	60.1
10	9.3	15.9	28.0	57.6
11	9.6	10.0	22.2	45.1
12	7.9	9.1	25.0	47.0
13	6.5	6.9	21.9	39.0
14	8.9	8.4	27.5	48.4
15	6.7	47.3	27.0	47.1
Mean	9.0	14.6	25.1	50.2
SD	1.9	9.8	5.2	8.7

Lean Body Mass of Physically Active, Quadriplegic Men

Participant	Lean body mass (kg)			
	Arms	Legs	Trunk	Total
1	9.7	17.3	26.2	57.3
2	6.4	11.0	25.6	48.0
3	7.5	14.7	30.7	58.0
4	4.4	12.9	24.0	44.9
5	6.2	10.9	29.7	50.9
6	5.8	12.3	27.5	50.1
7	6.3	16.4	31.1	57.9
8	6.2	13.5	28.1	52.0
9	6.0	15.3	28.8	54.4
Mean	6.5	13.8	28.0	52.6
SD	1.4	2.3	2.4	4.6

Lean Body Mass of Physically Inactive, Paraplegic Men

Participant	Lean body mass (kg)			
	Arms	Legs	Trunk	Total
1	11.4	10.2	23.9	49.5
2	6.8	9.7	26.0	46.5
3	10.4	17.1	34.1	65.5
4	7.9	13.5	33.1	58.7
5	6.7	7.8	22.5	40.9
6	10.7	14.6	38.5	68.5
7	7.2	13.8	32.1	57.2
Mean	8.7	12.4	30.0	55.3
SD	2.0	3.2	6.0	10.1

Lean Body Mass of Physically Inactive, Quadriplegic Men

Participant	Lean body mass (kg)			
	Arms	Legs	Trunk	Total
1	4.7	12.8	21.1	42.0
2	6.4	13.1	29.4	54.4
3	6.7	14.8	33.1	58.5
4	6.0	15.5	31.6	57.3
5	4.3	12.9	23.6	44.8
Mean	5.6	13.8	27.8	51.4
SD	1.0	1.2	5.2	7.5

Bone Mineral Density of Physically Active, Paraplegic Men

Participant	Bone mineral density (g/cm^2)			
	Arms	Legs	Trunk	Total
1	1.15	1.45	1.13	1.33
2	1.16	1.41	1.15	1.39
3	1.11	1.03	0.93	1.14
4	1.00	0.93	1.08	1.15
5	1.08	0.98	1.01	1.14
6	1.17	1.07	1.21	1.27
7	1.33	1.43	1.15	1.42
8	0.99	0.77	0.78	1.06
9	1.13	0.96	1.06	1.15
10	1.09	1.16	0.89	1.16
11	1.10	0.95	0.94	1.07
12	1.00	0.99	0.73	1.04
13	1.16	1.06	1.10	1.23
14	1.08	1.00	0.72	1.03
15	1.16	1.01	0.81	1.10
Mean	1.11	1.08	0.98	1.18
SD	0.09	0.20	0.16	0.12

Bone Mineral Density of Physically Active, Quadriplegic Men

Participant	Bone mineral density (g/cm^2)			
	Arms	Legs	Trunk	Total
1	1.05	1.13	1.03	1.16
2	1.02	0.90	0.76	1.02
3	1.04	0.97	0.85	1.07
4	0.87	1.01	0.67	0.96
5	0.91	0.75	0.74	0.95
6	0.71	0.84	0.71	0.99
7	1.00	0.95	0.75	1.00
8	0.92	1.03	0.75	1.03
9	0.91	1.12	0.72	1.05
Mean	0.94	0.97	0.78	1.03
SD	0.11	0.12	0.11	0.07

Bone Mineral Density of Physically Inactive, Paraplegic Men

Participant	Bone mineral density (g/cm^2)			
	Arms	Legs	Trunk	Total
1	1.09	1.03	0.98	1.16
2	0.93	0.97	0.74	1.03
3	1.06	1.03	0.98	1.16
4	0.97	0.80	0.81	1.02
5	0.87	1.04	0.68	0.98
6	0.97	1.01	0.83	1.10
7	0.90	0.82	0.74	1.00
Mean	0.97	0.96	0.82	1.07
SD	0.08	0.10	0.12	0.07

Bone Mineral Density of Physically Inactive, Quadriplegic Men

Participant	Bone mineral density (g/cm^2)			
	Arms	Legs	Trunk	Total
1	0.88	0.92	0.79	0.99
2	0.89	0.97	0.76	0.97
3	1.01	1.22	0.99	1.27
4	0.89	0.89	0.78	1.04
5	0.75	0.74	0.65	0.84
Mean	0.89	0.95	0.79	1.02
SD	0.09	0.17	0.12	0.16

APPENDIX C

SUMMARY OF STATISTICS

Differences in Physical Characteristics Among Groups

Tests of Between-Subjects Effects

Dependent Variable: RANK of age

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
pa	233.886	1	233.886	2.190	.1487	.064
injury	130.252	1	130.252	1.220	.2777	.037
pa * injury	50.363	1	50.363	.472	.4972	.015
Error	3417.313	32	106.791			
Total	16181.500	36				
Corrected Total	3860.500	35				

Tests of Between-Subjects Effects

Dependent Variable: RANK of ht

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
pa	105.450	1	105.450	1.028	.3182	.031
injury	365.279	1	365.279	3.562	.0682	.100
pa * injury	3.128	1	3.128	.031	.8625	.001
Error	3281.957	32	102.561			
Total	16172.500	36				
Corrected Total	3851.500	35				

Tests of Between-Subjects Effects

Dependent Variable: RANK of wt

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
pa	32.815	1	32.815	.287	.5956	.009
injury	186.985	1	186.985	1.638	.2098	.049
pa * injury	12.327	1	12.327	.108	.7446	.003
Error	3653.633	32	114.176			
Total	16198.500	36				
Corrected Total	3877.500	35				

Tests of Between-Subjects Effects

Dependent Variable: RANK of bmi

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
pa	6.245	1	6.245	.066	.7984	.002
injury	825.920	1	825.920	8.775	**.0057**	.215
pa * injury	8.407	1	8.407	.089	.7670	.003
Error	3011.884	32	94.121			
Total	16205.500	36				
Corrected Total	3884.500	35				

Tests of Between-Subjects Effects

Dependent Variable: RANK of time_inj

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
pa	7.683	1	7.683	.074	.7874	.002
injury	341.463	1	341.463	3.287	.0792	.093
pa * injury	50.613	1	50.613	.487	.4902	.015
Error	3324.633	32	103.895			
Total	16200.500	36				
Corrected Total	3879.500	35				

Differences in Percent Body Fat Among Groups
(Two-Way Between-Groups Multivariate Analysis of Covariance)

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
pa	Pillai's Trace	.210	1.730	4.000	26.000	.1738	.210
	Wilks' Lambda	.790	1.730	4.000	26.000	.1738	.210
	Hotelling's Trace	.266	1.730	4.000	26.000	.1738	.210
	Roy's Largest Root	.266	1.730	4.000	26.000	.1738	.210
injury	Pillai's Trace	.445	5.203	4.000	26.000	.0032	.445
	Wilks' Lambda	.555	5.203	4.000	26.000	**.0032**	.445
	Hotelling's Trace	.800	5.203	4.000	26.000	.0032	.445
	Roy's Largest Root	.800	5.203	4.000	26.000	.0032	.445
pa * injury	Pillai's Trace	.069	.485	4.000	26.000	.7466	.069
	Wilks' Lambda	.931	.485	4.000	26.000	.7466	.069
	Hotelling's Trace	.075	.485	4.000	26.000	.7466	.069
	Roy's Largest Root	.075	.485	4.000	26.000	.7466	.069

b. Design: Intercept+Rage+Rtime_in+Rbmi+pa+injury+pa * injury

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
pa	RANK of bf_arms	61.066	1	61.066	1.148	.2929	.038
	RANK of bf_legs	68.106	1	68.106	.771	.3872	.026
	RANK of bf_trunk	37.776	1	37.776	.847	.3650	.028
	RANK of bf_total	17.600	1	17.600	.307	.5836	.010
injury	RANK of bf_arms	429.550	1	429.550	8.073	**.0081**	.218
	RANK of bf_legs	184.760	1	184.760	2.091	.1589	.067
	RANK of bf_trunk	42.954	1	42.954	.963	.3346	.032
	RANK of bf_total	2.569	1	2.569	.045	.8338	.002
pa * injury	RANK of bf_arms	10.816	1	10.816	.203	.6555	.007
	RANK of bf_legs	.030	1	.030	.000	.9855	.000
	RANK of bf_trunk	29.688	1	29.688	.666	.4213	.022
	RANK of bf_total	3.193	1	3.193	.056	.8150	.002
Error	RANK of bf_arms	1543.069	29	53.209			
	RANK of bf_legs	2562.560	29	88.364			
	RANK of bf_trunk	1293.663	29	44.609			
	RANK of bf_total	1661.318	29	57.287			
Total	RANK of bf_arms	16205.500	36				
	RANK of bf_legs	16205.500	36				
	RANK of bf_trunk	16205.500	36				
	RANK of bf_total	16205.000	36				
Corrected Total	RANK of bf_arms	3884.500	35				
	RANK of bf_legs	3884.500	35				
	RANK of bf_trunk	3884.500	35				
	RANK of bf_total	3884.000	35				

3. pa * injury

Dependent Variable	pa	injury	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
RANK of bf_arms	Active	Para	13.615[a]	1.980	9.565	17.665
		Quad	23.377[a]	2.662	17.932	28.821
	Inactive	Para	17.883[a]	2.971	11.808	23.959
		Quad	25.240[a]	3.413	18.260	32.221
RANK of bf_legs	Active	Para	19.576[a]	2.552	14.356	24.795
		Quad	14.025[a]	3.431	7.009	21.041
	Inactive	Para	22.877[a]	3.828	15.047	30.706
		Quad	17.200[a]	4.398	8.204	26.196
RANK of bf_trunk	Active	Para	19.137[a]	1.813	15.428	22.845
		Quad	19.851[a]	2.437	14.866	24.836
	Inactive	Para	14.733[a]	2.720	9.170	20.296
		Quad	19.432[a]	3.125	13.040	25.823
RANK of bf_total	Active	Para	19.082[a]	2.055	14.879	23.284
		Quad	19.090[a]	2.762	13.441	24.739
	Inactive	Para	16.782[a]	3.082	10.478	23.086
		Quad	18.098[a]	3.541	10.855	25.341

a. Covariates appearing in the model are evaluated at the following values: RANK of age = 18.50000, RANK of time_inj = 18.50000, RANK of bmi = 18.50000.

Differences in Lean Body Mass Among Groups
(Two-Way Between-Groups Multivariate Analysis of Covariance)

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
pa	Pillai's Trace	.092	.660	4.000	26.000	.6256	.092
	Wilks' Lambda	.908	.660	4.000	26.000	.6256	.092
	Hotelling's Trace	.101	.660	4.000	26.000	.6256	.092
	Roy's Largest Root	.101	.660	4.000	26.000	.6256	.092
injury	Pillai's Trace	.601	9.803	4.000	26.000	.0001	.601
	Wilks' Lambda	.399	9.803	4.000	26.000	**.0001**	.601
	Hotelling's Trace	1.508	9.803	4.000	26.000	.0001	.601
	Roy's Largest Root	1.508	9.803	4.000	26.000	.0001	.601
pa * injury	Pillai's Trace	.135	1.014	4.000	26.000	.4186	.135
	Wilks' Lambda	.865	1.014	4.000	26.000	.4186	.135
	Hotelling's Trace	.156	1.014	4.000	26.000	.4186	.135
	Roy's Largest Root	.156	1.014	4.000	26.000	.4186	.135

b. Design: Intercept+Rage+Rtime_in+Rbmi+pa+injury+pa * injury

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
pa	RANK of lbm_arms	9.011	1	9.011	.213	.6479	.007
	RANK of lbm_legs	99.239	1	99.239	1.041	.3159	.035
	RANK of lbm_trunk	6.759	1	6.759	.098	.7565	.003
	RANK of lbm_total	17.945	1	17.945	.256	.6165	.009
injury	RANK of lbm_arms	878.391	1	878.391	20.759	**.0001**	.417
	RANK of lbm_legs	502.537	1	502.537	5.273	.0291	.154
	RANK of lbm_trunk	374.905	1	374.905	5.437	.0269	.158
	RANK of lbm_total	277.307	1	277.307	3.960	.0561	.120
pa * injury	RANK of lbm_arms	21.084	1	21.084	.498	.4859	.017
	RANK of lbm_legs	5.674	1	5.674	.060	.8089	.002
	RANK of lbm_trunk	133.124	1	133.124	1.931	.1753	.062
	RANK of lbm_total	89.199	1	89.199	1.274	.2683	.042
Error	RANK of lbm_arms	1227.099	29	42.314			
	RANK of lbm_legs	2763.600	29	95.297			
	RANK of lbm_trunk	1999.689	29	68.955			
	RANK of lbm_total	2030.895	29	70.031			
Total	RANK of lbm_arms	16206.000	36				
	RANK of lbm_legs	16206.000	36				
	RANK of lbm_trunk	16206.000	36				
	RANK of lbm_total	16206.000	36				
Corrected Total	RANK of lbm_arms	3885.000	35				
	RANK of lbm_legs	3885.000	35				
	RANK of lbm_trunk	3885.000	35				
	RANK of lbm_total	3885.000	35				

3. pa * injury

Dependent Variable	pa	injury	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
RANK of lbm_arms	Active	Para	22.906[a]	1.766	19.294	26.518
		Quad	12.345[a]	2.374	7.490	17.201
	Inactive	Para	23.407[a]	2.649	17.990	28.825
		Quad	9.489[a]	3.044	3.264	15.714
RANK of lbm_legs	Active	Para	16.590[a]	2.650	11.169	22.010
		Quad	24.977[a]	3.563	17.690	32.263
	Inactive	Para	11.810[a]	3.975	3.680	19.941
		Quad	21.939[a]	4.568	12.597	31.281
RANK of lbm_trunk	Active	Para	13.175[a]	2.254	8.565	17.786
		Quad	25.390[a]	3.030	19.192	31.588
	Inactive	Para	18.414[a]	3.382	11.498	25.330
		Quad	22.192[a]	3.885	14.245	30.138
RANK of lbm_total	Active	Para	14.845[a]	2.272	10.198	19.491
		Quad	25.175[a]	3.054	18.929	31.421
	Inactive	Para	16.636[a]	3.408	9.666	23.606
		Quad	20.060[a]	3.916	12.052	28.068

a. Covariates appearing in the model are evaluated at the following values: RANK of age = 18.50000, RANK of time_inj = 18.50000, RANK of bmi = 18.50000.

Differences in Bone Mineral Density Among Groups
(Two-Way Between-Groups Multivariate Analysis of Covariance)

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
pa	Pillai's Trace	.443	5.174	4.000	26.000	.0033	.443
	Wilks' Lambda	.557	5.174	4.000	26.000	**.0033**	.443
	Hotelling's Trace	.796	5.174	4.000	26.000	.0033	.443
	Roy's Largest Root	.796	5.174	4.000	26.000	.0033	.443
injury	Pillai's Trace	.358	3.628	4.000	26.000	.0177	.358
	Wilks' Lambda	.642	3.628	4.000	26.000	.0177	.358
	Hotelling's Trace	.558	3.628	4.000	26.000	.0177	.358
	Roy's Largest Root	.558	3.628	4.000	26.000	.0177	.358
pa * injury	Pillai's Trace	.231	1.953	4.000	26.000	.1316	.231
	Wilks' Lambda	.769	1.953	4.000	26.000	.1316	.231
	Hotelling's Trace	.300	1.953	4.000	26.000	.1316	.231
	Roy's Largest Root	.300	1.953	4.000	26.000	.1316	.231

b. Design: Intercept+Rage+Rtime_in+Rbmi+pa+injury+pa * injury

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
pa	RANK of bmd_arms	774.503	1	774.503	16.638	**.0003**	.365
	RANK of bmd_legs	441.346	1	441.346	4.797	.0367	.142
	RANK of bmd_trunk	147.363	1	147.363	3.043	.0917	.095
	RANK of bmd_total	233.550	1	233.550	4.017	.0545	.122
injury	RANK of bmd_arms	316.254	1	316.254	6.794	.0143	.190
	RANK of bmd_legs	58.903	1	58.903	.640	.4301	.022
	RANK of bmd_trunk	.303	1	.303	.006	.9375	.000
	RANK of bmd_total	80.958	1	80.958	1.392	.2476	.046
pa * injury	RANK of bmd_arms	134.897	1	134.897	2.898	.0994	.091
	RANK of bmd_legs	10.332	1	10.332	.112	.7399	.004
	RANK of bmd_trunk	326.631	1	326.631	6.745	.0146	.189
	RANK of bmd_total	174.436	1	174.436	3.000	.0939	.094
Error	RANK of bmd_arms	1349.920	29	46.549			
	RANK of bmd_legs	2667.854	29	91.995			
	RANK of bmd_trunk	1404.299	29	48.424			
	RANK of bmd_total	1686.043	29	58.139			
Total	RANK of bmd_arms	16205.000	36				
	RANK of bmd_legs	16204.000	36				
	RANK of bmd_trunk	16205.000	36				
	RANK of bmd_total	16203.000	36				
Corrected Total	RANK of bmd_arms	3884.000	35				
	RANK of bmd_legs	3883.000	35				
	RANK of bmd_trunk	3884.000	35				
	RANK of bmd_total	3882.000	35				

3. pa * injury

Dependent Variable	pa	injury	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
RANK of bmd_arms	Active	Para	26.883[a]	1.852	23.095	30.671
		Quad	15.292[a]	2.490	10.200	20.384
	Inactive	Para	11.718[a]	2.778	6.035	17.400
		Quad	8.620[a]	3.192	2.091	15.149
RANK of bmd_legs	Active	Para	23.002[a]	2.604	17.677	28.328
		Quad	18.658[a]	3.500	11.499	25.816
	Inactive	Para	13.585[a]	3.906	5.596	21.574
		Quad	11.591[a]	4.488	2.412	20.769
RANK of bmd_trunk	Active	Para	22.936[a]	1.889	19.072	26.800
		Quad	16.555[a]	2.540	11.361	21.749
	Inactive	Para	11.565[a]	2.834	5.770	17.361
		Quad	18.401[a]	3.256	11.741	25.060
RANK of bmd_total	Active	Para	24.090[a]	2.070	19.856	28.324
		Quad	15.545[a]	2.783	9.854	21.236
	Inactive	Para	13.265[a]	3.105	6.914	19.616
		Quad	14.378[a]	3.568	7.082	21.675

[a] Covariates appearing in the model are evaluated at the following values: RANK of age = 18.50000, RANK of time_inj = 18.50000, RANK of bmi = 18.50000.

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