NUTRIENT INTAKES OF ELITE CANADIAN ATHLETES WITH A SPINAL CORD INJURY

by

Jennifer Luella Krempien

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Abstract

Energy intakes of adults with spinal cord injury (SCI) have been reported to be relatively low with many micronutrients below recommended amounts but very little is known about the diets of athletes with SCI. This cross-sectional, observational study assessed energy intakes and estimated the prevalence of dietary inadequacy in a sample of elite Canadian athletes with SCI (n=32). Three-day self-reported food diaries completed at home and training camp were analyzed for energy (kcal), macronutrients, vitamins and elements and compared to the Dietary Reference Intakes (DRIs). Energy intakes were 2156 ± 431 kcal for men and 1991 ± 510 kcal for women and the macronutrient intakes as a percentage of energy were within the Acceptable Macronutrient Distribution Ranges for both men (55.6% carbohydrate, 17.9% protein, 28.1% fat) and women (53.3% carbohydrate, 17.9% protein, 28.9% fat). While at training camp, greater than 25% of men had mean intakes below the Estimated Average Requirement (EAR) for magnesium, zinc, riboflavin, folate and vitamin B12. At home, prevalence of inadequacy decreased for magnesium, zinc and riboflavin but not for folate. At home, men had greater intakes of vitamin D (160.1 ± 133.4 IU vs. 38.5 ± 78.3 IU, $p<0.05$) and calcium (856 ± 330 mg vs. 693 ± 204 mg, $p<0.05$). The proportion of women with intakes below the EAR was greater while at training camp for magnesium, niacin and folate. No significant differences in the mean intake of any nutrients were detected between home or training camp for women. Cognitive dietary restraint scores were higher than expected for men with relatively low scores for disinhibition and hunger.

These results demonstrate that athletes with SCI are at risk of several nutrient inadequacies relative to the DRIs, despite a diet with an appropriate macronutrient balance. A higher prevalence of nutrient inadequacy was observed in men especially while at training camp. Women were able to better maintain nutrient adequacy in both situations. This highlights an opportunity for coaches, administrators, sport scientists and dietitians working with these athletes to improve the access to better food choices and to educate athletes in making more balanced food choices.

Preface

This Master of Science thesis was prepared according to requirements as detailed by the Faculty of Graduate Studies at the University of British Columbia[1]. For Chapters 2 and 3, I conceived the study design and methods, identified the study objectives, recruited the participants, collected and managed all data, planned and conducted the data analyses, presented the findings and wrote the manuscript. My thesis supervisor (Dr. Susan Barr) was the Principal Investigator for the study and contributed continuously to all aspects of the study design, data management and analyses, interpretation and presentation of the results and key editorial contributions. My committee members (Dr. William Sheel and Dr. Andrei Krassioukov) made significant contributions by stimulating discussion pertaining to methodological choices, statistical analyses and provided editorial input to this manuscript

Ethics approval to conducted this research was obtained by the University of British Columbia - Behavioural Research Ethics Board (BREB) on April 14, 2007 (UBC BREB number: H07-00011) with renewals on March 31, 2008 and February 3, 2009. Ethics approval was terminated on November 19, 2009.

[1] The University of British Columbia Faculty of Graduate Studies. *Masters and Doctoral Thesis Preparation and Submission.* Available at http://www.grad.ubc.ca/current-students/dissertation-thesis-preparation/structure-masters-thesis.

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List of abbreviations

AB	able-bodied
AI	Adequate Intake
AIS	American Spinal Injury Association impairment scale
AIS-A	American Spinal Injury Association impairment scale – A indicating complete injury
AIS-B to D	American Spinal Injury Association impairment scale – B to D indicating incomplete injury
AMDR	Acceptable Macronutrient Distribution Range
ASIA	American Spinal Injury Association
BMI	body mass index (kg/m^2)
BMR	basal metabolic rate
BREB	Behavioural Research Ethics Board
C	cervical spine
C4	cervical spine, 4^{th} spinal cord segment
cm	centimetre
CVD	cardiovascular disease
d	day
DRI(s)	Dietary Reference Intake(s)
DXA or DEXA	dual energy X-ray absorptiometry
EAR	Estimated Average Requirement
EER	Estimated Energy Requirement
F	female
FFQ	food frequency questionnaire
g	gram
H	home
HDL	high density lipoprotein cholesterol
IU	International Units
kcal	kilocalorie
kg	kilogram
kJ	kilojoule
L	lumbar spine
LDL	low density lipoprotein cholesterol
M	male
m	metre
mcg	microgram
μmol/L	micromole per litre
MET hr/d	calculated metabolic equivalent hours per day
MET(s)	metabolic equivalent(s)
mg	milligram
mg/dL	milligram per decilitre

mm	millimetre
mmol	millimole
mmol/L	millimole per litre
n	sample size
NR	not reported
P	paraplegia
PASIPD	Physical Activity Scale for Individuals with a Physical Disability
RDA	Recommended Dietary Allowance
RE	retinol equivalents
REE	resting energy expenditure
RMR	resting metabolic rate
RPE	rate of perceived exertion
S	sacral spine
SCI	spinal cord injury
SD	standard deviation
SHAPE-SCI	Study of Health and Activity in People with Spinal Cord Injury
SPSS	Statistical Package for Social Sciences
T	tetraplegia
T	thoracic spine
T1	thoracic spine, 1st spinal cord segment
TC	training camp
TEE	total energy expenditure
TEF	thermic effect of feeding
TFEQ	Three-Factor Eating Questionnaire
TG	triglycerides
UK	United Kingdom
USDA	United States Department of Agriculture
vs.	versus
YEPQ	Yale Eating Pattern Questionnaire

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For my parents who have unconditionally encouraged, loved, supported and celebrated with me throughout this degree and all aspects of my life, thank you simply feels inadequate. I love you both and truly appreciate all that you have taught me.

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Chapter 1: Introduction

1.1 Background

Spinal cord injury (SCI) occurs when the spinal cord is damaged by trauma or disease and results in a loss of function (1). The spinal cord does not need to be completely severed for a loss of function to occur and in many cases moderate damage to the spinal cord is sufficient to result in a loss of functioning (1, 2). In 2008, the Canadian incidence rate for SCI was estimated at 1,200 per year, with an estimated 41,000 Canadians living with SCI (3). Advancements in the immediate treatment of SCI, medical management of chronic medical issues and improved rehabilitation over the past five decades have improved outcomes for individuals living with SCI (4). Most individuals with SCI continue to enjoy a high quality of life with many choosing competitive sport as a venue for challenging the barriers and obstacles created by SCI (5).

Competitive sport opportunities for individuals with a disability have blossomed over the past 60 years culminating in an exhibition of athletic excellence at the winter and summer Paralympic Games. The competitive nature of the Paralympic Games demands athletes to optimize training and performance strategies to attain competition goals. Olympic and able-bodied athletes have benefited from decades of research with the aim to improve training and monitoring protocols, recovery techniques and nutrition strategies. However, the research to support the training and performance strategies of athletes with a disability is still in its infancy. While a long-term goal would be the establishment of specific evidence-based performance nutrition recommendations directed towards athletes with a SCI, it is important to first better understand what elite athletes with an SCI are consuming and explore what factors are influencing those nutrition choices.

1.2 Literature review

1.2.1 Overview

This review of the current research regarding athletes with SCI and their nutrition choices is organized into three sections. To provide background information on how SCI could affect dietary choices, the first section provides a brief description of SCI and the relevant metabolic differences associated with it. The physiological adaptations and autonomic functional changes are also addressed as they pertain to the physical and cardiovascular capacity following SCI. Body composition is influenced by physical activity, spinal cord injury and can also be influenced by nutrition. Accordingly, this review then shifts to illustrate some of the body composition changes that occur following SCI with a comparative look at body composition differences between athletes and non-athletes with SCI. Energy expenditure including the energy expenditure associated with physical activity is then examined including reports of predicted versus actual intakes and some of the difficulties in using predictive equations in this population. This review then offers an in depth discussion of the nutrient intakes and dietary adequacy of community dwelling individuals with SCI, finishing with a review of the few reported studies of dietary intakes in athletes with SCI.

1.2.2 Spinal cord injury

The nervous system consists of an intricate and large neural communication network of which the primary role is to establish connections between the brain and the rest of the body. When trauma, disease or congenital defects damage the spinal cord, a change in motor or sensory function occurs. SCI can be divided into two types of injury based on motor and sensory function - complete or incomplete. A complete injury means that there is no function below the level of the injury; no sensation and no voluntary movement (6). An incomplete injury means that there is some motor or sensory function below the primary level of the injury (6).

Spinal cord functions differ by level and structure (**Table 1.1**), with injury or disease resulting in varying types and degrees of dysfunction depending on the specific neural structures affected (7, 8). Typically, if the injury is higher in the spinal cord the impact of the injury with loss of motor and sensory function is more pronounced (9, 10). Cervical injuries usually result in tetraplegia and injuries above the C4 spinal cord segment and may require ventilator support for the person to breathe. Those with a C5 injury often retain shoulder and biceps control, but limited or absent wrist or hand control. Those with C6 injury generally retain wrist control, but no or limited hand function. Individuals with C7 or T1 injury can straighten their arms but still may have dexterity problems with the hand and fingers. Injuries of the upper thoracic level T1 – T8 result in poor trunk control as the result of lack of abdominal muscle control but full function of the shoulders, arms and hands remain. With injury to the lower thoracic level T9 – T12, good truck control and good abdominal muscle control remains with lower limbs affected with loss of function. Lumbar and sacral injuries yield decreasing control of the hip flexors and legs. SCI can be classified based on the level of injury and remaining function. Those with injury to the cervical spinal cord, are categorized as tetraplegic, or more simply all four limbs are affected with reduced function. Those with injury to the thoracic, lumbar or sacral spinal cord are categorized as paraplegic, as the lower limbs are affected with reduced function.

Table 1.1 Segmental spinal cord level and function

Spinal Cord Level	Function
C1-C6	Neck flexors
C1-T1	Neck extensors
C3, C4, C5	Supply of diaphragm
C5, C6	Shoulder movement (arm raise, elbow flexion, C6 externally rotates arm)
C6, C7, C8	Triceps and wrist extensors, pronates wrist
C7, C8, T1	Wrist flexion
C8, T1	Small muscles of hands
T1 -T6	Intercostals and trunk control above waist
T7-L1	Abdominal muscles
L1, L2, L3, L4	Thigh flexion
L2, L3, L4	Thigh adduction
L4, L5, S1	Thigh abduction
L5, S1 S2	Extension of leg at the hip (gluteus maximus)
L2, L3, L4	Extension of the leg at the knee (quadriceps femoris)
L4, L5, S1, S2	Flexion of the leg at the knee (hamstrings)
L4, L5, S1	Dorsiflexion of foot (tibialis anterior)
L4, L5, S1	Extension of toes
L5, S1, S2	Plantar flexion of foot
L5, S1, S2	Nexion of toes

Adapted from Tortora & Derrickson, 2006. (10)
Abbreviations: C, Cervical Spine; T, Thoracic Spine; L, Lumbar Spine; S, Sacral Spine

1.2.3 Metabolic changes associated with spinal cord injury

Metabolic syndrome

Metabolic syndrome is defined as a clustering of anthropometric, biochemical and clinical symptoms known to increase an individual's risk of cardiovascular disease (11). The National Cholesterol Education Program's Adult Treatment Panel III report identified abdominal obesity, dyslipidemia, elevated blood pressure, insulin resistance with or without glucose intolerance, a proinflammatory state and a prothrombotic state to be key components of metabolic syndrome as it relates to cardiovascular disease (CVD) risk (12). Individuals with SCI exhibit many of these traits common in metabolic syndrome including increased abdominal obesity (13-16), dyslipidemia (17-20), hypertension (21, 22), insulin resistance (18, 23, 24) and a proinflammatory state (25, 26). While the exact cause of these observed abnormalities is not fully understood, it is most likely a combination of the direct hormonal, biochemical or autonomic changes associated with SCI and secondary factors including decreased muscle mass, increased adiposity and reduced physical activity related to the SCI.

Given this pattern of the presence of metabolic syndrome characteristics, the observation that CVD is the leading cause of death in SCI (27), and that there are greater rates of CVD related morbidity in SCI compared to able-bodied populations, it would be reasonable to assume that, when compared to able-bodied populations, those with SCI are at an increased risk for metabolic syndrome and ultimately CVD (28). However, the picture is not that clear. A cross-sectional study of 185 men with SCI matched with able-bodied controls measured anthropometric and biochemical indices associated with metabolic syndrome. Those with SCI did not appear to have increased prevalence of metabolic syndrome (29). While a difference in the prevalence of metabolic syndrome *per se* was not detected, differences in the metabolic profile were observed with the SCI group having higher total cholesterol, low density lipoprotein cholesterol (LDL), triglycerides (TG), and glucose concentrations when adjusted for waist circumference, education, household income and smoking status as compared to their matched controls. In a similar cross-sectional study of adults with SCI, Finnie et al. found a 2.0 to 5.4 times lower prevalence of metabolic syndrome compared to the general population depending on the criteria and definition of metabolic syndrome (30). The authors postulated that current definitions of metabolic syndrome and screening tools such as Framingham Risk Scoring underestimate prevalence of metabolic syndrome in those with SCI. For example, elevated fasting glucose levels are a criterion for metabolic syndrome, but in SCI, fasting levels may be normal whereas glucose tolerance is impaired (30). Thus, in those with SCI, different criteria may be more appropriate, and it may prove to be beneficial to include markers of inflammation such as C-reactive protein in the determination of metabolic syndrome prevalence (25, 31).

Carbohydrate metabolism

Glucose intolerance is more frequent in those with SCI (18, 20, 32, 33). Most individuals with SCI who have abnormal glucose metabolism show resistance to the action of insulin in mediating glucose uptake by peripheral tissues (28, 33, 34). In general, fasting glucose levels in SCI are not abnormally elevated but glucose concentrations following a glucose load are significantly higher at the 60, 90 and 120 minute post-load measurements (23, 24, 35). Abnormal glucose metabolism is multi-factorial with genetic predisposition, impaired insulin action, pancreatic beta cell function and modifiable risk factors all contributing to overall risk of developing type 2 diabetes (36). The level of neurological impairment is associated with the degree to which glucose metabolism is affected. For example, those with tetraplegia demonstrated hyperinsulinemia more frequently than those with paraplegia (53% vs. 37%, $p<0.05$), and those with complete tetraplegia had higher values for serum glucose concentration with an oral glucose tolerance test than incomplete tetraplegic or paraplegic subjects (23). Thus SCI contributes another dimension to the list of risk factors for altered glucose metabolism.

Lipid metabolism

Low serum concentrations of high density lipoprotein (HDL) cholesterol and high concentrations of low density lipoprotein (LDL) cholesterol play an important role in the development of atherosclerotic plaque formation and coronary heart disease (12). Higher concentrations of HDL cholesterol have been shown to be protective against atherosclerotic plaque formation while an elevated serum LDL cholesterol concentration is an independent CVD risk factor (12). Individuals with SCI have been studied as a model for accelerated and premature coronary heart disease as they tend to have an increased odds ratio of death due to CVD (Odds Ratio 1.86, 95% confidence interval 0.86 – 4.05) (27). There is a general consensus among researchers that the concentration of HDL cholesterol is lower in persons with SCI compared to able-bodied populations (35, 37-39). Bauman et al. (39) found serum HDL cholesterol levels below 35 mg/dL (0.9 mmol/L) in 40% of subjects with SCI and a strong inverse correlation between serum triglyceride and HDL cholesterol concentrations. As with glucose, there is a strong association between the level of neurological defect and lipid metabolism as those with complete tetraplegia tend to have a more abnormal lipid profile in comparison to those with incomplete tetraplegia, complete and incomplete paraplegia (20, 40). Although HDL cholesterol concentrations are generally depressed in SCI, improvement of cardiopulmonary fitness and increased levels of physical activity have been shown to improve HDL cholesterol levels (38, 41-44). LDL cholesterol concentrations measured in SCI populations tend to be similar to those observed among able-bodied populations with approximately 25% of individuals having an elevated serum LDL cholesterol concentration (35, 42).

1.2.4 Autonomic function following spinal cord injury

A healthy, intact spinal cord is responsible for transmitting motor and sensory neural signals within the somatic nervous system and an array of signals for the autonomic nervous system. The autonomic nervous system is a key regulator for a myriad of essential physiological functions including cardiovascular control through heart rate determination, stroke volume, vascular resistance, arterial blood pressure and cardiac output (45). The physiological and biochemical regulation of the autonomic nervous system involve complex processes and are beyond the scope of this review. For a detailed and informative review, the reader is directed to an article by Krassioukov & Claydon (46).

Following SCI, many autonomic disturbances or clinical symptoms can be experienced. Those with a higher level of SCI (cervical or high thoracic injury) may experience low blood pressure and episodes of orthostatic hypotension (47). To prevent episodes of orthostatic hypotension, some clinicians recommend increasing plasma volume through hydration and increased salt intake in combination with postural changes (48). The cardiovascular effects of autonomic dysfunction are likely the most profound symptoms but the alterations in autonomic nervous system function extend to impact thermoregulation (49, 50), sweat rate (51) and control of epinephrine release in response to exercise or stress (45). In those with cervical SCI, resting supine plasma adrenaline and noradrenaline concentrations are low (52, 53). Whereas resting supine plasma adrenaline and noradrenaline concentrations were normal in those with thoracic SCI (52). Those with cervical SCI have less ability to increase catecholamine concentrations in response to orthostatic challenge (52) or in response to maximal exercise (54).

Physiological adaptations in athletes with spinal cord injury

Additional physiological adaptations occur in response to exercise in those with SCI. Alteration in cardiac structure and function are common among those with SCI with circulatory dysregulation and hypotension occurring in those with injuries to the cervical spine (55). A low mean arterial pressure challenges the ability to regulate systemic blood pressure during orthostatic challenge and physical activity (56). As well, cardiac ventricular size and function are diminished (57). In paraplegia, blood pressure control, left ventricular mass and resting cardiac output remain normal (58). However, those with paraplegia have lower stroke volume because of a decreased venous return from the immobile lower extremities (59). There is strong support of a direct relationship among the level of injury, peak workload, and peak oxygen uptake attained during arm crank ergometry (60-63). Those with a higher level of injury, especially those with injury above the level of sympathetic outflow to the heart have significantly lower resting stroke volumes and higher resting heart rates than able-bodied individuals (64).

In summary, SCI is associated with a number of metabolic and physiological changes. Observed trends of dyslipidemia, glucose intolerance and hypertension in the context of high rates of mortality and increased morbidity from CVD may influence the diets and nutritional choices of those with SCI. Often the first treatment recommended is therapeutic lifestyle modification including modification of dietary fats, decreased sodium intake, increased intake of whole-grains, increased intake of vegetables and fruit and increased physical activity (65). These recommendations may influence the types and quantities of foods selected by individuals with SCI in an attempt to decrease some of the modifiable risk factors associated with CVD.

1.2.5 Body composition changes associated with spinal cord injury

Body fat

Following SCI, body fat appears to increase in comparison to pre-injury body composition or compared to able-bodied controls. Suggested ranges for ideal body fat percentage (body fat relative to body weight) for able-bodied men are 13 – 18% and 28 – 32% for women (66). Although international standards for evaluating body fat percentages do not currently exist, it has been proposed that men with body fat percentages greater than 25% can be considered obese as are women with body fat percentages greater than 38% (66). In 1988, Nuhlicek et al. reported body fat percentages of men with SCI to be significantly higher than able-bodied controls (67). When level and completeness of SCI injury were considered, body fat percentage increased along with the severity of the injury with tetraplegics having 35% body fat compared to paraplegics with 30% body fat.

Spungen et al. (68) studied the body composition of 133 males with SCI (66 men with tetraplegia, 67 men with paraplegia) with an age-, height-, weight- and ethnicity-matched control group of 100 subjects. Using dual energy X-ray absorptiometry (DXA), Spungen et al. found the SCI group was 13 ± 1% (mean ± standard error) fatter per unit of body mass index (kg/m^2) ($p<0.0001$). Tetraplegic and paraplegic groups had significantly higher total fat mass (24.11 ± 1.34 kg; 23.86 ± 1.42 kg respectively) compared to the control group (18.74 ± 1.08 kg), as well as a 50% higher percentage total body fat (33% vs. 22%). Interestingly, when regional distribution of fat mass was considered a significantly greater amount of arm fat mass in both paraplegics (3.23 ± 0.02 kg) and tetraplegics (3.16 ± 0.02 kg) existed compared to the control group (1.63 ± 0.01 kg). Within the paraplegic and tetraplegic groups, those with complete injury had higher absolute fat mass but this did not remain significant once adjusted for body size. In this well designed cross-sectional study (68), those with SCI are clearly shown to have much higher total fat mass and percent body fat, including a higher regional percent body fat of the arms.

Muscle mass

Altered body composition following SCI is characterized by increased fat mass and relative body fat percentage but perhaps more clinically important is the reduction in lean tissue or fat-free mass and muscle stores. A small sample (n=5) of adult males with paraplegia compared with ten age- and height-matched controls demonstrated significant body composition changes assessed by dual energy x-ray absorptiometry (DXA) (69). The SCI group had a lean tissue mass of 48.7 ± 6.7 kg ($p<0.01$), fat mass of 24.0 ± 13.6 kg ($p<0.05$) and percent body fat of 30.1 ± 9.0% ($p<0.01$), in comparison to the control group body composition of 57.9 ± 3.7 kg lean tissue, 12.6 ± 4.9 kg fat mass, and 16.6 ± 5.0% body fat respectively. Consistent with these observations, Maggioni et al. (70) also reported that a group of 13 subjects with SCI had a significantly lower percentage of total body fat-free mass (62.2 ± 8.9% vs. 73.5 ± 6.4%, $p<0.05$). When these authors assessed the regional distribution of fat-free mass, they found that the percentage of fat-free mass was significantly higher in the upper limbs of SCI compared to the control (10.6 ± 2.3% vs. 8.7 ± 1.0%, $p<0.05$), whereas lower percentages were observed in total body, trunk and lower body regions. The authors presented body composition data as a percentage of body weight of fat mass, fat-free mass and bone mineral density. The overall pattern of percent lean and percent fat is similar to the results found by Spungen et al. (68) with values of approximately 63% of body weight as lean mass in those with SCI compared to 73% in controls and 31% of body weight as fat mass in those with SCI compared to 21% in controls.

Cardus and McTaggart (71) estimated total body protein in adults with SCI using a crude estimation method subtracting total body fat and total body water from the weight of bone mineral free body and reported a 24 to 30% reduction in absolute amount of total body protein. An interesting study by Spungen et al. (72) investigated body composition of monozygotic twins discordant for spinal cord injury. Their data from eight pairs of male twins, one having a SCI (T6 – L1, motor complete lesion) demonstrate some unique body composition changes following SCI. Generally, the SCI group weighed less; had less total body, lower body and trunk lean tissue mass; and had similar arm lean tissue mass. On average, the difference in total body weight was 10.1 ± 11.5 kg which was predominantly from the loss of lean tissue in the lower body (-10.0 ± 4.1 kg). As the time from injury increased, the loss of lean tissue was more pronounced (72).

<u>Bone mineral density and content</u>

Several studies have documented the phenomenon of decreased bone mass following SCI (69, 73-75). Post injury demineralization of bone occurs in areas below the neurological lesion and predominantly in the long bones of the lower limbs increasing fracture risk at the distal femur and proximal tibia (72, 75-77). A cross-sectional study by Dauty et al. (78) of 11 tetraplegics and 20 paraplegics more than one year post injury demonstrated a significant demineralization of the distal femur (-52%) and the proximal tibia (-70%) compared to age-matched controls. The bone mineral density and bone mineral content is clearly reduced in regions below the level of injury in paraplegics compared to controls (78). In tetraplegia, the regions of reduced bone mineral density and content extend to include the upper extremities (78). It is thought that the demobilization and loss of mechanical force on the bone contributes to the decrease in bone mineralization (79) although this remains somewhat controversial. It is interesting to note that the use of body weight supported treadmill training in a small number of subjects with tetraplegia shortly after injury did not prevent or slow the rate of bone loss (80, 81). The benefits of physical activity on bone density were investigated comparing male paraplegic basketball players to male sedentary paraplegics (82). Both groups had decreased bone densities in the lower body (trochanters and femoral necks), whereas densities of lumbar and radial regions were slightly increased in both groups. The radial density was significantly higher in the athletes compared with the sedentary group suggesting participation in sport may be beneficial to preserve bone density in upper extremities.

1.2.6 Body composition of athletes with spinal cord injury

Relatively few studies have specifically considered the potential impact of high levels of physical activity in those with SCI. Ide et al. (83) were one of the first groups to present data on the anthropometric characteristics of a large sample of wheelchair marathoners. Anthropometric data from 2,677 competitors were collected over a ten year period from

1983 to 1992 as a part of a health check program associated with the race. The competitors from each year were classified as fine racers if they had completed the full marathon race (n=710) or classified as poor racers if they did not complete the half marathon (n=99). The remaining participants (n=1868) were excluded from the analysis if they completed the half marathon or failed to complete the full marathon. Statistical analysis was performed using a best versus worst performance approach with data from the 10 years pooled. The comparison between the two groups showed the fine racers to have greater upper arm muscle power and a greater lung vital capacity. The measures of body composition of the fine versus poor racers were not statistically different until the last year of data collection which showed the fine racer group had a lower body fat percentage (18.7 ± 4.3% vs. 23.7 ± 8.8%). The girth measurements of chest and upper arm were significantly larger in the fine racers group which is likely related to increased muscle mass as measures of strength were also higher. As the years progressed, the scores for strength measures improved in the fine racer group indicating a training effect. One limitation of this interesting study is that the same athletes often compete in the race for multiple years which may have biased the statistical analysis.

Bulbulian et al. (84) compared athletes with paraplegia to a heterogeneous sample of able-bodied subjects classified as having either mesomorph or ectomorph physiques. Skinfold measurements of pectoral, tricep, subscapular, abdomen, thigh and calf sites in the athletes with SCI were all significantly larger than both mesomorph and ectomorph control groups. Olle et al. (85) compared a sedentary and active SCI group found that the increased level of activity had a positive effect with lower estimates of percentage of fat mass and higher estimates of percentage of fat-free mass in the active group as measured by total body electrical conductivity. However, there was only a trend of reduced skinfold thicknesses in the athlete group. A more recent study by Goosey-Tolfrey (86) monitored the British men's national wheelchair basketball team for the two years leading up to the 2000 Paralympic Games. Measures of fitness (VO_2 peak) improved but body composition, as measured by the sum of skinfolds from 4 sites, did not statistically improve. Mojtahedi and colleagues (87) compared the body composition (measured by DXA) of 14 athletes with

SCI with a control group of 17 age- and BMI-matched able-bodied sedentary controls. Despite matching for BMI, the SCI group weighed less (57.6 ± 11.0 kg vs. 70.5 ± 12.5 kg, $p<0.05$) and were shorter in stature (161.6 ± 11.1 cm vs. 172.1 ± 11.4 cm, $p<0.05$). Statistically significant differences were also detected in body composition with SCI athletes having less fat mass, lean tissue and trunk fat mass but there was no difference in the overall measure of percentage of body fat (25.1 ± 7.0% vs. 26.5 ± 7.2%).

Although the data are limited and not completely consistent, the few studies that have reported on body composition in athletes with SCI suggest beneficial effects of strength and cardiovascular training in lowering the percentage of body fat. Although somewhat inconclusive, it appears that the effects of training on body composition are not systemic but rather affect regions above the level of injury.

1.2.7 Energy expenditure

Energy expenditure is often described as total energy expenditure (TEE) which is comprised of three components, resting energy expenditure (REE), thermic effect of food (TEF) and energy expenditure of physical activity. TEE has been found to be lower in individuals with SCI compared to able-bodied populations (88). The three components of TEE and the impact of SCI are described in the following sections.

Resting energy expenditure in spinal cord injury

REE is largely determined by body size and the amount of fat-free mass. Fat-free mass consists of all residual lipid-free chemicals and tissues including water, muscle, bone, connective tissue and internal organs (89) and is described as the metabolically active component at the molecular and cellular level of body composition. In normally active individuals, REE generally accounts for approximately 65% of TEE. REE is determined by extrapolating the resting metabolic rate (RMR) which is typically measured when the subject is at rest, at least 4 hours post-prandial and in ambient temperatures to reflect energy expenditure at rest for a 24 hour period. The RMR is typically 10% higher than the basal metabolic rate (BMR) which is measured under more stringent conditions where the subject is fasted overnight, in a supine position, in a thermo-neutral environment and shortly after waking (90).

Absolute measured REE has been found to be considerably less in individuals with SCI compared with able-bodied individuals (16, 88, 91-93). The decrease in REE in SCI can be explained by a decrease in fat-free mass (88, 91, 93-97). Fat-free mass accounts for 25 to 85% variation in REE (94, 98, 99) with fat-free mass the single best predictor of RMR in those with paraplegia (r^2=0.70, $p<0.0001$) (91). Adjusting REE for fat-free mass eliminates the differences between SCI and able-bodied groups in most studies (16, 91, 92). Monroe et al. (88) found that 24 hour energy expenditure was lower in those with SCI (-180 kcal/day, $p<0.01$) compared to able-bodied controls after adjusting for fat-free mass, fat mass and age. Monroe et al. measured 24 hour energy expenditure, BMR, sleeping metabolic rate, spontaneous physical activity, TEF and the 24 hour respiratory quotient while subjects were housed in a respiratory chamber. While the respiratory chamber is not the ideal condition for detecting differences between groups as the subjects are restricted to a small area, the observation of differences in energy expenditure after correcting for differences in body composition adds strength to the body of evidence that energy expenditure is less in those with SCI. In free-living conditions, it would be expected that the differences in physical activity levels between the two groups would be more obvious as studies have shown that those with SCI tend to be more sedentary than able-bodied populations (88, 93).

Thermic effect of feeding in spinal cord injury

Thermic effect of feeding (TEF) accounts for approximately 10% of total energy expenditure. Three studies (88, 91, 100) have considered the potential impact of TEF in evaluating the energy expenditure of SCI. One study found that TEF, expressed as a percentage of energy intake in male SCI subjects was lower than that of able-bodied controls (12.1 ± 2.7 vs. 15.3 ± 4.4, $p<0.05$) (88). Conversely, in the other two studies, no differences in TEF were observed: paraplegia had no apparent effect on TEF (91), and SCI compared to able-bodied groups had similar TEF when expressed as a percentage of either energy intake or RMR (100).

Energy expenditure of physical activity in spinal cord injury

Physical activity is the third component of total energy expenditure and on average, contributes 25 to 30% of TEE. As previously discussed, it is unlikely that expenditure of metabolically active fat-free mass or the thermic effect of food is significantly different between SCI and able-bodied populations. Differences in physical activity levels, in combination with a reduction in fat-free mass between the groups would account for the differences in TEE. The physical activity levels of adults with SCI were measured by heart rate monitoring and activity records (93). Over half (55.6%) of the subjects participated in structured physical activity at least one time during the three day observation period. However, TEE was low; indicating that structured activity was not of sufficient frequency or intensity to offset the sedentary nature of daily living for this population. Monroe et al. (88) measured energy expenditure and physical activity of SCI and controls in a respiratory chamber setting. The amount of spontaneous physical activity was significantly lower in the SCI group (4.6 ± 1.9% vs. 6.5 ± 2.0% per 24 hours, $p<0.05$). However, this was not an ideal measurement circumstance to reproduce energy expenditure in free-living individuals as the subjects were restricted to the chamber. When men with SCI were monitored using heart rate telemetry, total daily energy expenditure on 'inactive' days was significantly lower than able-bodied controls (101). On 'active' days the total energy expenditure was not significantly different between the SCI and able-bodied groups. Individuals with SCI are at an increased risk of leading a sedentary lifestyle. The impact of high intensity, high frequency physical activity and exercise on the total energy expenditure in athletes with SCI has not been measured.

Predictive equations

Energy expenditure may be measured using indirect calorimetry or doubly labeled water methods. When it is not feasible to measure REE, predictive equations have been developed for a variety of healthy and clinical populations to predict energy requirements (90, 99, 102, 103). The majority of such equations were developed using able-bodied individuals as the reference population and these predictive equations have been shown to over predict measured REE in individuals with SCI by 5 – 32% (16, 88, 91, 96). Mojtahedi and Evans (104) measured resting metabolic rate (indirect calorimetry) and body composition (DXA) in college-aged athletes with SCI and compared the measured values with estimates from commonly used predictive equations. Measured resting metabolic rate for males was 1598 ± 187 kcal/day and 1120 ± 129 kcal/day for women. For the group, the Harris-Benedict equation (103) significantly over predicted RMR (1501 ± 236 kcal/day vs. 1337 ± 291 kcal/day, p=0.001). Interestingly, when measured RMR was compared with the predicted RMR using the equation developed by Buchholz et al. (91) in a population of adults with paraplegia as the reference group, predicted RMR was still greater than measured (1530 ± 223 kcal/day vs. 1337 ± 291 kcal/day, p<0.001). They found the predictive equations overestimate resting metabolic rate in highly active people with SCI. There are currently no validated equations or methods to predict energy requirements in this population. However, for the purposes of this study and literature review, comparisons of reported energy intakes and the values predicted by the EER developed by the Institute of Medicine (90) have been made. It is understood that these predictive equations were developed with a reference population of able-bodied adults and the interpretation of these comparisons should be done with the utmost of caution.

1.2.8 Assessment of nutrient adequacy

This section describes the framework of how nutrient adequacy is assessed and how the prevalence of nutrient inadequacy in a group is determined. Before commenting on the available literature that reports nutrient intakes of individuals with SCI, it is important to describe the current framework established with the Dietary Reference Intakes (DRIs) (105, 106) and provide some explanation of how dietary adequacy was evaluated prior to the DRIs. The terminology used in the DRI model is defined in **Table 1.2** and a graphical schematic is provided in **Figure 1.1** as a reference for the reader.

The DRIs provided us with reference data for nutrient intakes and established a novel framework for the assessment of the *prevalence of nutrient inadequacy* in a group (104). For nutrients with both an Estimated Average Requirement (EAR) and a Recommended Dietary Allowance (RDA), the prevalence of inadequacy can be estimated as the proportion of the group with usual intakes below the EAR. For other nutrients, the data were not sufficiently robust to allow an EAR to be identified and for these nutrients, Adequate Intakes (AIs) were established. The AI represents an intake level thought to meet or exceed the requirements of almost all members of a group, should it have been possible to determine the requirement distribution. Inferences regarding nutrient adequacy for nutrients with an AI are limited: if the group mean intake meets or exceeds the AI, it is probable that the prevalence of inadequacy in the group is low.

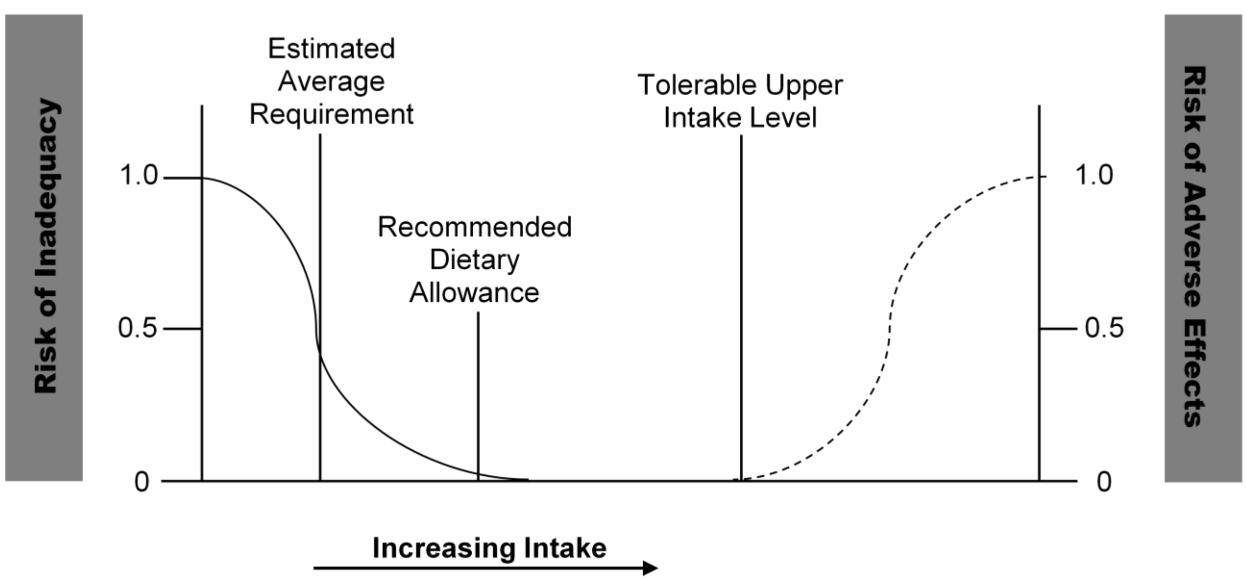
Prior to the introduction of the DRIs, the RDA was the only available reference standard, and it was not always based on knowledge of the requirement distribution. Frequently, authors compared mean group intakes to the RDA (or in some cases to a percentage of the RDA, such as 67%), and assessed them as “adequate” if mean intake exceeded the RDA and “inadequate” if below the RDA. While it is very likely that some proportion of the group would have inadequate intakes when mean intake falls below the RDA, this system did not permit insight into whether a small versus a large proportion of the group had inadequate intakes. Furthermore, because the variability of intake distributions greatly exceeds the variability of requirement distributions, some prevalence of inadequacy will occur in a group even when mean intakes meet or slightly exceed the RDA. Thus, comparing literature published before and after the introduction of the DRIs is challenging. Nevertheless, when older literature reports that intakes were “inadequate” (based on the group’s mean intake falling below the RDA), it can be inferred that intakes of at least some proportion of the group did not meet their requirements.

Table 1.2 Explanation of terminology from Dietary Reference Intake framework

Estimated Average Requirement (EAR): The average daily nutrient intake level that is estimated to meet the requirements of half of the healthy individuals in a particular life stage and gender group. i.e., intake that meets the requirements of 50% of an age/sex group (mean intake)
Recommended Dietary Allowance (RDA): The average daily dietary nutrient intake level that is sufficient to meet the nutrient requirements of nearly all (97 – 98 percent) of healthy individuals in a particular life stage and gender group. i.e., intake that meets the requirements of almost all members of an age/sex group (mean intake + 2 standard deviations)
Adequate Intake (AI): The recommended average daily intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people that are assumed to be adequate; used when an RDA cannot be determined.
Prevalence of Nutrient Inadequacy in a Group: An estimate of the proportion of the group with intakes that are below their estimated requirements.
Tolerable Upper Intake Level (UL): The highest average daily nutrient intake level that is likely to pose no risk of adverse health effects to almost all individuals in the general population. As intake increases about the UL, the potential risk of adverse effects may increase.

Adapted from Institute of Medicine, Dietary Reference Intakes 2000 (106)

Figure 1.1 Schematic of Dietary Reference Intake requirement distribution



1.2.9 Nutrient intakes in community living individuals with spinal cord injury

The body of literature which comprehensively evaluates energy intakes along with both macronutrient composition and micronutrient adequacy is limited with only four published reports of community-living adults with SCI and an additional two reports documenting the intakes of athletes with SCI. Several other studies have measured and reported energy intake as a covariate of one of the study variables, or reported on one or two components of dietary intake but overall the evaluation of the full diet has been omitted from the published results. The key findings of these studies are summarized in **Table 1.3**.

The first report of dietary intakes of individuals with SCI was published in 1992 by Levine and colleagues (107). The dietary intake of 33 adults with SCI (21 with tetraplegia, 11 with paraplegia, 1 did not describe SCI) was self-reported for 7 days with average intake compared to the Recommended Dietary Allowance (RDA) (108). Mean intakes for each nutrient were calculated and reported as a percentage of the RDA. The energy intake was reported to be 1682 ± 429 kcal for men and 1282 ± 418 kcal for women. For men, the percentage of energy from macronutrients was 46% carbohydrate, 38% fat and 17% protein. Women had slightly higher carbohydrate intake at 52% of calories, slightly lower fat intake at 32% of calories and similar protein intake at 17%. Fibre intake for both men (12.2 ± 4.7 g; range of 6.0 – 22.7 g) and women (14.3 ± 8.8 g; range of 4.4 – 27.6 g) was below the recommended intake and it is interesting that women had a slightly greater fibre intake while consuming fewer calories.

Intakes of several micronutrients were below the RDA for men including: vitamin A (815 ± 455 RE, 82% RDA), thiamin (1.32 ± 0.43 mg, 88% RDA), riboflavin (1.46 ± 0.45 mg, 86% RDA), vitamin B6 (1.51 ± 0.49 mg, 76% RDA), vitamin E (7.8 ± 4.3 mg TE, 78% RDA), calcium (550 ± 268 mg, 69% RDA), magnesium (217 ± 65 mg, 62% RDA) and zinc (10.2 ± 4.1 mg, 68% RDA). Women reported intakes below the RDA for calcium (525 ± 263 mg, 66% RDA), iron (13.5 ± 8.33 mg, 90% RDA) magnesium (242 ± 123 mg, 86% RDA) and zinc (9.3 ± 5.8 mg, 78% RDA). Overall, the diets of this group were found to be low in energy intake, low in fibre with several micronutrients at risk of inadequate intake. Women tended to have a diet with fewer micronutrient inadequacies despite a very low reported caloric intake.

The results of this study are limited as the weight and height of subjects were not reported. As body composition directly impacts energy requirements, it would have been helpful to know if this population was under or overweight as the reported energy intakes are quite a bit lower than in later reports. The authors comprehensively reported on the mean intakes with standard deviation and ranges for all macro and micronutrients with comparison to the RDA. This study provides a good example of the difficulties in the assessment of the prevalence of inadequacy in a group because the tools required to estimate the prevalence of inadequacy in a group were not available. As a result, the authors compared mean intakes to the RDA or some proportion of the RDA and assessed intakes as inadequate if the group mean fell below that standard. However this does not mean that everyone in the group had inadequate intakes. Moreover, even when a mean intake of a group equals or is slightly above the RDA, it is possible that some proportion of the group would have inadequate intakes (106). However, even with these limitations, this report provided a comprehensive initial description of the dietary adequacy of community living SCI population.

Tomey and colleagues evaluated the nutritional status of 95 men with paraplegia using a seven-day semi-quantitative food frequency questionnaire to measure dietary intakes (15). Dietary adequacy was assessed by reporting the proportion of participants with mean intakes below the EAR for iron, vitamin C and folate or the proportion of participants meeting 67% of the AI for fibre, calcium and vitamin D. Energy intake was reported at 9479 ± 3117 kJ (2264 ± 745 kcal) with 49.3 ± 8.8% of kcal from carbohydrate, 36.2 ± 7.1% of kcal from fat and 14.5 ± 3.0% of kcal from protein. Fibre intake was reported at 17.1 ± 7.3 g per day with only 12% of participants exceeding the cut-point of 25 g of fibre (67% of AI). Almost no participants had intakes below the EAR for iron, while approximately 25% of individuals had intakes of vitamin C below the EAR and 33% of individuals had intakes of folate below the EAR. The mean calcium intake was 755 ± 373 mg with only 57% of participants reporting intakes above 670 mg (67% of the AI). The strengths of this study include the sample size and relative homogeneity of the participants and the method of collecting dietary intake reflected usual intake patterns and decreased the chance of an unusual or abnormal dietary intake. Dietary supplement usage was not reported which may have decreased the frequency of inadequacy. While the DRIs were used as the reference cut-points, the adjustment of the cut-point for nutrients with an AI to 67% may overestimate those with adequate intakes for a particular nutrient (106).

Groah and colleagues studied nutrient intakes in a sample of 73 adults (61 men and 12 women) with SCI (109). Participants completed a four-day food record including at least one weekend day but excluded supplement intake. Reported energy intake was statistically different with men consuming 2049 kcal and women reporting 1662 kcal (p=0.04). There was no statistical difference in energy intake between the men with paraplegia (2088 kcal) and men with tetraplegia (2012 kcal). Subgroup analyses were not completed for women as there was only one woman with tetraplegia. The percentage of energy from macronutrients varied based on gender and SCI with the general trend of 44.3 – 52.5% kcal from carbohydrate, 31.7 – 36.6% kcal from fat and 14.2 – 18.5% kcal from protein. Fibre intake was quite low with intakes ranging from 12.7 g to 14.5 g per day. Vitamin and mineral intakes were reported as mean intakes for each of the four subgroups. Statistical differences in mean intakes of vitamin D (3.53 mcg vs. 2.22 mcg) and vitamin B6 (1.73 mg vs. 1.32 mg) were detected as men with paraplegia reported a higher intake compared to men with tetraplegia. No other significant differences were detected. Of note, calcium intake for men ranged from 649 mg (male-paraplegia) to 779 mg (male-tetraplegia) excluding the value for the one woman with tetraplegia who consumed 856 mg of calcium. Unfortunately, there were no reports of the proportion of subjects with median intakes above the AI or the proportion of subjects with intakes below the EAR which makes it challenging to interpret or assess the probability of adequacy. Data were only presented as means without standard deviation or ranges so it was difficult to interpret variability of the anthropometrics and nutrient intakes.

One of the more complete studies reporting on the dietary intakes and adequacy population of adults with SCI was recently published by Walters and colleagues (110) as a subset of data collected for the Study of Health and Activity in People with Spinal Cord Injury (SHAPE-SCI) (111). Dietary intake was collected by interviewer administered multiple-pass 24 hour recalls (n=77) with a repeat measure in six months time (n=68). Mean usual intakes of macronutrients were compared to the Acceptable Macronutrient Distribution Range (AMDR) while inadequacy of micronutrients was determined by the percentages of participants with mean intakes below the EAR for a given nutrient. For nutrients with an AI as the reference value, if the median intake of the nutrient met or exceeded the AI it was assumed that there was a low risk of inadequacy. If the median intake was below the AI, no assessment of inadequacy was made.

For men the mean usual energy intake was 2096 ± 420 kcal per day with 52% of energy from carbohydrate, 30% from fat and 16% from protein. Women reported intakes of 1711 ± 152 kcal per day with 53% of energy from carbohydrate, 28% from fat and 17% from protein. The median intakes for vitamin D, calcium, potassium and fibre for all age groups and both genders were below the AI. All intakes of sodium were well above the respective AI for the age and gender group. Nutrient inadequacies, reported as percentage of participants with mean intake below EAR were detected for several nutrients for both men and women. Greater than 50% of men had intakes below the EAR for vitamin A (92%), magnesium (89%), folate (75%), zinc (71%) and vitamin C (52%). Greater than 50% of women had inadequate intakes of folate (79%), magnesium (71%) and vitamin A (57%). Overall, the women had a decreased prevalence of mean intakes below the EAR as compared to the men. The only statistically significant difference based on SCI was that those with a complete SCI consumed more calcium than those with an incomplete SCI (947 ± 449 mg vs. 758 ± 348 mg, $p<0.05$). Usage of vitamin and mineral supplements was reported at 53% of participants consuming a calcium, multivitamin, vitamin C or vitamin D supplement.

This study was well designed with several strengths. The method of dietary intake data collection used reduced much of the potential participant bias by conducting the interview in person, in home and with graduated food models to estimate portion in a standardized manner (106). As well the data collection was repeated at a six month interval with 88% of participants providing a second report of dietary intake. Dietary intakes were adjusted to remove intra-individual variation to provide a more precise estimate of the usual intake distribution before comparison to the DRIs was made. A minor limitation of this study was that dietary supplements were not incorporated into dietary analysis to determine if the supplemental vitamins and minerals may have decreased the prevalence of inadequacies.

Although vitamin and mineral supplements were not directly incorporated into the dietary analysis of the Walters et al. study, the pattern of supplement usage from the SHAPE-SCI group over a period of 18 months was recently reported (112). In a study of 77 adults with SCI (from SHAPE-SCI), 24% of participants consumed a multivitamin, 20% consumed a calcium supplement and 16% consumed supplemental vitamin D. Intake was measured at three time points (0, 6 and 18 months) and 71.4% of participants reported taking a supplement at least once during the 18 month period while 50.6% of participants were consistent supplement users (reported supplement usage at least two out of three reporting periods).

Measurements of serum vitamin concentrations support the findings of suboptimal dietary intakes in adults with SCI (113, 114). Plasma concentrations of vitamin C were measured in a sample of 23 adults with physical disabilities of which SCI was included and compared to a control group (n=50) (113). The group with disabilities had a lower plasma concentration of vitamin C as compared to the control group (62.1 ± 28.5 μmol/L vs. 77.9 ± 24.5 μmol/L, p=0.02). Average daily intake of citrus fruits was also lower in the group with disabilities (0.25 ± 0.30 servings vs. 0.65 ± 0.66 servings, p=0.008) as was the dietary intake of fruits and vegetables (excluding potatoes) (1.02 ± 0.68 servings vs. 2.29 ± 1.2 servings, p=0.02). Moussavi and colleagues (114) measured serum concentrations of vitamin A, C and E in 110 adults with SCI. They reported 16.4% of subjects had a serum concentration of vitamin A below the lower limit of the reference range, 37.3% of subjects had a serum concentration of vitamin C below the reference range and 30.0% of subjects were below the reference range for vitamin E. In a sample of 22 individuals with physical disabilities, Burri and Neidlinger (115) measured dietary vitamin A, vitamin E and total carotenoids along with plasma concentrations of retinol, α-tocopherol and total carotenoids. Compared to a control group (n=35), significantly lower plasma concentrations of α-tocopherol (23 ± 7 μmol/L vs. 28 ± 8 μmol/L, p=0.004) and total carotenoids (1.0 ± 0.3 μmol/L vs. 1.5 ± 0.5 μmol/L, p=0.002) were detected. The only significant difference in dietary intake between the groups was the number servings of fruits and vegetables (except potatoes) reported was lower in the subjects with disabilities compared to the control group (1.5 ± 1.0 servings vs. 2.2 ± 1.1 servings, p=0.01).

Interpretation and comparison of the data presented to date on dietary adequacy in the SCI population is difficult due to selection of cutpoints, reliance on reporting of mean intakes and a shift in the framework from Recommended Dietary Allowances to the concept of Estimated Average Requirements. Until the most recent study by Walters et al., the concept of reporting prevalence of individuals with mean intakes below a cut-point was not well established. However, in spite of these methodological shifts and differences in the data reported, trends have emerged from the limited research which has attempted to quantify and assess dietary intakes of adults with SCI. Reported energy intakes are generally below what is estimated using a variety of predictive equations. The distribution of macronutrients within the reduced energy intake follows the recommendations set by the AMDR except for consistently low fibre intakes. The intake of micronutrients is concerning with several micronutrients identified as being at risk for suboptimal intakes including folate, vitamin C, magnesium and zinc. The mean intakes of calcium and vitamin D are consistently below the recommended intake levels for healthy adults. Those with SCI are at extremely high risk of developing osteoporosis below their injury (78, 116) and a general recommendation of increased calcium and vitamin D intakes to optimize bone health following SCI has been suggested by physiatrists (117, 118).

Table 1.3 Summary of studies on dietary adequacy in adults with spinal cord injury

Reference	Sample Size	Sample	Method of Diet Data Collection	BMI (kg·m^{-2})	Energy Intake (kcal·day^{-1})	Nutrients at risk of inadequacy
Levine et al. (1992) (107)	n=33	M: 24 F: 9 P: 11 T: 21	7 day food record and FFQ	not reported	M:1682 ± 429 F: 1282 ± 418	M: vitamin A, thiamin , riboflavin, pyridoxine, vitamin E, calcium, magnesium, zinc, fibre F: calcium, iron, magnesium, zinc, fibre
Potvin et al. (1996) (119)	n=10 (athletes)	M:10	3 day food record (weighed intake)	M: 20.5	M: 2138 ± 473	M: vitamin E, zinc
Tomey et al. (2005) (15)	n=95	M: 95 P: 95	7 day food record and FFQ	M: 26.2±6.5	M: 2264 ± 745	M: fibre, folate, calcium, vitamin C
Groah et al. (2009) (109)	n=73	M: 61 F: 12 P: 48 (11 F, 37 M) T:25 (1 F, 24 M)	4 day food record	M-P: 25.2 M-T:24.2 F-P:21.2 F-T: 46.0	M-P: 2012 M-T: 2088 F-P: 1662 F-T: 2685	M: vitamin D, folate, calcium , zinc, fibre F: vitamin D, folate, calcium, fibre
Walters et al. (2009) (110)	n=77	M: 63 F: 14 P: 38 T: 39	multiple pass 24 hr recall, repeat 6 month interval	M: 26±5 F: 26±7	M: 2096 ± 492 F: 1711 ± 152	M: calcium, vitamin D, potassium, fibre, vitamin A, vitamin C, folate, magnesium, zinc F: calcium, vitamin D, potassium, fibre, vitamin A, folate, vitamin B12, magnesium, zinc
Abbreviations: BMI, Body Mass Index; M, Male; F, Female; P, Paraplegia; T, Tetraplegia; FFQ, food frequency questionnaire; n, sample size						

1.2.10 Nutrient intakes in athletes with spinal cord injury

To date, only two articles and one abstract have been published which report on nutrient intakes in athletes with SCI (119-121). The study by Potvin et al. (119) reported on the dietary intakes of ten Canadian male elite wheelchair marathoners. The researchers weighed and measured all food consumed by these athletes for three days during a team training event. Caloric intakes were reported to be 2138 ± 473 kcal per day (34.5 kcal per kg of body weight) with a macronutrient breakdown of 47.9% energy from carbohydrate, 32.1% energy from fat and 19.5% energy from protein. Based on the Dietary Reference Intakes for Estimated Energy Requirements (EER) (90) the predicted energy intake for this group was 2300 kcal per day based on a sedentary physical activity coefficient and 2512 kcal per day based on a low active physical activity coefficient (**Table 1.4**).

Potvin and colleagues also reported on vitamin and mineral intakes (119). Mean intakes were compared to Recommended Nutrient Intake (RNI) with a cut-point of 67% of the RNI. Mean intakes of vitamins and minerals were all above the cut-point with the exception of vitamin E (six athletes had intakes below) and zinc (three athletes had intakes below). Interestingly, in this study the athletes consumed 1154 ± 416 mg of calcium and 6.26 ± 4.00 μg of vitamin D which are the highest reported intakes of both of these nutrients in the literature.

However, these results might not reflect true intakes of the athletes as food was provided for athletes and intake was closely monitored and weighed for the three days of data collection potentially biasing food choices of the athletes. Unfortunately, this report did not fully describe the level of injury or motor function of SCI for the subjects so it is difficult generalize the results. It is evident however, that in this small sample of wheelchair marathoners, the energy intakes were below what one may expect or predict especially considering the probable high physical activity levels of these individuals.

Results presented in abstract form from Lally et al. (120) found similar results when investigating the dietary characteristics of sixteen American and twelve Japanese marathoners. Based on a 24 hour recall, energy intake for the American marathoners was 1909 kcal/day and 1627 kcal/day for the Japanese marathoners. The macronutrient composition of the diet was not different between the groups and was 53% of energy from carbohydrate, 26% of energy from fat and 20% of energy from protein. The American athletes were also reported to have a higher weekly training volume (379 vs. 296 minutes).

A study by Ribeiro et al. (121) described the nutritional status and dietary intakes of 60 Brazilian male wheelchair basketball athletes. The subjects' disability was categorized as either SCI (n=28) or poliomyelitis sequels in the legs (n=32). Ribeiro et al. used three consecutive 24 hour dietary recalls to capture dietary intakes combined with laboratory and body composition analysis. Similar to the study by Potvin et al. (119), this group reported energy intakes which were considerably less than expected when predictive equations accounted for estimated fat-free mass. The equations predicted 41 kcal/kg body weight using the predictive equation using fat-free mass developed by Cunningham et al. (99), whereas energy intakes of 25 kcal/kg body weight were observed. The anthropometric data of the subjects reported by Ribeiro et al. can be used to estimate energy requirements using the DRIs (90). The equations predict an estimated energy requirement of 2745 – 3180 kcal per day which is similar to the predictions for the subjects in the Potvin et al. study (119). The macronutrient distribution (50% of kcal from carbohydrate, 37% kcal from fat, 20% kcal from protein) for the subjects in the Ribeiro et al. study (121) was within the AMDR for carbohydrate and protein but slightly above recommendations for fat. The results reported for micronutrients were limited to calcium with an average intake of 701 ± 392 mg. It is unfortunate that mean intakes of key micronutrients and assessment of the prevalence of dietary inadequacy were not reported from the dietary intakes of these athletes.

Of the published reports, it is clear that the observed energy intakes are lower than the predicted values for sedentary individuals. The predictive methods used in the studies (90, 99, 108) are based on data gathered from able-bodied individuals and cannot be generalized for use with individuals with SCI. It is also disappointing that all the subjects were male. Female athletes have been reported to restrict energy intakes (122) and it would be interesting to know if this trend also holds true among female athletes with SCI.

Table 1.4 Energy intakes of athletes with SCI: measured and predicted intakes

Study	Subjects	Measured Energy Intakes		Predicted Energy Intakes[a]	
	mean age, height, weight	kcal/day	kcal/kg	kcal/day	kcal/kg
Potvin et al. (39)	30.7 years, 1.74 m, 62.2 kg	2138 ± 473	34.5	2300 – 2512[a]	37 – 40
Ribeiro et al. (41)	18 – 40 years, 1.68 m, 62.1 kg	NR (estimated at 1552 kcal using mean weight)	25	2266 – 2474[a] ~2540[b]	37– 40 ~41[b]
Lally et al. (40)	NR	1909 kcal (American) 1627 kcal (Japanese)	NR	NR	NR

[a] Predicted energy intakes based on estimated energy requirements for age, gender, height and weight adjusted for estimated activity levels (90). Range presented is based on sedentary to low active physical activity coefficient.
[b] Predicted energy intakes using Cunningham equation (99)
Abbreviations: NR, not reported

1.3 Limits to current knowledge

Individuals with SCI and in particular highly trained athletes with SCI provide a unique model to investigate. Significant changes to body composition including a decrease in fat-free mass and increased adiposity (especially below the level of injury) contribute to a number of undesirable metabolic abnormalities. While an increased incidence of dyslipidemia and glucose intolerance has been observed, the reasons why individuals with SCI are experiencing these metabolic patterns are not fully understood. Current theories relate to the impact of decreased lean muscle or increased adipose tissue, the potential impact of high rates of obesity in this population, the effect of a more sedentary lifestyle or most likely a combination of all these factors. As the level of physical activity increases, those with SCI tend to have a more 'normal' metabolic profile. Nutrition therapy, along with increased physical activity and reduction of obesity rates could offer better outcomes of CVD related morbidity and mortality post-SCI.

On the other side of the SCI spectrum of physical activity, athletes are challenging their bodies to adapt to the physical limitations of SCI and maximize the physical systems that remain intact. Nutrition as a performance and recovery strategy remains largely unstudied. It is unknown what the specific energy and macronutrient requirements are for athletes with SCI to optimize glycogen replenishment or promote muscle recovery. At a more basic level of understanding, it is unclear if these athletes are consuming a diet which meets the recommendations for all Canadians or if there are macronutrients in excess or micronutrient intakes which are suboptimal.

1.4 Rationale

Elite athletes with a spinal cord injury are placing extreme athletic demands on their bodies with the expectation of excellence within their sport. Advances in equipment, competitive opportunities and training protocols have supported these athletes in surpassing what was once believed to the ceiling of physical performance. The physiological alterations and adaptations associated with SCI in combination with the high physical demands of training and competition create a unique situation of energy intakes and demands. For these athletes to optimize nutrition as a performance enhancing strategy they must negotiate the macronutrient and energy balance associated with the energy expenditure of training and competition within the reduced energy expenditure (16, 88, 91-93) associated with decreased lean muscle mass and SCI (68). This presents a novel and interesting population in which to explore and describe dietary intakes and practices.

1.4.1 Research objectives

The primary purpose of this study was to explore and describe the current dietary intakes of elite Canadian athletes with a spinal cord injury. As this study was designed to be exploratory in nature, to better understand what elite athletes with SCI are consuming and what factors are influencing those dietary choices, specific hypotheses were not established. Rather, specific objectives were established to guide the study and data analyses.

Objectives for chapter 2

1. Evaluate the dietary adequacy of macronutrient and micronutrient intakes of elite athletes with a spinal cord injury using the Dietary Reference Intakes for macronutrients (90), vitamins and elements (123-127) as comparative tools.

2. Assess the usage of supplemental vitamins and minerals and evaluate the impact on dietary adequacy.

3. Compare and contrast the energy and nutrient intakes of athletes while training at home and at a national team event.

4. Assess athletes' understanding of nutrition recommendations using a nutrition knowledge questionnaire (128).

5. Compare and contrast the energy and nutrient intakes of elite athletes with a spinal cord injury to the Canadian population (129).

Objectives for chapter 3

1. Describe food related attitudes and behaviours as assessed by the Three-Factor Eating (130) and Yale Eating Patterns Questionnaires (131).

2. Explore cognitive dietary restraint scores and associations with dietary intake, anthropometrics and SCI characteristics.

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Chapter 2: Elite Canadian Athletes with Spinal Cord Injury Are At Risk of Nutrient Inadequacies While at Home and Team Training Events

2.1 Introduction

Canadian athletes with a spinal cord injury (SCI) are training at intensities, durations and frequencies that rival those of their Olympic colleagues. The competitive nature of the Paralympic Games demands athletes optimize training and performance strategies to attain competition goals. Knowledge of sport-specific nutritional requirements of athletes with SCI is almost nonexistent while there is a wealth of knowledge to guide and support performance nutrition practices for able-bodied athletes (1). However, before the sport-specific nutritional needs of athletes with SCI are investigated it is important to understand what dietary choices these athletes are making and to assess the nutrient adequacy of those choices.

There is evidence that individuals with SCI are at greater risk than able-bodied individuals for a number of metabolic abnormalities including dyslipidemia (2, 3), hyperinsulinemia (4), obesity (5-7), hypertension (8) and diabetes mellitus (9). Those with SCI comprise a unique population with physiological differences which dramatically impact metabolism, cardiovascular control (10, 11) and body composition (7). Sedentary individuals with SCI have been investigated as a model for premature aging as those with SCI have a higher risk of cardiovascular disease, impaired glucose metabolism and obesity (12, 13). Physical activity is able to attenuate, but not completely eliminate, some of these negative metabolic effects in the SCI population (14-16).

Three studies have investigated dietary adequacy in the SCI population (17-19). The studies were consistent in reporting energy intakes of approximately 2100 – 2250 kcal per day for men and approximately 1700 kcal per day for women with a similar pattern of energy from macronutrients (46 – 53% kcal from carbohydrate, 28 – 36% kcal from fat and 15 – 17% kcal from protein). Using multiple-pass 24-hour recalls repeated at six months, Walters et al. (17) reported that a group of 77 community-living Canadians with SCI had mean usual intakes of calcium, vitamin D, potassium and fibre below the Adequate Intake (AI) for their age and gender. Greater than 50% of individuals in this sample had median intakes below the Estimated Average Requirements (EAR) for vitamin A, vitamin C, folate, magnesium and zinc and greater than 20% of individuals had mean intakes below the EAR for thiamin, vitamin B6 and vitamin B12. Groah et al. (18) reported the dietary intake of 73 individuals with SCI using four days of self-reported food records and found a similar pattern of intakes below the recommended level for calcium, vitamin D, fibre, folate and zinc. Tomey et al. (19) reported on the dietary intakes of 95 men with paraplegia using a 7-day semi-quantitative food frequency questionnaire and found low intakes of calcium, vitamin C, folate and fibre.

The studies which targeted athletes with a disability are less robust with outcomes focused on energy intakes and percentage of energy from macronutrients (20-22). Riberio et al. (20) reported on dietary intakes of 28 wheelchair basketball athletes with paraplegia and found energy intakes of approximately 1550 kcal (25 kcal per kg) with 50% of kcal from carbohydrate, 37% kcal from fat and 20% kcal from protein. The only micronutrient reported was a mean calcium intake of 701 ± 392 mg. Potvin et al. (21) reported energy intakes of 2138 kcal per day (48% carbohydrate, 32% fat, 20% protein) and macronutrients for ten wheelchair marathoners. In this small sample, athletes were assessed to be at risk of suboptimal nutrient intakes for zinc (n=3) and vitamin E (n=6) as the mean intake was below a cut-point of 67% of the Recommended Dietary Allowance (RDA) (23).

The physiological alterations and adaptations associated with SCI in combination with the physical demands of training and competition create a unique situation of energy intakes and demands. This presents a novel and interesting population in which to explore and describe dietary intakes and adequacy. Accordingly, the primary objectives of this study were to assess the energy intakes and dietary adequacy of elite Canadian athletes with a SCI by comparing dietary intakes to the Dietary Reference Intakes (DRIs) and the reported dietary intakes of Canadians. Secondary objectives included comparing intakes between home and national team training environments and an assessment of the athletes' understanding of nutrition principles.

2.2 Methods

2.2.1 Overview of study design

This exploratory cross-sectional study was designed to assess energy, macronutrient and micronutrient intakes of elite Canadian athletes with SCI. Participants were enrolled between May 2007 and March 2009. An investigator attended a national team training event to recruit participants, explain study procedures, collect questionnaire data, measure anthropometrics and assist participants with the completion of three-day food and activity records. Athletes were instructed on how to accurately complete the three-day food records including methods to estimate portion sizes, recording strategies and the importance of including condiments and beverages. In addition, an investigator was present during meal times to provide support with completing the food diary and answer any questions the participants had regarding how to record certain foods.

A questionnaire was self administered to record demographic data such as age, number of years on the national team, usual training practices, nutrition related goals, medications and details related to spinal cord injury including self-reporting of the level and completeness of injury. The motor and sensory function of the participant's SCI was assessed using a modified assessment of neurological function based on the American Spinal Injury Association (ASIA) standard system for classification of spinal cord injury (24, 25). Participants also completed a questionnaire-based assessment of nutrition knowledge (26), the Three-Factor Eating questionnaire (27) and the Yale Eating Patterns questionnaire (28, 29). Results of the Three-Factor Eating and Yale Eating Patterns questionnaires are presented elsewhere (**Chapter 3**). For three days at the national team event, participants also recorded their time spent engaged in physical activity and rated the intensity of the activity using a rating of perceived exertion scale (30, 31). On the last day of the national team event, the questionnaire data, three-day food records and three-day activity records were collected and participants were provided with the necessary forms to repeat the three-day food and activity records at home, along with a self-addressed stamped envelope to return these forms to the investigator. Instructions were given to the participants to complete the home food and activity records for three consecutive days, including one weekend day and return the complete records within two weeks. Upon receipt of the records, if data were unclear or details missing, the investigator contacted the participant for clarification. The study protocol was approved by the Behavioural Research Ethics Board at The University of British Columbia (**Appendix 1**) and participants provided informed written consent (**Appendix 2**).

2.2.2 Participant recruitment

Recruitment and identification of potential athletes was conducted by an initial letter of invitation (**Appendix 3**) sent to all national team head coaches associated with the Canadian Paralympic Committee. At the time of this study, Canada had athlete representation in 21 Paralympic sports and 11 of the sports met the eligibility requirements of providing competitive opportunities for athletes with SCI, with an expected minimum of 12 hours of physical training per week. Coaches from all 11 eligible sports (4 winter and 7 summer) received an invitation to participate via email and each coach was contacted to discuss the study and arrange for an investigator to attend a national training camp or event. Head coaches were requested to provide athletes with information pertaining to the study and alert the athletes that a researcher (Jennifer Krempien) would be at a national team event to collect data, should they choose to participate. Detailed information regarding the recruitment procedures is outlined in **Appendix 4**. It is estimated that between 75 and 80 athletes within Canada met the inclusion criteria during the recruitment period. A total of 41 athletes were approached in person to participate in the study and a total of 34 athletes consented to participate with 32 athletes completing all aspects of the study.

To be eligible, athletes had a SCI resulting in paraplegia or tetraplegia, with either complete or incomplete impairment of motor function. Elite athletes were targeted for this study. Each athlete met a minimum of one of the following criteria: member of a senior national team, received senior level funding from the Sport Canada Athlete's Assistance Program, ranked in the top three for his or her sport within Canada or ranked in the top five in the world for his or her sport discipline. For athletes participating in a team sport, the last international ranking for the team was used to establish the athlete's international ranking. For example, the wheelchair rugby team finished third at the 2006 World championships so all athletes on that roster were ranked as third and thus met the inclusion criteria. If an athlete was not a member of the national team, their ranking was based on their provincial team performance at Canadian Nationals. All athletes participated in ongoing physical training for a minimum of 12 hours per week. Athletes were 19 years of age or older and understood written and spoken English.

2.2.3 Participant characteristics

Data pertaining to participant characteristics were self-reported by participants using a questionnaire developed for this purpose. Demographics such as age, sport information including years on the national team, international ranking, training information and nutrition related goals were included. Details of the participant's SCI were also recorded including year of injury, level of SCI, cause and description of SCI. Additional medical conditions or prescription medications were listed. A copy of the demographic questionnaire is included in **Appendix 5**.

2.2.4 Description of spinal cord injury

The American Spinal Injury Association (ASIA) developed a standard system for the classification and description of spinal cord injury tool designed for physiatrists to test the remaining motor and sensory function following SCI (24, 25, 32, 33). The full assessment is quite burdensome for the subject as the sensory examination requires light touch and pin prick testing to each of 28 dermatomes on the right and left sides of the body and a strength evaluation of ten muscle groups. For the purpose of this study, the ASIA Impairment Scale (AIS) was limited to classification of the neurological completeness of the injury. A score of AIS-A indicated no motor or sensory function preserved in the sacral segments S4-S5 indicating a complete injury while AIS-B through D combined to indicate incomplete SCI. Each athlete was also categorized as either tetraplegic if they self-reported an injury to their cervical spine or paraplegic if they self-reported thoracic injury.

2.2.5 Anthropometry and body composition

Weight (kg) was measured to the nearest 0.1 kg with athletes wearing light indoor clothing without shoes using a portable digital scale with remote display (Universal Weight Enterprise Company Ltd., Model AMP-150, Taipei, Taiwan). The scale was modified with a larger seating platform and non-ambulatory participants sat directly on the scale for measurement. Length (m) was measured with participants in a supine position on a firm surface with the soles of the participant's feet against a wall. The subject's length was marked on the surface and then measured. The measured length was verbally reported to the subject. If the measurement was greater than 2 cm different than what the subject believed his or her height to be, the measurement procedure was repeated.

All skinfold measurements were taken according to standardized procedures (34) using Harpenden skin calipers. All measurements were taken on the right side of the body at triceps, biceps, subscapular and iliac crest sites. Measurements were taken with subjects seated, with triplicate measurements taken in rotation to the nearest 0.2 mm, with the mean of the results used for calculations. Additional measurements were taken if a measurement was different by greater than 10% from the other measurements from the same site (example: 20 ± 2 mm for iliac crest skinfold) and the closest three values averaged.

As reliable and validated predictive equations for body composition do not yet exist for SCI populations, many researchers have used the sum of skinfolds as a gross indicator of body fat (35-41). While the sum of skinfolds is not able to accurately predict body density (or ultimately body fat percentage) in those with SCI (42), it can provide a crude body composition assessment of the individuals tested based on the assumptions that a relationship exists between the subcutaneous adipose tissue and total body fat and that the sum of several skinfold thicknesses can be used to estimate total body fat. However, the relationship between subcutaneous and visceral adipose tissue in those with SCI may be different than able-bodied individuals. A comparison of abdominal visceral adipose tissue to abdominal subcutaneous adipose tissue found those with SCI had a significantly greater ratio of visceral to subcutaneous adipose tissue (6). It is not understood if this observation extends to other regions of the body but as the skinfold measurements are not attempting to predict body fatness, the sum of skinfold measurements remains the most appropriate field method of anthropometric testing.

2.2.6 Physical activity assessment

Three methods were used to assess the frequency and intensity of physical activity for this study (copies of the instruments used are included in **Appendices 5 - 7**). An athlete recorded the number of hours per week he or she typically engages in physical training, with the total number of training hours delineated by the number of hours spent in sport specific training, strength and aerobic training. This self-reported global assessment of training assisted in describing the training patterns of athletes and for comparison of general training regimes between sports.

Athletes were instructed to keep a three-day activity log for the same three-day periods in which food diaries were recorded. For each training or sport related activity, athletes were requested to record the time spent participating in the activity, a description of the activity and also rate perceived exertion of the activity using the Borg scale for rating of perceived exertion (RPE) (30). The Borg scale uses a numerical system to rate perceived exertion on a scale of 6 (no exertion at all) to 20 (maximal exertion). The scale was designed for use in able-bodied athletes to predict heart rate during activity (the rating approximates heart rate divided by 10 – for example, an RPE of 20 reflects a heart rate of approximately 200 beats per minute in a young adult) and has been shown to have good validity and reliability, especially among athletes (31). Unfortunately, the Borg scale has not been validated for predicting heart rate from perceived exertion in athletes with spinal cord injury as these athletes have altered heart rate and cardiovascular control during exercise (43, 44). The utility of the RPE scale in this study is as a standard scale of exercise exertion to aid individual athletes when assessing exercise intensity.

The third method of assessment was a self-administered Physical Activity Scale for Individuals with a Physical Disability (PASIPD) (45). This tool was developed to evaluate leisure time, household, and occupational activity in community dwelling individuals with a physical or mobility impairment. Athletes were asked to recall the number of days in a week they participated in an activity or category of activities and rank as never, seldom (1 – 2 days per week), sometimes (3 – 4 days per week), or often (5 – 7 days per week). Athletes were also asked to estimate on average how many hours per day were spent in the activity as less than 1 hour, 1 to 2 hours, 2 – 4 hours or greater than 4 hours. All PASIPD questionnaires were scored according to the instructions provided by the authors with the total score used in analyses. The total score was calculated by using the average number of hours per day for an activity and multiplying that time by a metabolic equivalent (MET) value. This calculated a value for metabolic equivalent hours per day (MET hr/d) for each activity and the metabolic equivalent hours were then summed for all 13 items. METs reflect multiples of the resting metabolic rate (RMR): For example, 20 MET hr/d could reflect 5 hours of activity at 4 METs (4 times RMR) or 2 hours of activity at 10 METs. PASIPD was tested for construct validity in a sample of 227 men and 145 women with disabilities and was found to have low-to-moderate internal consistency within factors (Cronbach alpha ranging from 0.37 to 0.65). The PASIPD has not yet been tested with additional populations, so the external validity of this instrument is unknown. As this tool was developed for a population with low to moderate activity levels, it may not fully capture the activity frequency or intensity of elite level athletes. Thus, activity logs in combination with the Borg scale of rate of perceived exertion were indicated.

2.2.7 Self-reported food diary

Nutrient intake data were collected using a self-reported three day food diary method (**Appendix 8**). The recording period was three consecutive days during the training camp with a three day follow-up period once the athlete had returned to his or her home environment. The food diary completed at home for three consecutive days (two weekdays and one weekend day) reflected the athletes' typical dietary choices and intakes in a less artificial environment. Participants were also instructed to record the brand name and amount consumed for all vitamin, mineral and herbal supplements.

For athletes, a three to seven day diet monitoring period is believed to provide a reasonably accurate and precise estimation of habitual energy and macronutrient consumption in both individuals and groups (46). The issue of under and over reporting is of concern with most collection techniques for dietary intakes (47). In this study, the issue of inaccurate reporting was addressed by providing a tutorial to the athletes prior to recording of intakes, and by having an investigator available to the athletes during meals to assist with data recording.

2.2.8 Dietary analysis

Food record data were entered into Food Processor for Windows, version 9.0.0 (database version December 2007, ESHA Research, Salem, Oregon). The Canadian Nutrient File (2007) database (48) was the primary nutrient reference database used. If food values were not available from the Canadian Nutrient File database, the nutritional content for equivalent items from the USDA Standard Reference database (49) or values provided by the manufacturer were used. Because of a software technical issue, nutrient values for vitamin D were calculated manually and vitamin A values were omitted. The three-day food intakes from both training camp and home food records were averaged separately to compute mean nutrient intakes of energy (kcal); carbohydrate, fat, protein in both grams and percentage of calories; dietary fibre (g); elements and vitamins.

2.2.9 Prediction of energy expenditure

For each athlete, energy expenditure was predicted using the Estimated Energy Requirement (EER) equations developed by the Institute of Medicine (50). The EER is defined as “the average dietary energy intake that is predicted to maintain energy balance in a healthy adult of a defined age, gender, weight, height and level of physical activity consistent with good health” (50). Predictive equations were developed using a population of normal weight individuals with total daily energy expenditure measured by the doubly labeled water technique. The EER equations have not been validated for individuals with SCI, and it is challenging to derive estimates of energy expenditure associated with physical activity because of the relatively smaller amounts of muscle mass in the SCI population. To date, validated equations to predict energy expenditure in those with SCI have not been established. For this reason, and to be most conservative, sedentary and low active physical activity levels were used to develop a range of predicted values for energy expenditure.

2.2.10 Nutrition knowledge

General nutrition knowledge was assessed using a nutrition knowledge assessment tool (**Appendix 9**) developed for use in adults in the United Kingdom (UK) (26). This assessment tool has been tested previously and has been shown to have acceptable internal consistency (Cronbach's alpha of 0.7 – 0.97), test-retest reliability (Pearson's correlation 0.8 – 0.98) and construct validity. Slight modifications were necessary to substitute foods used in the questions but not commonly consumed in Canada. For example; kippers was substituted with deli meat, mackerel was substituted with salmon, wholemeal was substituted with wholegrain and biscuit was substituted with cookie. The assessment of nutrition knowledge consisted of four subscales measuring dietary recommendations, sources of nutrients, choosing everyday foods and the diet-disease relationship. This tool was validated using an adult population in the UK but has not been validated specifically for athletes or those with a SCI.

2.2.11 Statistical analysis

All statistical analyses were completed using SPSS version 17.0. Descriptive statistics are presented as means, standard deviations, medians and ranges. A p-value of <0.05 was considered to be a statistically significant difference. Independent t-tests were used to compare means between groups based on SCI (complete versus incomplete lesion, paraplegic versus tetraplegic), gender or sport. Paired sample t-tests were used to detect differences in mean nutrient intakes between home and training camp. Independent t-tests were performed to compare mean training times between groups with paired sample t-tests to detect differences in activity times between home and training camps.

Three-day averages for home and training camp were calculated for energy (kcal), grams of carbohydrate, fat and protein which allowed for the contribution to total energy for each macronutrient. Percentage of energy from carbohydrate, fat and protein was then compared to the Acceptable Macronutrient Distribution Range (AMDR) with the proportion of the group with intakes falling outside of the AMDR reported as excessive or inadequate. Dietary micronutrient intakes were compared to the Dietary Reference Intakes (DRIs) to assess adequacy. Specifically, for nutrients with an Estimated Average Requirement (EAR), the prevalence of inadequate intakes was estimated as the proportion of individuals with mean intakes below the EAR (51). The proportion of individuals with three day average intake below the EAR at home and training camp environments was compared using crosstabs and Pearson chi-square. The proportion of individuals with six day average intakes from food alone below the EAR was compared to the proportion of individuals with combined intakes from food and supplements was compared using the McNemar test as the populations were related. For nutrients with an Adequate Intake (AI) a different approach was used. If the median intake for the population was at or above the AI, it was assumed that the group's usual intake was adequate with a relatively low risk of inadequacy. If the median intake fell below the AI, no assessment of adequacy for that nutrient can be determined (51). In addition, the prevalence of inadequacy and a comparison of mean intakes from food alone versus intakes from the combination of food and vitamin/mineral supplements were compared using six day averages.

2.3 Results

2.3.1 Participant characteristics

A total of 32 athletes met the inclusion criteria, consented to participate and completed all components of the study. Most subjects were on the wheelchair rugby team (n=20) with the remainder of athletes competing in wheelchair basketball (n=7), para-alpine skiing (n=3) and wheelchair athletics (n=2). Background characteristics including age (years), height (m), weight (kg), BMI ($kg \cdot m^{-2}$) and description of spinal cord injury (SCI) are presented in **Table 2.1**. Twenty of the participants had a complete SCI while 12 had an incomplete SCI. Based on level of SCI, 20 had injuries resulting in tetraplegia and 12 had injuries resulting in paraplegia. There were no differences between men and women pertaining to age or years since spinal cord injury. As expected, the men were taller, weighed more and had a higher BMI as compared to the women. There was no difference in the sum of the skinfolds or the triceps, subscapular or iliac crest sites but a statistically significant difference (p=0.025) was detected at the biceps site with women having a 3 mm larger skinfold. When the population was stratified by spinal cord injury (**Table 2.2**), no significant differences in anthropometrics were detected between those with paraplegia or tetraplegia. When stratified by complete or incomplete injury, those with incomplete injury had a greater BMI compared to those with complete injury.

Table 2.1 Participant background characteristics with group and subgroup analyses based on gender

	Group (N=32)	Men (n=24)	Women (n=8)
Characteristic			
Age (year)	30.6 ± 6.2[a]	30.5 ± 6.7	30.6 ± 4.7
Anthropometrics			
Length (cm)	177.2 ± 8.9	179.2 ± 9.0[b]	171.1 ± 5.8[c]
Weight (kg)	67.0 ± 13.7	70.9 ± 13.3[b]	55.4 ± 6.0[c]
BMI ($kg{\cdot}m^{-2}$)	21.26 ± 3.4	22.1 ± 3.5[b]	18.9 ± 1.9[c]
Sum of skinfolds (mm)	51.1 ± 20.6	50.9 ± 22.8	51.5 ± 13.4
Triceps (mm)	12.1 ± 5.6	11.7 ± 6.2	13.2 ± 3.1
Biceps (mm)	7.6 ± 3.6	6.8 ± 3.4[b]	10.1 ± 3.2[c]
Subscapular (mm)	14.7 ± 6.1	15.2 ± 6.6	13.2 ± 4.2
Iliac crest (mm)	16.1 ± 7.9	17.2 ± 8.6	15.0 ± 5.5
Spinal Cord Injury			
Years since SCI	13.4 ± 6.5	13.8 ± 6.8	12.5 ± 5.9
Paraplegic	12 (37.5%)	7 (29.2%)	5 (62.5%)
Tetraplegic	20 (62.5%)	17 (70.8%)	3 (37.5%)
Complete (ASIA A)	20 (62.5%)	15 (62.5%)	5 (62.5%)
Incomplete (ASIA B - D)	12 (37.5%)	9 (37.5%)	3 (37.5%)

Abbreviations: BMI, Body mass index; ASIA, American Spinal Injury Association (a classification system for spinal cord injury); SCI, spinal cord injury
[a] mean ± standard deviation
[b,c] pair with a statistically significant difference $p < 0.05$

Table 2.2 Group participant characteristics with comparisons made within the group based on level of injury (paraplegic vs. tetraplegia) and motor function of injury (complete vs. incomplete)

Group (N=32)	Paraplegic (n=12)	Tetraplegic (n=20)	Complete (n=20)	Incomplete (n=12)
Characteristic				
Age (year)	29.3 ± 5.1[a]	31.4 ± 6.7	31.5 ± 6.6	29.0 ± 5.3
Anthropometrics				
Length (m)	174.1 ± 8.6	179.0 ± 8.8	178.6 ± 8.4	174.8 ± 9.6
Weight (kg)	64.6 ± 13.0	68.4 ± 14.2	64.0 ± 12.0	72.0 ± 15.3
BMI ($kg \cdot m^{-2}$)	21.3 ± 3.7	21.2 ± 3.4	20.0 ± 2.9[b]	23.4 ± 3.3[c]
Sum of Skinfolds (mm)	50.2 ± 18.0	51.6 ± 22.5	45.4 ± 21.4[b]	60.5 ± 15.9[c]
Triceps (mm)	11.0 ± 4.0	12.7 ± 6.4	11.1 ± 6.3	13.3 ± 6.1
Biceps (mm)	8.6 ± 4.1	7.1 ± 3.3	7.0 ± 3.9	8.8 ± 3.0
Subscapular (mm)	14.6 ± 4.3	14.8 ± 7.1	13.3 ± 6.1	17.1 ± 5.6
Iliac crest (mm)	16.1 ± 7.3	16.9 ± 8.4	14.1 ± 7.2[b]	20.9 ± 7.4[c]
Spinal Cord Injury				
Years since SCI	14.0 ± 7.4	13.1 ± 6.1	12.8 ± 6.1	14.5 ± 7.3
Complete (ASIA A)	6 (50%)	14 (70%)	20 (100%)	0 (0%)
Incomplete (ASIA B - D)	6 (50%)	6 (30%)	0 (0%)	12 (100%)

Abbreviations: BMI, Body mass index; ASIA, American Spinal Injury Association (a classification system for spinal cord injury); SCI, spinal cord injury

[a] mean ± standard deviation

[b,c] pair (within paraplegic versus tetraplegic or within completed versus incomplete injury) with a statistically significant difference p <0.05

2.3.2 Dietary analysis from food sources only

Three-day food diaries were completed at the national team event and then repeated when the athlete returned home. Average intake for each of the three day periods and an average for all six days are shown in **Table 2.3**. Predicted energy expenditure using the Institute of Medicine regression equations that reflect gender, age, height, weight and physical activity level of either sedentary or low active are also shown in **Table 2.3** (50). Comparison of the energy intakes between the home and training environment for the complete group showed an increased energy intake during the training camp. When stratified by gender, sport, level of SCI or motor function of SCI, statistically higher energy intakes at training camp versus home environments were detected for rugby athletes and those with incomplete SCI.

A comparison of the six day average energy intakes, with subgroup analyses by gender, sport, and SCI to the predicted Estimated Energy Requirement (EER) indicates the energy intake of men was significantly less than the predicted value for both sedentary and low active physical activity coefficient. Women had energy intakes comparable to the EER for the sedentary and low active category with no statistically significant differences detected. Subgroup analyses for sport showed rugby athletes had energy intakes below the sedentary EER and low active EER estimates whereas the energy intakes of basketball athletes were within the EER estimated range. Those with tetraplegia had intakes below both sedentary and low active estimates whereas those with paraplegia had intakes comparable to the sedentary EER but intakes were significantly less than the low active EER. Those with incomplete SCI had intakes significantly less than low active and sedentary EER whereas those with complete SCI had energy intakes similar to the sedentary EER values but less than the low active EER.

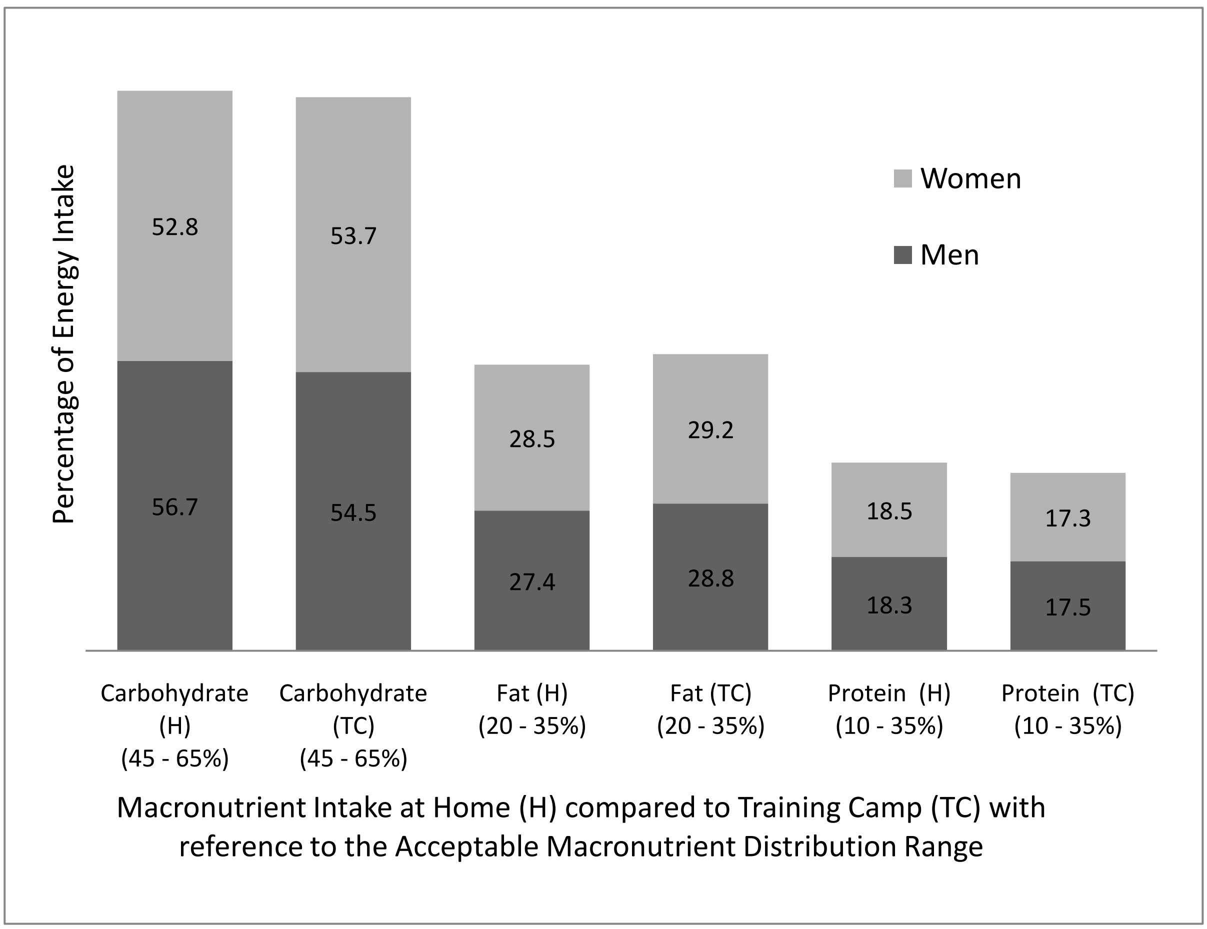
Table 2.3 Reported and predicted energy intakes categorized by gender, sport and spinal cord injury

Group (N=32)	n	Training Camp (kcal)	Home (kcal)	Six-day Average (kcal)	Predicted EER (Sedentary)[c]	Predicted EER[a] (Low Active)[b]
Gender						
Men	24	2285 ± 540[d]	2028 ± 528	2156 ± 431	2465 ± 226†	2695 ± 251*
Women	8	2056 ± 458	1927 ± 510	1991 ± 383	1903 ± 112	2115 ± 122
Sport						
Rugby	20	2213 ± 556[e]	1899 ± 566[f]	2056 ± 453	2421 ± 265*	2650 ± 288*
Basketball	7	2398 ± 570	2263 ± 339	2330 ± 378	2256 ± 409	2486 ± 432
Other	5	2044 ± 265	2055 ± 452	2049 ± 272	2034 ± 212	2243 ± 213
Level of Injury						
Paraplegic	12	2318 ± 509	2161 ± 479	2239 ± 414	2231 ± 307	2452 ± 347†
Tetraplegic	20	2173 ± 537	1908 ± 527	2040 ± 416	2381 ± 307*	2899 ± 361*
Motor Function						
Complete	20	2196 ± 556	2058 ± 535	2127 ± 428	2278 ± 288	2500 ± 306*
Incomplete	12	2279 ± 481[e]	1910 ± 494[f]	2095 ± 424	2402 ± 365†	2634 ± 390*

Abbreviations: EER, Estimated Energy Requirement; kcal, kilocalorie; SCI, spinal cord injury
Notes:
[a] Based on Dietary Reference Intakes: Estimated Energy Requirements for Adults (50)
[b] Low Active indicates physical activity coefficient of 1.11 for males and 1.12 for females
[c] Sedentary indicates physical activity coefficient of 1.00 for males and 1.00 females
[d] All values presented as mean ± standard deviation
[e,f] indicates pair with a statistically significant difference $p < 0.05$
†predicted EER (low active or sedentary) compared to six day average kcal intake with a statistical significance of $p<0.05$ (independent sample t-test)
*predicted EER (low active and sedentary) compared to six day average kcal intake with a statistical significance of $p<0.01$

Based on six-day mean usual intakes, all participants had macronutrient distributions that were within the AMDR (**Figure 2.1**). No significant differences were detected between men and women or between home and training camp environments for the proportion of energy from the macronutrients. The mean intakes representing the three days from home indicate only one male had a carbohydrate intake (% of kcal from carbohydrate) which was below the AMDR. During the training camp, the number of men with the percentage of kcal from carbohydrate outside of the AMDR increased with one male reporting carbohydrate intake that fell below the AMDR and three reporting intakes that were greater than the AMDR. While at home, all women reported carbohydrate intakes that fell within the AMDR. During training camp, all women exceeded the lower end of the AMDR for percentage of energy from carbohydrate with two women consuming slightly more than the 65% upper end of the range. All participants had carbohydrate intakes that were well above the EAR of 100 g.

Figure 2.1 Percentage of energy from macronutrients with reference to the Acceptable Macronutrient Distribution Range



Results for nutrients with an Adequate Intake (AI) as the reference value are presented in **Table 2.4**. All participants had dietary fibre intakes well below the recommended amount with no differences observed based on gender or training environment. While both men and women reported intakes of vitamin D which were below the AI of 200 IU, women typically consumed more vitamin D than men in both environments while consuming fewer calories. Men reported a drastic reduction in vitamin D intake while at training camp. Vitamin D intake for men at training camp was not normally distributed (skewness score of 3.77 and kurtosis score of 15.39). Statistical significance remained with a non-parametric test (Wilcoxon signed ranks test) of the difference between the vitamin D intake at home and training camp (p<0.001). Women consumed more calcium compared to men and managed to maintain their mean intakes above the AI in both environments. Men consumed less potassium and more sodium while at training camp compared to when at home. Mean intake of sodium in all cases was above both the AI of 1500 mg and the Upper Tolerable Limit Level (UL) of 2300 mg.

Table 2.4 Usual intakes from food sources only compared to Adequate Intake of selected nutrients for men and women

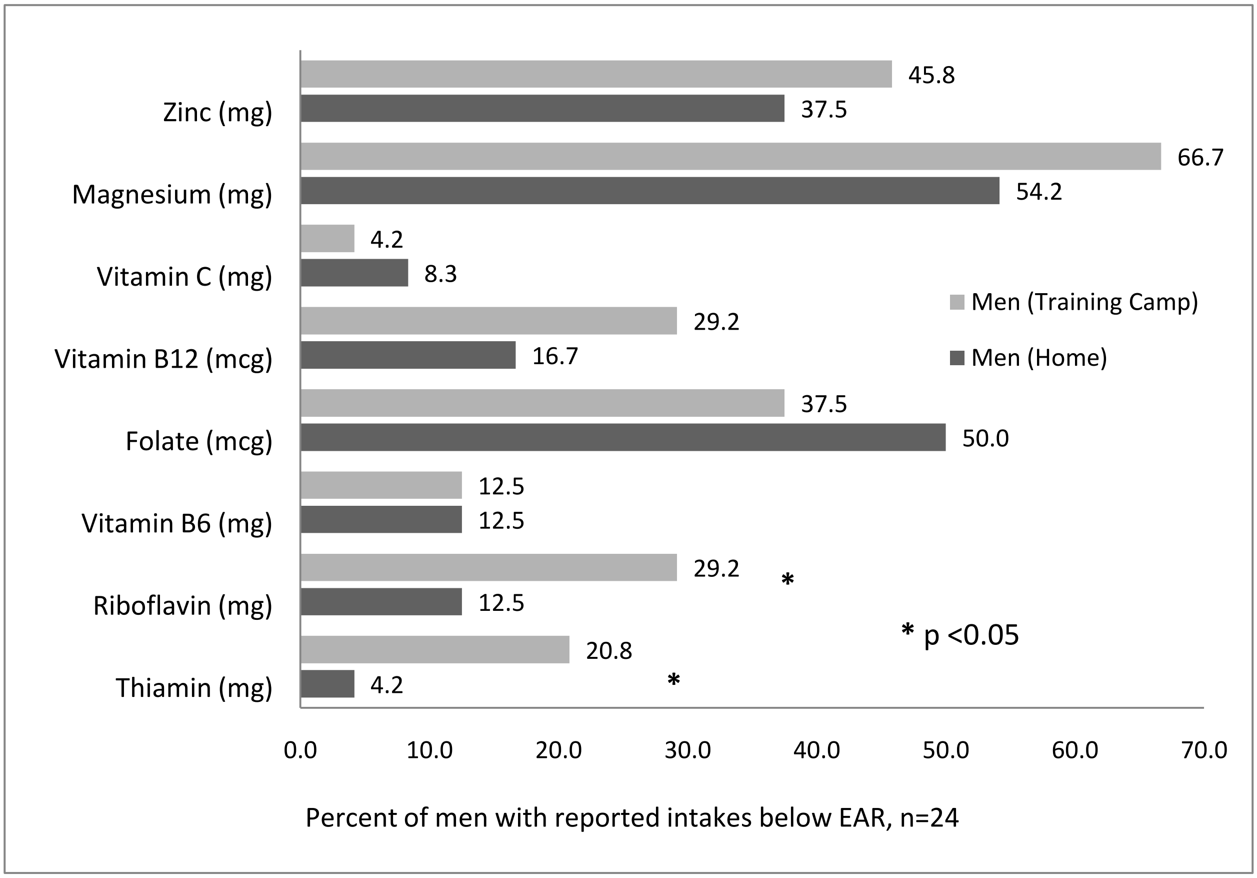
	Men (n=24)			Women (n=8)		
	AI	Home	Training Camp	AI	Home	Training Camp
Fibre (g)	38	20.6 ± 6.0[a]	19.1 ± 4.0	25	19.1 ± 4.0	18.8 ± 4.7
Vitamin D (IU)	200	160.1 ± 133.4[b]	38.5 ± 78.3[c]	200	179.9 ± 197.1	151.3 ± 131.3
Calcium (mg)	1000	856 ± 330[b]	693 ± 204[c]	1000	1077 ± 481	1102 ± 433
Potassium (mg)	4700	3201 ± 741[b]	2872 ± 648[c]	4700	3478 ± 1272	3014 ± 849
Sodium (mg)	1500	3582 ± 1016[b]	4702 ± 1302[c]	1500	3353 ± 1145	3383 ± 1024

Abbreviations: AI, Adequate Intake; IU, International Units; g, gram; mg, milligram
[a] mean ± standard deviation
[b,c] pair with a statistically significant difference p <0.05

Using median intakes from all six days of food records, the proportion of women reporting intakes greater than the AI were as follows: fibre (25%, n=2), vitamin D (12.5%, n=1), calcium 50%, n=4), and potassium (12.5%, n=1). For men, the proportion reporting intakes greater than the AI were as follows: fibre (0%, n=0), vitamin D (17%, n=4), calcium (21%, n=5), and potassium (0%, n=0). The median intake of sodium for both men (4252 mg) and women (3106 mg) was well above both the AI and the UL Level of 2300 mg. With the exception of one woman (results from at home and training camp), no athletes had mean intakes above the AI for potassium. The AI for men and women is 4700 mg: mean intakes ranged from 2872 ± 647 mg (men at training camp) to 3478 ± 1273 mg (women at home).

For the remaining nutrients, the prevalence of inadequate intakes was approximated by determining the proportion of individuals with usual mean intakes below the EAR. The proportion of men with mean intakes from food sources exclusively below the EAR was greatest while at training camp with greater than 25% of men with reported intakes below EAR for riboflavin, folate, vitamin B12, magnesium and zinc (**Figure 2.2**). While at home, greater than 25% of men reported intakes below the EAR for folate, magnesium and zinc. Using Pearson chi-square to detect differences in the proportions of men with intakes below the EAR, statistically significant differences were observed for thiamin and riboflavin with a greater proportion of men below the EAR while at training camp for both nutrients. Paired t-tests comparing the mean intakes from food sources alone for men, detected statistically significantly higher intakes of riboflavin and thiamin while at home (**Table 2.5**). The men reported greater intakes of protein while at training camp (1.43 ± 0.39 g/kg/d versus 1.28 ± 0.38 g/kg/d, p=0.028) (data not shown).

Figure 2.2 Percentage of men with mean intakes from food sources only below Estimated Average Requirements (EAR)



Notes:

1. Three nutrients were omitted from this figure as all men had intakes above the EAR while at home and training camp. There were no observed instances of nutrient inadequacy in men for niacin, iron and phosphorous.
2. Difference in proportion of men with intakes below EAR between home and training camp detected with Pearson chi-square test.

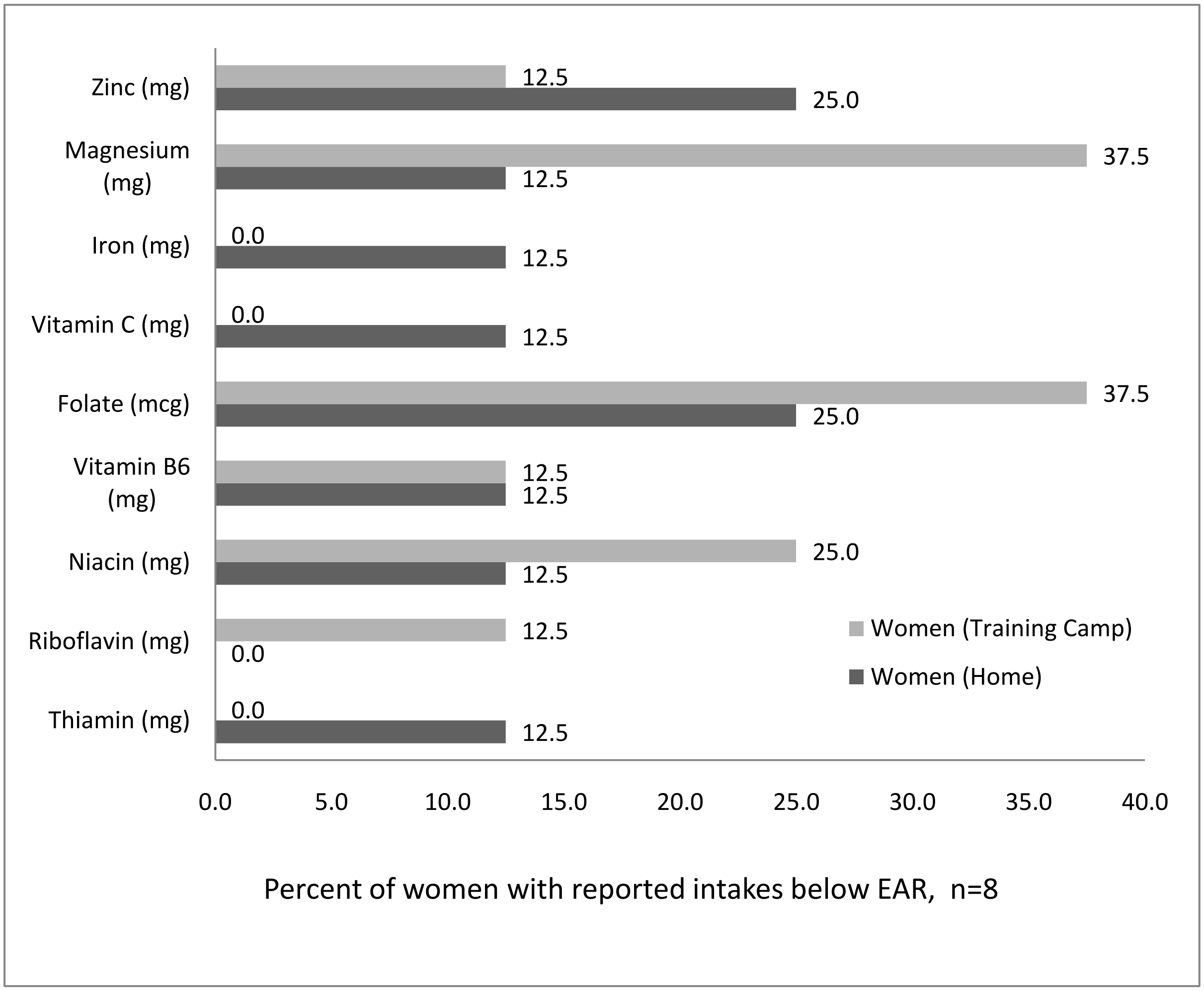
Table 2.5 Comparison of the mean intakes for men from food alone for selected nutrients while at home and training camp with reference to the Estimated Average Requirement

(n=24)	EAR	Home	Training Camp	p-value
Thiamin (mg)	1.0 mg	1.7 ± 0.6[a]	1.4 ± 0.4	0.007
Riboflavin (mg)	1.1 mg	1.8 ± 0.6	1.4 ± 0.5	0.001
Niacin (mg)	12.0 mg	20.1 ± 7.7	18.8 ± 7.5	0.417
Vitamin B6 (mg)	1.1 mg	1.9 ± 0.7	1.7 ± 0.7	0.249
Folate (mcg)	320.0 mg	339.3 ± 118.9	340.8 ± 94.0	0.954
Vitamin B12 (mcg)	2.0 mcg	3.8 ± 1.9	3.4 ± 2.5	0.260
Vitamin C (mg)	75.0 mg	164.5 ± 73.1	173.8 ± 79.7	0.679
Iron (mg)	6.0 mg	14.5 ± 4.2	15.1 ± 4.3	0.599
Magnesium (mg)	350.0 mg	336.2 ± 84.1	322.8 ± 77.6	0.483
Phosphorous (mg)	580 mg	1373 ± 416	1278 ± 363	0.222
Zinc (mg)	9.4 mg	10.3 ± 3.6	9.5 ± 2.9	0.350

Abbreviations: EAR, Estimated Average Requirement
[a] data presented as mean ± standard deviation
Paired t-test used to compare mean intakes.
Statistically significant difference when p-value <0.05

The proportion of women reporting usual mean intakes from food sources alone (**Figure 2.3)** below the EAR was considerably different than the men. While at training camp, greater than 25% of women reported intakes below the EAR for niacin, folate and magnesium. While at home, greater than 25% of women reported intakes below the EAR for magnesium. Using Pearson chi-square, a statistically significant difference in the proportion of women with intakes below the EAR at home compared to training camp was not detected for any of the nutrients. When comparing mean intakes between training camp and home environments for women, no statistical differences were detected (**Table 2.6**).

Figure 2.3 Percentage of women with mean intakes from food sources only below Estimated Average Requirements (EAR)



Notes:

1. Two nutrients were omitted from this figure as all women had intakes above the EAR while at home and training camp. There were no observed instances of nutrient inadequacy in women for vitamin B12 or phosphorous.
2. No significant differences in the proportion of women with intakes below EAR between home and training camp were detected using Pearson chi-square test.

Table 2.6 Comparison of the mean intakes for women from food alone for nutrients while at home and training camp with reference to the Estimated Average Requirement

(n=8)	EAR	Home	Training Camp	p-value
Thiamin (mg)	0.9 mg	1.7 ± 0.8[a]	1.8 ± 0.9	0.616
Riboflavin (mg)	0.9 mg	1.9 ± 0.5	2.1 ± 0.7	0.569
Niacin (mg)	11.0 mg	14.5 ± 3.9	16.6 ± 6.3	0.496
Vitamin B6 (mg)	1.1 mg	1.8 ± 0.7	2.8 ± 2.3	0.241
Folate (mcg)	320.0 mg	390 ± 92	332 ± 113	0.316
Vitamin B12 (mcg)	2.0 mcg	8.3 ± 13.4	9.6 ± 13.3	0.130
Vitamin C (mg)	60.0 mg	195.1 ± 95.1	151.1 ± 44.4	0.355
Iron (mg)	8.1 mg	15.2 ± 7.1	17.0 ± 5.7	0.241
Magnesium (mg)	265.0 mg	372 ± 174	328 ± 114	0.483
Phosphorous (mg)	580 mg	1563 ± 687	1500 ± 502	0.798
Zinc (mg)	6.8 mg	9.5 ± 4.2	11.1 ± 3.5	0.386

Abbreviations: EAR, Estimated Average Requirement
[a] mean ± standard deviation
Paired t-test used to compare mean intakes. Statistically significant difference when p-value <0.05. No statistically significant differences were detected.

2.3.3 Dietary analysis incorporating supplemental vitamin and minerals

Participants were instructed to record all vitamin, mineral and herbal supplements they consumed as a part of their food diaries. While at home, 44% of participants (n=14; n=9 men and n=5 women) reported consuming a nutritional supplement of some sort. Twelve athletes reported taking a daily multivitamin, four athletes reported taking calcium with vitamin D, and one athlete consumed supplemental iron. Four athletes reported taking a variety of other supplements such as B complex, omega 3 fatty acids or vitamin C. While at training camp, the number of participants who reported consuming a supplement was slightly lower at 34% (n=11) with only two women reporting supplement consumption. Seven participants reported taking a daily multivitamin, one reported taking calcium with vitamin D, and two reported taking iron. Six participants reported taking a variety of other products including vitamin C, ginseng and garlic.

The dosage of supplemental micronutrients was incorporated into the data from the food diaries and the analyses repeated to evaluate the impact of vitamin and mineral supplementation on dietary adequacy. Mean intakes from all six days of reported food intake were compared to mean intakes from all six days of reported food intakes with the additional micronutrients from reported dietary supplements incorporated. The additional calcium increased the proportion of men and women with intakes above the AI slightly but the marginal increase did not reach statistical significance using the McNemar test (**Table 2.7**). The proportion of men with vitamin D intakes above the AI increased significantly from 4.2% to 29.2% while the proportion of women with vitamin D intakes above the AI only slightly increased. The mean intakes of vitamin D were significantly increased with the supplemental nutrients for men but not women as shown in **Table 2.8**. The mean intakes of calcium were not statistically different for either men or women.

Table 2.7 Percentage of subjects with mean intakes above the Adequate Intake for six-day average intake from food sources only and food sources with additional supplements

		Food Sources Only		Food and Supplements		
	AI	n	%	n	%	p-value
Men (n=24)						
Calcium	1000 mg	5	20.8	7	29.2	0.500
Vitamin D	200 IU	1	4.2	7	29.2	0.031
Women (n=8)						
Calcium	1000 mg	4	50	5	62.5	1.000
Vitamin D	200 IU	2	25	3	37.5	1.000

Abbreviations: AI, Adequate Intake; mg, milligrams; IU, International Units
Statistically significant difference ($p < 0.05$) using McNemar test.

Table 2.8 Comparison of six-day mean intakes of calcium, vitamin D from food sources alone and food sources with additional supplements

	AI	Food Sources Only	Food and Supplements	p-value
Men (n=24)				
Calcium (mg)	1000 mg	775 ± 206[a]	853 ± 283	0.054
Vitamin D (IU)	200 IU	86.9 ± 65.5	176.8 ± 200.1	0.018
Women (n=8)				
Calcium (mg)	1000 mg	1089 ± 419	1118 ± 428	0.170
Vitamin D (IU)	200 IU	165.6 ± 130.1	215.6 ± 173.0	0.090

Abbreviations: mg, milligram; IU, International Unit
[a] mean ± standard deviation
p-value of <0.05 considered a statistically significant difference. (Paired t-test)

For nutrients with an EAR, the additional nutrients provided by the consumption of vitamin and mineral supplements decreased the proportion of men with intakes below the EAR for riboflavin, folate, vitamin B12, magnesium and zinc; however, none of the changes were significant (**Table 2.9).** For women, the additional nutrients did not improve the percentage of women with intakes below the EAR (**Table 2.10**). A slight improvement for folate was observed with the percentage of women with intakes below the EAR decreasing from 37.5% (n=3) to 25% (n=2), while the percentage of women with intakes below the EAR for other nutrients remained unchanged.

Table 2.9 Percentage of men with six-day mean intakes from food and food plus supplements below Estimated Average Requirement

(n=24)	EAR	Food Sources Only n	Food Sources Only %	Food and Supplements n	Food and Supplements %	p-value†
Thiamin (mg)	1.0 mg	2	8.3	2	8.3	1.000
Riboflavin (mg)	1.1 mg	5	20.8	4	16.7	1.000
Niacin (mg)	12.0 mg	2	8.3	2	8.3	1.000
Vitamin B6 (mg)	1.1 mg	1	4.2	1	4.2	1.000
Folate (mcg)	320.0 mcg	11	45.8	7	29.2	0.125
Vitamin B12 (mcg)	2.0 mcg	4	16.7	3	12.5	1.000
Vitamin C (mg)	75.0 mg	0	0.0	0	0.0	not calculated
Iron (mg)	6.0 mg	0	0.0	0	0.0	not calculated
Magnesium (mg)	350.0 mg	12	50.0	10	41.7	0.500
Phosphorous (mg)	580.0 mg	0	0.0	0	0.0	not calculated
Zinc (mg)	9.4 mg	11	45.8	6	25.0	0.063

Abbreviations: EAR, Estimated Average Requirement; mg, milligram, mcg, microgram
Statistically significant difference ($p < 0.05$) using McNemar test.
†No statistically significant differences were detected as all p-values were above 0.05.

Table 2.10 Percentage of women with six-day mean intakes from food and food plus supplements below Estimated Average Requirement

		Food Sources Only		Food and Supplements		
(n=8)	EAR	n	%	n	%	p-value†
Thiamin (mg)	0.9 mg	0	0.0	0	0.0	not calculated
Riboflavin (mg)	0.9 mg	0	0.0	0	0.0	not calculated
Niacin (mg)	11.0 mg	1	12.5	1	12.5	1.000
Vitamin B6 (mg)	1.1 mg	0	0.0	0	0.0	not calculated
Folate (mcg)	320.0 mcg	3	37.5	2	25.0	1.000
Vitamin B12 (mcg)	2.0 mcg	0	0.0	0	0.0	not calculated
Vitamin C (mg)	60.0 mg	0	0.0	0	0.0	not calculated
Iron (mg)	8.1 mg	0	0.0	0	0.0	not calculated
Magnesium (mg)	265.0 mg	1	12.5	1	12.5	1.000
Phosphorous (mg)	580.0 mg	0	0.0	0	0.0	not calculated
Zinc (mg)	6.8 mg	1	12.5	1	12.5	1.000

Abbreviations: EAR, Estimated Average Requirement; mg, milligram; mcg, microgram
Statistically significant difference ($p < 0.05$) using McNemar test.
†No statistically significant differences were detected as all p-values were above 0.05.

A comparison of the six-day average intakes from food alone and food with the additional supplements incorporated is presented in **Table 2.11**. The mean intakes for men improved with the addition of the supplements with a statistically significant improvement in most micronutrients with an EAR reference value with the exception of vitamin B12. The mean intakes for women were not observed to be statistically different with the supplemental vitamins and minerals.

Table 2.11 Comparison of six-day mean intakes of selected nutrients from food sources alone and food sources with additional supplements for nutrients

	Men (n=24)			Women (n=8)		
	Food Only	Food and Supplements	p-value	Food Only	Food and Supplements	p-value
Thiamin (mg)	1.5 ± 0.5	2.1 ± 1.5	0.038	1.8 ± 0.8	2.0 ± 1.2	0.170
Riboflavin (mg)	1.6 ± 0.5	2.6 ± 1.7	0.017	2.0 ± 0.4	2.4 ± 1.0	0.170
Niacin (mg)	19.5 ± 6.7	22.1 ± 7.5	0.001	15.6 ± 3.1	17.4 ± 5.0	0.170
Vitamin B6 (mg)	1.8 ± 0.6	3.6 ± 2.6	0.001	2.3 ± 1.2	3.6 ± 3.5	0.170
Folate (mcg)	340 ± 84	454 ± 178	0.001	361 ± 69	480 ± 192	0.084
Vitamin B12 (mcg)	3.6 ± 2.1	34.4 ± 124.0	0.235	9.0 ± 13.3	12.1 ± 13.4	0.170
Vitamin C (mg)	169 ± 54	262 ± 174	0.012	173 ± 39	204 ± 80	0.170
Iron (mg)	14.8 ± 3.4	16.3 ± 4.3	0.002	16.1 ± 6.1	21.6 ± 12.4	0.227
Magnesium (mg)	330 ± 66	352 ± 78	0.003	350 ± 121	363 ± 132	0.170
Zinc (mg)	9.9 ± 2.5	13.0 ± 5.3	0.003	10.3 ±2.9	12.2 ± 5.6	0.170

Abbreviations: mg, milligram; mcg, microgram
p-value of <0.05 considered a statistically significant difference. (Paired t-test)

2.3.4 Nutrition knowledge

All participants completed a general nutrition knowledge questionnaire modified from the questionnaire developed by Parmenter and Wardle (26). Nutrition knowledge scores for the group with subgroup analyses based on gender are presented in **Table 2.12**. Women scored higher than men on the aggregate score out of a possible 110 points. A statistically significant difference in score was detected for only one category with women scoring higher than men on the food sources of nutrients subscale. Subgroup analyses among sports, between level of SCI and motor function of SCI showed no significant differences in either the total score or subscales (data not shown).

Table 2.12 Nutrition knowledge scores with subgroup analyses based on gender

	Maximum Score	Total Group (N=32)	Men (n=24)	Women (n=8)	p-value
Total Score	110	69.0 ± 10.9[a] (42 - 86)[b]	66.7 ± 10.8 (42 - 86)	76.1 ± 7.9 (57 - 82)	0.031
Dietary Recommendations	11	7.9 ± 1.3 (5 - 10)	7.8 ± 1.3 (5 - 10)	8.4 ± 1.1 (7 - 10)	0.237
Food Sources of Nutrients	69	48.1 ± 7.8 (30 - 59)	46.5 ± 7.6 (30 - 59)	52.9 ± 6.8 (37 - 59)	0.043
Choosing Everyday Foods	10	6.0 ± 1.6 (3 - 9)	5.9 ± 1.7 (3 - 9)	6.3 ± 1.2 (5 - 8)	0.573
Diet Disease Relationship	20	7.1 ± 2.7 (0 - 13)	6.6 ± 2.8 (0 - 13)	8.6 ± 1.9 (6 - 12)	0.062

[a] mean ± standard deviation
[b] range of scores
Nutrition knowledge questionnaire adapted from Parmenter & Wardle (26)
p-value of <0.05 considered statistically significant comparison with subgroup analyses based on gender

2.3.5 Physical activity

Participants self-reported their usual training regime reporting the total number of training hours per week and the number of hours per week spent in aerobic, strength and sport specific training. As a group, the mean number of total training hours per week was 14.7 ± 4.5 hours with a range of 8 – 25 hours. Athletes reported 4.8 ± 2.5 hours engaged in aerobic training, 3.7 ± 1.7 hours engaged in strength training and 6.2 ± 3.7 hours engaged in sport specific training. Differences were detected between basketball and rugby athletes with basketball athletes reporting 8.0 ± 3.5 hours of strength training compared to 5.2 ± 2.6 hours for rugby (p=0.035). Athletes with paraplegia also reported more hours of strength training compared to athletes with tetraplegia (4.7 ± 1.6 hours vs. 3.2 ± 1.4 hours, p=0.009). The similarity between these findings on strength training likely reflects that athletes with tetraplegia typically play rugby and those with paraplegia typically play basketball.

Athletes recorded the number of minutes they participated in physical activity for the same six days they recorded food intake during training camp and while they were at home. During training camp, the group reported an average total training time of 492 ± 266 minutes over three days with a range of 123 – 1170 minutes. Differences in total training time over the three day period were detected between sports with basketball athletes reporting 739 ± 276 minutes and rugby athletes reporting 410 ± 238 minutes ($p=0.006$). The basketball athletes also reported more minutes described as "hard exertion" compared to the rugby athletes (454 ± 199 minutes versus 145 ± 115 minutes, $p<0.001$)

The self-reported training time for the three-day period at home period was 366 ± 172 minutes for the group which is less than the reported time while at training camp ($p <0.05$). When total training time was analyzed using subgroups, no differences were detected. Compared to the time at training camp, while at home, athletes tended to spend less time engaged in activity with a RPE of 6 – 10 or "light exertion" (50 ± 54 minutes vs. 87 ± 78 minutes, $p <0.05$) and less time engaged in activity with a RPE of 15 – 17 or "hard exertion" (127 ± 115 minutes vs. 221 ± 181 minutes, $p <0.05$). The reported time spent in activities of "moderate exertion" or RPE of 11 – 14 was similar with 120 ± 98 minutes at training camp versus 130 ± 128 minutes at home, $p=0.728$.

Usual participation in recreational, household and occupational activity was assessed using the Physical Activity Scale for Individuals with Physical Disabilities (PASIPD) (45). The group scored 25.7 ± 15.5 metabolic equivalent hours per day (MET hr/day) with a range of 7.3 to 89.6 MET hr/day. No statistical differences were detected based on gender, sport or SCI.

2.4 Discussion

This study is the first to report on usual dietary intakes of athletes with a spinal cord injury while comparing intakes to the established standards of the Dietary Reference Intakes. This study found athletes reported energy intakes that were typically less than the conservative estimates of either sedentary or low active physical activity levels, while their reported physical activity was generally quite high at a total of 492 minutes over the 3 days at training camp (an average of 2.7 hours per day) and a total of 366 minutes over the 3 days at home (an average of 2 hours per day). Although the macronutrient composition for all athletes was within the AMDR range with 53% of energy from carbohydrate, 29% from fat and 18% from protein, intakes of several micronutrients were below the recommended amount. Male athletes in particular did not consume adequate amounts of vitamin D, calcium, potassium, folate, magnesium or zinc. Compared to intakes at home, while at training camp the proportion of men with intakes below the EAR increased for thiamin, vitamin B12, magnesium and zinc, despite slightly greater energy intakes. Women reported dietary intakes with few micronutrient inadequacies while consuming fewer calories than the men. As a group, the women did have marginal intakes of folate and zinc while at home and marginal intakes of niacin, folate and magnesium at training camp. On average, women consumed adequate amounts of calcium with the mean intakes greater than the AI while their vitamin D intake was less than the AI.

The average energy intakes of 2156 ± 431 kcal per day for men and 1927 ± 510 kcal per day for women in this study can be compared to other reported energy intakes for athletes and non-athletes with SCI as well as the values predicted by the EER. The energy intakes are similar to the 2138 ± 473 kcal per day reported for male marathoners by Potvin et al. (21) in spite of the observation that the men in this study were slightly taller and weighed slightly more. Lally et al. reported energy intakes which were considerably lower at 1909 kcal for American marathoners and 1627 kcal for Japanese marathoners (22). Food intake was measured by diet recall for one 24 hour period which may not accurately reflect usual intake and the day to day variation in dietary intake. While Lally et al. did not report height, weight or gender for their participants, the lower reported energy intakes compared to the results of this study may be explained by the difference in reported training times. Japanese marathoners reported training 296 minutes per week (42 minutes per day) while American marathoners reported training 379 minutes per week (54 minutes per day). This is in contrast to the average reported training practices in this study of 366 minutes over 3 days (122 minutes per day) while at home and 492 minutes over 3 days (164 minutes per day) while at training camp. The results by Ribeiro et al. are more difficult to interpret as energy intake was reported as 25 ± 21 kcal/kg and when multiplied by the average weight of subjects (62 kg) the daily energy intake was estimated at 1545 kcal (20). The difference in energy intakes may be due, at least in part, to differences in body size as the Brazilian wheelchair basketball athletes were shorter (168 cm versus 179 cm) and weighed less (62 kg versus 71 kg) than the men in this study. The energy intakes of female athletes with SCI and wheelchair rugby athletes have not yet been reported on and provide novel information to the body of research pertaining to the dietary intakes of athletes with SCI.

Energy intakes of community-living adults with SCI are typically reported in the range of 2000 – 2100 kcal per day (6, 17, 18) with Tomey et al. reporting a slightly higher energy intake of 2265 kcal per day (19). It is likely that the energy intakes of that population of men with paraplegia was greater than the requirements given the high prevalence of overweight with 57% reported as having a BMI greater than 25 $kg \cdot m^{-2}$ and 19% of subjects having a BMI greater than 30 $kg \cdot m^{-2}$ as compared to the male athletes in this study with a BMI of 22.2 $kg \cdot m^{-2}$. The male participants in the study by Walters et al. also had a high BMI of 26 ± 5 $kg \cdot m^{-2}$ with a mean weight of 79.5 kg.

The energy intakes reported by men in this study are comparable to the results of marathoners in the study by Potvin and colleagues yet greater than the athletes in the studies by Lally et al. and Ribeiro et al. The differences in the energy intakes can most likely be accounted for by differences in the training practices and body size. Typically, the athletes were of an appropriate weight for height with BMI less than 25 $kg \cdot m^{-2}$. However, an optimal BMI range for ideal weight in adults with SCI has not been clearly established but there is some evidence that a BMI above 22 $kg \cdot m^{-2}$ (rather than 25 $kg \cdot m^{-2}$) is a better predictor of overweight and obesity in SCI (52). It is interesting that the reports of energy intakes among community living men with SCI are equal to or greater than the athletes with SCI. The combination of a greater prevalence of overweight individuals, reduced physical activity and excessive energy intakes contributing to the weight gains likely accounts for the increased reported energy intakes in community living men with SCI. It can be hypothesized that while athletes are consuming about the same number of calories per day, they are expending a similar amount of energy with physical activity and maintaining their weight to height ratio.

Females with SCI who are not athletes have reported energy intakes of 1663 kcal per day (18) and 1771 kcal per day (17). Based on these two studies, the female athletes in this study consume between 200 and 300 additional calories per day (1991 ± 383 kcal per day). The women in the study by Groah et al. (18) had a slightly greater BMI and considerably less energy intake compared to the athletes in this study. The women in the study by Walters et al. (17) had a considerably higher BMI and less energy intake compared to the athletes in this study. One hypothesis is that the athletes are strength training thereby increasing the amount of lean mass, in addition to aerobic and sport specific training. The physical activity levels of the athletes are likely quite a bit higher than the community living women and this increased physical activity could account for the additional energy intakes.

The predictive equations developed by the Institute of Medicine (50) were inappropriate for predicting the estimated energy requirements for athletes with SCI. Women, basketball athletes, those with paraplegia and those with a complete SCI had energy intakes that were between the energy intakes predicted for sedentary and low active physical activity levels. In contrast, men had reported energy intakes that were below the sedentary level of physical activity for men despite average training times of over two hours per day. In some instances the predictive equations considerably overestimated apparent energy needs as reflected by reported energy intakes while in other instances, reported energy intakes were comparable to the sedentary or low active EERs. These equations have not been validated in those with SCI and the physical activity coefficients developed for able-bodied individuals do not accurately predict energy needs of sedentary or active individuals with SCI. Accurate and reliable tools for estimating energy needs in both active and non-active individuals with SCI are greatly needed to predict energy needs of these athletes.

Distinct differences in dietary adequacy were observed between home and training environments. While energy intakes were statistically greater for the group and rugby athletes at training camp, the trend was for all subgroups except for “other sports” to have greater energy intakes at training camp. These higher energy intakes, however, were not associated with improved nutrient adequacy. At training camps, men consumed on average 1200 mg more of sodium and the proportion of men with vitamin or mineral intakes below the EAR increased for thiamin, riboflavin, niacin, vitamin B12, magnesium and zinc. The women in this study maintained more consistency in their diets while at training camp with very few statistical differences between the two environments detected.

In the assessment of the athletes’ understanding of nutrition knowledge, women scored better than men in both the overall score and in food sources of key nutrients. Two studies have evaluated the nutrition knowledge of adults with SCI (19, 53). Tomey et al. (19) assessed the nutrition knowledge of a group of community living men with paraplegia using a modified, shortened version of the Parmenter & Wardle (26) nutrition questionnaire. Unfortunately, the authors did not describe what components of the nutrition knowledge instrument they selected for the shortened version making a comparison between groups based on nutrition knowledge difficult, if not impossible. However, the men in their study scored 18.8 ± 5.5 out of a possible 28 (a score of approximately 67%) compared to the men in this study who scored approximately 61% while the women scored 69%. The second study (53) measured nutrition knowledge of athletes with physical disabilities (primarily SCI and amputees) at a pre- and post-test following a nutrition education intervention. The questionnaire used was compiled from a variety of sources with additional questions related to nutrition issues important to athletes with disabilities and the results, as presented, do not lend themselves to a quantitative assessment of nutrition knowledge. A Canadian sample of able-bodied adults recently completed the Parmenter & Wardle questionnaire and scored 71/110 for the total score, 7.8/11 for dietary recommendations, 47.2/69 for food sources of nutrients, 6.7/10 for choosing everyday foods, 9.4/20 for diet disease relationships (54). A significant difference was detected with women scoring higher than men in the food sources of nutrients category as well as the total score. The results from the able-bodied population were comparable to the results of this study including the observation of women scoring higher in the overall score and subscale of food sources of nutrients. These differences in nutrition knowledge may at least partially explain why women were able to maintain dietary adequacy while away from home.

A comparison of the population in this study to the results from the Canadian Community Health Survey (55) (summary tables in **Appendix 10**) confirms a disparity in energy intakes of men, with the able-bodied men consuming almost 600 kcal more in a day (2737 kcal vs. 2156 kcal). Interestingly, the women with SCI in this study reported similar energy intakes as Canadian women aged 19 – 30 years (1991 kcal vs. 1902 kcal). There were many similarities in the proportion of individuals with intakes below the EAR or above the AI between this population and Canadians in general for riboflavin, thiamin, vitamin B12, vitamin C, vitamin D, calcium, phosphorus, magnesium and sodium. Differences were observed as athletes with SCI had a greater proportion of individuals with intakes below the EAR for folate (men only), niacin and zinc compared to Canadians. Overall, the patterns of dietary inadequacies of micronutrients were similar between the athletes with SCI and Canadians across the country.

The consumption of vitamin and mineral supplements was reported by 44% of athletes while at home and 34% of athletes while at training camp. This is slightly less than the 50.6% of individuals with SCI who classify themselves as consistent supplement users (56). However, when compared to vitamin and mineral supplement consumption rates in other populations of elite athletes this is similar to multivitamin usage reported by Division I varsity athletes at 47.3% (57) but almost double consumption rates by high performance Canadian athletes, among whom 20% reported taking a vitamin or mineral supplement (58). The consumption of vitamin and mineral supplements by men in this study improved mean intakes of most nutrients but did not improve the proportion of men with intakes below the EAR. The consumption of supplemental nutrients made little difference to the mean intakes or proportion of women with intakes below the EAR for women. The overall quality of the diets of female athletes was adequate in meeting the estimated requirements for most of the micronutrients. These women could benefit from supplemental vitamin D, zinc and magnesium. The men would benefit from improving their food choices to increase the nutrient density before adding vitamin and mineral supplements.

2.4.1 Strengths and limitations

The strengths of this study include the repeated measurements of activity and food records. The consumption and usage of vitamin and mineral supplements was reported daily which allowed for the additional vitamins and minerals to be incorporated into dietary analysis for an additional assessment of dietary adequacy. Comparison of dietary intakes to the standards established by the Institute of Medicine allowed for a more comprehensive analysis of dietary adequacy. The intent of this study was to explore the dietary intakes of this unique population and while the study was not specifically powered to detect differences between subgroups, recruitment was sufficient to detect some statistical differences between groups. A wide variety of data was collected on the athletes, in addition to food intake which allowed for a complete description of this population.

One of the major limitations with this study was the reliance on self-reporting of dietary intake and activity and the risk of under- or over-reporting. However, many steps were taken to minimize these risks including a) providing a detailed explanation of how to accurately record food intake, b) having a researcher with the athletes for the initial 3 day period to assist with recording food records, c) clarification if any of the recorded information was unclear and d) discreet observation of athletes' food choices. Furthermore, it is the author's impression that the athletes were motivated to record their data as accurately as possible based on the level of detail in the reporting of food intake on most food diaries and the high return rate for the second set of food diaries (94% return).

Another limitation of this study was the imbalance in the distribution of sports with rugby athletes being the largest overall group. As athletes with tetraplegia typically play wheelchair rugby, this population had a disproportionate number subjects with tetraplegia. This could have skewed the results as these athletes tended to have the lowest energy intakes. As well, this study may not have accurately assessed if athletes were intentionally trying to alter their dietary intakes to manage aspects of their SCI such as bowel or bladder management, sodium or fluid status for orthostatic blood pressure control or to manage other aspects of autonomic dysfunction.

This sample is not representative of elite athletes competing within Canada as the number of athletes competing in wheelchair athletics was under represented. Those competing in athletics tend to have demanding training schedules which may have impacted energy intakes. Ideally, a minimum number of 15 to 20 athletes per sport (rugby, basketball, athletics) with additional athletes from sports with less participation (alpine and cross-country skiing, tennis, rowing) is necessary to make comparisons between sports. As well, the limited number of women made statistical comparisons difficult.

2.4.2 Conclusions

This study provides preliminary evidence of dietary intakes and inadequacies in elite Canadian athletes with a spinal cord injury. This study demonstrates that these athletes are typically consuming energy intakes at, or below, the lower range of predicted energy intakes and the energy intakes of elite male and female athletes with SCI are relatively low in comparison to their able-bodied colleagues. While the macronutrient distribution was within the recommended ranges, intakes of several vitamins and minerals were below the recommended amount. Within the limited energy intakes, it is even more important for these athletes to optimize their dietary choices to ensure they are consuming adequate amounts of micronutrients to reduce the risk of suboptimal nutrient intakes. It may be necessary for many of the athletes, especially those with energy intakes below 1800 kcal per day to supplement their diets with additional vitamins and minerals.

Dietary inadequacies were more pronounced at national team events highlighting an opportunity for coaches, administrators, sport scientists and Registered Dietitians working with these athletes to improve the access to better food choices and to educate athletes in making more balanced food choices. As the nutrient density of food choices needs to be optimal for these athletes to meet their recommended vitamin and mineral intakes, a closer evaluation of the dietary choices available to athletes at national team events is warranted.

Restaurant meals may not be appropriate to provide the complement of vitamins and minerals within a reduced energy intake and customized lower fat meals emphasizing whole grains, vegetables and fruits, low fat milk and milk products should be considered to provide the most appropriate food choices for athletes. While the prevalence of dietary inadequacies was typically less when the athletes were at home, several improvements could still be made to optimize the athlete's daily training diet. Ongoing nutrition education and individualized micronutrient supplementation recommendations provided by Registered Dietitians with expertise in the area of sport nutrition would be a valuable asset to the integrated support team for all athletes with SCI.

This study was designed to quantify what athletes with SCI typically ate and evaluate the dietary adequacy of those diets but many questions remain. It is unknown if the macronutrient, vitamin or mineral requirement reference values established by the Institute of Medicine based on healthy adult populations are applicable to those with SCI. Many physiological and metabolic differences are observed in SCI and it is unknown if these differences may increase or decrease the requirements for specific nutrients. Accordingly, more research is required to assess whether nutrient requirements differ among those with SCI, and if an increased level of physical training alters those requirements.

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Chapter 3: Eating Attitudes and Behaviours in Elite Canadian Athletes with Spinal Cord Injury

3.1 Introduction

Spinal cord injury (SCI) is associated with a number of significant metabolic changes including glucose intolerance (1), dyslipidemia (2-4) and differences in hormone concentrations (5, 6). Body composition changes occur following SCI and often include increased adiposity (7-9), especially below the level of injury (10) and decreased lean tissue (10, 11). Related to these changes in body composition, energy requirements are relatively low (12) and are not accurately predicted with equations developed for able-bodied populations (12, 13). Despite demanding training regimes, athletes with SCI appear to have relatively modest energy requirements (14-16). Similar to able-bodied athletes, it is important for athletes with SCI to maintain favourable body composition to support optimal performance. The literature suggests that, with this link between body composition and athletic performance, some able-bodied athletes may be susceptible to subclinical eating disorders (17). There is virtually no information regarding the eating attitudes and behaviours of athletes with SCI, yet with their relatively modest energy requirements, it is possible that these athletes may be at risk for disordered eating attitudes.

The Three-Factor Eating Questionnaire (18) was developed to as a method to assess three aspects of eating attitudes and food related behaviours. Cognitive dietary restraint or simply dietary restraint is described as the purposeful monitoring and attempt to control or limit food intake by an individual in order to achieve or maintain a desired body weight or composition (18). This is in contrast to eating in response to physiological or hormonal hunger and satiety cues. Disinhibition reflects a tendency toward overeating and eating opportunistically, or the feeling that once a person begins to eat, it is very difficult to stop (18, 19). The trait of hunger is related to eating in response to innate physiological and hormonal cues.

Cognitive dietary restraint has been studied extensively in women and high levels of restraint have been associated with several physiological and metabolic changes including elevated urinary and salivary cortisol excretion (20-22), lower bone mineral density (23) and ovulatory disturbances (22, 24-26). Higher levels of restraint is associated with greater frequency of exercise (20, 27). Women with a stronger tendency towards cognitive dietary restraint also tend to have a stronger expression of disinhibition (26, 28). In comparison to women, men consistently score lower on the cognitive dietary restraint scale (28-31). While there is a considerably smaller body of literature which assessed eating behaviours in men with the TFEQ, there is some evidence that overweight men have higher scores for disinhibition and hunger but not for restraint (32, 33).

Differences in reported dietary intakes have also been detected between those discordant for cognitive dietary restraint. Women with higher levels of restraint typically report consuming fewer calories (20, 34-39) with reduced carbohydrate and fat intakes and increased protein intake (35, 40, 41). Those with higher cognitive restraint often select diets that include more reduced calorie and reduced fat products (42), consume less red meat, desserts, soft drinks and alcohol (39, 43, 44). There is also a greater likelihood that women with higher restraint scores will choose a vegetarian diet (26).

To our knowledge, the psychometric traits related to eating behaviours have not been reported in a population of adults with SCI. Accordingly, the objectives of this study were to describe food related attitudes and behaviours among elite athletes with SCI and explore associations with dietary intake and anthropometric variables.

3.2 Methods

3.2.1 Overview of study design

This cross-sectional observational study was designed to explore eating attitudes and behaviours in a group of elite Canadian athletes with SCI. Participants were enrolled between May 2007 and May 2009. An investigator attended a national team training event to recruit participants, collect questionnaire data, measure anthropometrics and provide instruction on the completion of the three-day self-reported food records. Participants repeated three-day self-reported food records when they returned home, providing a total of six days of dietary intake. A general questionnaire was self-administered to capture demographic information such as age, sport and training information and spinal cord injury details. The Three-Factor Eating Questionnaire (TFEQ) (18) and Yale Eating Patterns Questionnaire (YEPQ) (45) were self-administered to assess eating attitudes and behaviours.

The data and results presented in this chapter comprise a subset of the data collected for this thesis research project. This chapter will focus on the results pertaining to eating behaviours and attitudes with summary data on participant characteristics, anthropometrics and SCI used for subgroup and comparative analyses. Detailed participant characteristics and the analyses of dietary adequacy are presented in **Chapter 2** of this thesis. The study protocol was approved by the Behavioural Research Ethics Board at The University of British Columbia (**Appendix 1**) and participants provided informed written consent (**Appendix 2**).

3.2.2 Participant recruitment

Recruitment and identification of potential athletes was conducted by an initial letter of invitation (**Appendix 3**) sent to all national team head coaches associated with the Canadian Paralympic Committee. At the time of this study, Canada had athlete representation in 21 Paralympic sports and 11 of the sports met the eligibility requirements of providing competitive opportunities for athletes with SCI, with an expected minimum of 12 hours of physical training per week. Coaches from all 11 eligible sports (4 winter and 7 summer) received an invitation to participate via email and each coach was contacted to discuss the study and arrange for an investigator to attend a national training camp or event. Head coaches were requested to provide athletes with information pertaining to the study and alert the athletes that the graduate student researcher (Jennifer Krempien) would be at a national team event to collect data, should they choose to participate. Detailed information on the recruitment procedures is outlined in **Appendix 4**. It is estimated that between 75 and 80 athletes within Canada met the inclusion criteria during the recruitment period. A total of 41 athletes were approached in person to participate in the study and a total of 34 athletes consented to participate with 32 athletes completing all aspects of the study.

To be eligible, athletes had a SCI resulting in paraplegia or tetraplegia, with either complete or incomplete impairment of motor function. Elite athletes were targeted for this study. Each athlete met a minimum of one of the following criteria: member of a senior national team, received senior level funding from the Sport Canada Athlete's Assistance Program, ranked in the top three for his or her sport within Canada or ranked in the top five in the world for his or her sport discipline. For athletes participating in a team sport, the last international ranking for the team was used to establish the athlete's international ranking. For example, the rugby team finished third at the 2006 World championships so all athletes on that roster were ranked as third and thus met the inclusion criteria. If an athlete was not a member of the national team, their ranking was based on their provincial team performance at Canadian Nationals. All athletes participated in ongoing physical training for a minimum of 12 hours per week. Athletes were 19 years of age or older and understood written and spoken English.

3.2.3 Participant characteristics

Data pertaining to participant characteristics were self-reported by participants using a questionnaire developed for this purpose. Detailed demographic information including age, gender, sport information, years on the national team, international ranking, training information, description of SCI and additional medical conditions was collected. A copy of the demographic questionnaire is included in **Appendix 5**.

Description of spinal cord injury

The American Spinal Injury Association (ASIA) developed a standard system for the classification and description of spinal cord injury tool designed for physiatrists to assess and quantify the remaining motor and sensory function following SCI (46-49). The full assessment is quite burdensome for the subject as the sensory examination requires light touch and pin prick testing to each of 28 dermatomes on the right and left sides of the body and a strength evaluation of ten muscle groups. For the purpose of this study, the ASIA Impairment Scale (AIS) was limited to classification of the neurological completeness of the injury. A score of AIS-A indicated no motor or sensory function preserved in the sacral segments S4-S5 indicating a complete injury while AIS-B through D were combined to indicate incomplete SCI. Each athlete self-reported his or her level of injury (e.g., injury to spinal cord segment T7 or C6). Athletes with a cervical injury were classified as tetraplegic and those with a thoracic or lumbar injury were classified as paraplegic for the purposes of subgroup analyses.

Anthropometrics

Weight (kg) was measured to the nearest 0.1 kg with athletes wearing light indoor clothing without shoes using a portable digital scale with remote display (Universal Weight Enterprise Company Ltd., Model AMP-150, Taipei, Taiwan). The scale was modified with a larger seating platform and non-ambulatory participants sat directly on the scale for measurement. Length (m) was measured with participants in a supine position on a firm surface with the soles of the participant's feet against a wall. The subject's length was marked on the surface and then measured. The measured length was verbally reported to the subject. If the measurement was greater than 2 cm different than what the subject believed his or her height to be, the measurement procedure was repeated.

All skinfold measurements were taken according to standardized procedures (50) using Harpenden skin calipers. All measurements were taken on the right side of the body at triceps, biceps, subscapular and iliac crest sites. Measurements were taken with subjects seated, with triplicate measurements taken in rotation to the nearest 0.2 mm, with the mean used for calculations. Additional measurements were taken if a measurement was different by greater than 10% from the other measurements from the same site (example: 20 ± 2 mm for iliac crest skinfold) and the closest three values averaged. The sum of skinfolds was calculated from these measurements.

3.2.4 Dietary intake

Dietary intake data were collected using a three-day self-reported food diary (**Appendix 7**). The recording period was three consecutive days during the training camp with a three day follow-up period once the athlete returned home. The food diary completed at home for three consecutive days (two weekdays and one weekend day) reflected the athletes' typical dietary choices and intakes in a less artificial environment. For athletes, a three to seven day diet monitoring period is believed to provide a reasonably accurate and precise estimation of habitual energy and macronutrient consumption in both individuals and groups (51). The issue of under- and over-reporting is of concern with most collection techniques for dietary intakes (52). In this study, the issue of inaccurate reporting was addressed by providing a tutorial to the athletes prior to recording of intakes and by having an investigator available to the athletes during meals to assist with data recording. Food diary entries were reviewed and the participant was contacted if clarification was required.

Food record data were entered into Food Processor for Windows, version 9.0.0 (database version December 2007, ESHA Research, Salem, Oregon). The Canadian Nutrient File (2007) database (53) was the primary nutrient reference database used. If food values were not available from the Canadian Nutrient File database, the nutritional content for equivalent items from the USDA Standard Reference database (54) or values provided by the manufacturer were used. Six days of reported food intake from training camp and home food records were averaged to compute average energy intake (kcal), carbohydrate (g), fat (g) and protein (g).

3.2.5 Three-Factor Eating Questionnaire

The Three-Factor Eating Questionnaire (TFEQ) measured three aspects of human eating behaviour (18). This 51 item scale assessed cognitive dietary restraint, disinhibition and hunger and has been shown to have good test-retest reliability (18, 55). The TFEQ was administered and scored as outlined by the authors, with minor adaptations as suggested by Guest and Barr (22). For example, the first question was modified from “When I smell a sizzling steak…” to “When I smell my favourite food…” to improve question suitability for those who may not consume meat. The questionnaire was scored as outlined by the authors. Each scale was scored separately with a higher score indicating a greater tendency toward the measured trait. A copy of the modified questionnaire is included in **Appendix 11**.

3.2.6 Yale Eating Patterns Questionnaire

The Yale Eating Patterns Questionnaire (YEPQ) was developed as a taxonomy of eating behaviour for the general population (45). This questionnaire measured characteristics related to the emotionality of eating, satiation cues, attitudes towards dieting, and weight history along with typical snacking and food intake patterns. The YEPQ is a 70 item questionnaire used to measure nine scales of eating behaviour: uninhibited, oversnacking, binging, dieting, satiation–full, satiation–nausea, satiation–guilty, attribution of overweight to physical factors and attribution of overweight to emotional factors. This questionnaire was tested for validity and reliability in a sample of college students at the time of development with Cronbach’s alpha coefficients ranging from 0.69 to 0.92. However, the original published study did not report on response formats or scoring methods. Items on the two scales which assessed the importance the individual placed on the contribution of physical or emotional factors to being overweight were scored with a 4-point response format (very important, quite important, not very important, not at all important). All other items were scaled on a 5-point response format (never, seldom, sometimes, often, very often) and thus the validity of the tool may be impacted. A copy of the modified questionnaire with the adapted scoring system is included in **Appendix 12**.

3.2.7 Statistical analysis

All statistical analyses were completed using SPSS version 17.0. Descriptive statistics are presented as means and standard deviations. A p-value of <0.05 was considered to reflect a statistically significant difference. Independent t-tests were used to compare questionnaire subscale scores between groups based on SCI (paraplegic vs.

tetraplegic) and gender. Nutrient intakes were calculated and averaged from six days of food records. The group was divided on the basis of cognitive restraint scores using the group median as the cut-point. Chi-square or Fisher's exact test for small cell size were used to test for a difference in proportions based on cognitive restraint score (high vs. low). Pearson's product moment correlation was used to explore the relationship between the questionnaire subscale scores and anthropometric or dietary intake variables. Because these analyses were considered exploratory, a p-value of <0.05 was determined to be significant with greater emphasis placed on p-values of <0.01 to avoid Type 1 statistical error for correlational data.

3.3 Results

3.3.1 Participant characteristics

A total of 32 athletes met the inclusion criteria, consented to participate and completed all components of the study. Most subjects were on the wheelchair rugby team (n=20) with the remainder of athletes competing in wheelchair basketball (n=7), para-alpine skiing (n=3) and wheelchair athletics (n=2). When described by level of SCI, the group was made up of 20 participants with tetraplegia (17 male, 3 female) and 12 participants with paraplegia (7 male, 5 female). There were 20 participants with complete SCI (AIS-A) and 12 with incomplete SCI (AIS-B through D). Background characteristics including age (years), height (m), weight (kg) and body mass index (BMI; $kg \cdot m^{-2}$) of the group with subgroup analyses based on gender are presented in **Table 3.1**. There were no differences between men and women pertaining to age but as expected, the men were taller, weighed more and had a greater BMI. No difference was detected in the sum of skinfold thickness between men and women. When the population was stratified by level of SCI (**Table 3.2**), no significant differences in age or anthropometrics were detected between those with paraplegia or tetraplegia.

Table 3.1 Participant anthropometrics with subgroup analyses based on gender

Characteristic	Group (N=32)	Men (n=24)	Women (n=8)	p-value
Age (year)	30.6 ± 6.2[a]	30.5 ± 6.7	30.6 ± 4.7	0.974
Anthropometrics				
Length (cm)	177.2 ± 8.9	179.2 ± 9.0	171.1 ± 5.8	0.025
Weight (kg)	67.0 ± 13.7	70.9 ± 13.3	55.4 ± 6.0	0.004
BMI ($kg{\cdot}m^{-2}$)	21.3 ± 3.4	22.1 ± 3.5	18.9 ± 1.9	0.022
Sum of Skinfolds (mm)	51.1 ± 20.6	50.9 ± 22.8	51.5 ± 13.4	0.949

Abbreviations: BMI, body mass index; cm, centimetre; mm, millimetre; kg, kilogram; m, metre
[a] mean ± standard deviation
p-value <0.05 considered significant. Student's t-test used to compare means between groups.
Sum of skinfolds from four upper body sites: bicep, tricep, subscapular, iliac crest

Table 3.2 Participant anthropometrics with subgroup analyses based on level of spinal cord injury

Characteristic	Group (N=32)	Paraplegia (n=12)	Tetraplegia (n=20)	p-value
Age (year)	30.6 ± 6.2[a]	29.3 ± 5.1	31.4 ± 6.7	0.360
Anthropometrics				
Length (cm)	177.2 ± 8.9	174.1 ± 8.6	179.0 ± 8.8	0.128
Weight (kg)	67.0 ± 13.7	64.6 ± 13.0	68.4 ± 14.2	0.455
BMI ($kg{\cdot}m^{-2}$)	21.3 ± 3.4	21.3 ± 3.7	21.2 ± 3.4	0.952
Sum of Skinfolds (mm)	51.1 ± 20.6	50.2 ± 18.0	51.6 ± 22.5	0.864

Abbreviations: BMI, body mass index; cm, centimetre; mm, millimetre; kg, kilogram; m, metre
[a] mean ± standard deviation
p-value <0.05 considered significant. Student's t-test used to compare means between groups.
Sum of skinfolds from four upper body sites: bicep, tricep, subscapular, iliac crest

3.3.2 Dietary intake

Dietary intake was averaged from six days of food records with a reported energy intake of 2115 ± 420 kcal per day for the group and a macronutrient distribution of 54% of energy from carbohydrate, 29% from fat and 18% from protein. No statistically significant differences for any of the nutrients were detected upon subgroup analyses based on gender (**Table 3.3**) or SCI (**Table 3.4**). The dietary intakes of those with paraplegia showed a tendency to be higher in fat but again these differences did not reach statistical significance.

Table 3.3 Average nutrient intakes with subgroup analyses based on gender

Average Nutrient Intakes[a]	Group (N=32)	Men (n=24)	Women (n=8)	p-value
Energy (kcal)	2115 ± 420[b]	2156 ± 431	1991 ± 383	0.345
Carbohydrate (g)	285.1 ± 56.9	289.9 ± 57.0	270.6 ± 57.7	0.415
Fat (g)	67.4 ± 18.8	69.3 ± 18.8	63.4 ± 19.1	0.444
Protein (g)	92.8 ± 21.6	93.1 ± 21.2	92.1 ±24.2	0.917

Abbreviations: kcal, kilocalorie; g, gram
[a] nutrient intakes averaged from six days of reported dietary intake
[b] mean ± standard deviation
p-value <0.05 considered significant. Student's t-test used to compare means between groups.

Table 3.4 Average nutrient intakes with subgroup analyses based on level of spinal cord injury

Average Nutrient Intakes[a]	Group (N=32)	Paraplegia (n=12)	Tetraplegia (n=20)	p-value
Energy (kcal)	2115 ± 420[b]	2239 ± 414	2040 ± 416	0.199
Carbohydrate (g)	285.1 ± 56.9	294.4 ± 64.3	279.5 ± 52.9	0.482
Fat (g)	67.4 ± 18.8	74.7 ± 18.6	63.7 ± 18.1	0.052
Protein (g)	92.8 ± 21.6	102.3 ± 19.2	87.1 ± 21.3	0.112

Abbreviations: kcal, kilocalorie; g, gram
[a] nutrient intakes averaged from six days of reported intake (home and training camp)
[b] mean ± standard deviation
p-value <0.05 considered significant. Student's t-test used to compare means between groups.

3.3.3 Three-Factor Eating Questionnaire

The means and standard deviations for each of the three scales of the Three-Factor Eating Questionnaire (TFEQ) are presented in **Table 3.5**. No statistical differences were detected for any of the three scales (cognitive dietary restraint, disinhibition or hunger) when compared within the group based on gender or SCI (paraplegia vs. tetraplegia). When analyses were done to compare mean scores between subgroups based on completeness of SCI, a difference between the mean scores for disinhibition was detected as those with incomplete SCI reported a higher score compared to those with complete SCI (3.75 ± 1.5 vs. 2.2 ± 1.7, p=0.014) (data not shown). No other significant differences between mean scores based on level or completeness of SCI were detected.

Table 3.5 Mean scores from the Three-Factor Eating Questionnaire for the group with subgroup analyses based on gender and level of spinal cord injury

		n	Cognitive Dietary Restraint	Disinhibition	Hunger
Maximum Score			21	16	14
Group		32	10.8 ± 4.7[a]	2.8 ± 1.8	3.1 ± 2.2
Gender					
	Men	24	11.1 ± 5.0	2.7 ± 1.8	3.2 ± 2.2
	Women	8	9.8 ± 4.0	3.0 ± 1.9	2.9 ± 2.4
Level of SCI					
	Paraplegic	12	11.5 ± 4.6	3.2 ± 1.5	3.2 ± 2.0
	Tetraplegic	20	10.4 ± 4.8	2.6 ± 1.9	3.1 ± 2.3

Abbreviations: SCI, spinal cord injury
[a] scores presented as mean ± standard deviation
Comparison between sub-groups (men vs. women; paraplegic vs. tetraplegic) done using student's t-test for independent samples.
p-value < 0.05 considered significant. No significant differences detected.

3.3.4 Yale Eating Patterns Questionnaire

The means and standard deviations for each of the nine scales of the Yale Eating Patterns Questionnaire (YEPQ) for the group are presented in **Table 3.6**. Student's t-test was used to compare means for each of the subscales between groups based on gender and level of SCI. No statistically significant differences between mean scores were detected for any of the nine scales for either subgroup analyses.

Table 3.6 Mean scores from the Yale Eating Patterns Questionnaire for the group with subgroup analyses based on gender and level of spinal cord injury

YEPQ Subscale Categories	Maximum Score	Group (N=32)	Men (n=24)	Women (n=8)	Paraplegia (n=12)	Tetraplegia (n=20)
Uninhibited	45	21.5 ± 3.8[a]	21.8 ± 4.0	20.6 ± 3.1	21.1 ± 3.4	21.8 ± 4.1
Oversnacking	60	25.6 ± 4.9	25.6 ± 4.9	25.6 ± 5.4	24.2 ± 4.2	26.1 ± 5.6
Binging	65	29.8 ± 4.7	29.5 ± 4.8	30.9 ± 4.7	28.8 ± 5.2	30.5 ± 4.5
Dieting	25	11.2 ± 2.8	11.1 ± 2.8	11.5 ± 3.0	12.3 ± 2.9	10.6 ± 2.6
Satiation: Full	25	15.2 ± 2.3	15.4 ± 2.3	14.4 ± 2.3	15.5 ± 2.5	15.0 ± 2.3
Satiation: Nausea	40	16.6 ± 4.2	17.1 ± 4.4	14.9 ± 3.1	15.8 ± 3.4	17.1 ± 4.6
Satiation: Guilty	30	12.0 ± 3.1	12.0 ± 3.2	12.0 ± 3.0	11.4 ± 3.1	12.4 ± 3.1
Attribution of overweight to physical factors	40	18.2 ± 4.8	18.2 ± 5.2	18.3 ± 3.8	17.6 ± 2.9	18.6 ± 5.7
Attribution of overweight to emotional factors	8	3.8 ± 1.3	4.0 ± 1.4	3.4 ± 0.9	3.4 ± 0.8	4.1 ± 1.5

Abbreviations: YEPQ, Yale Eating Patterns Questionnaire
[a] scores presented as mean ± standard deviation
p-value <0.05 considered significant. Comparison between subgroups (men vs. women, paraplegia vs. tetraplegia) done using student's t-test for independent samples

3.3.5 High versus low cognitive dietary restraint

Individuals were categorized as high or low restraint using the group median score for the TFEQ restraint scale as the cut-point. The median score was 11.5 and those with scores of 11 or below were classified as low restraint and those with scores of 12 or above were classified as high restraint. On the basis of gender, completeness of SCI and level of SCI, the percentage of individuals with low and high restraint was equally divided as shown in **Table 3.7.** Based on gender, 50% of men and 50% of women were classified as high restraint. A slightly greater proportion of athletes with paraplegia were classified as high restraint as compared to athletes with tetraplegia but this was not a significant difference when tested with Fisher's exact test.

Table 3.7 Percentage of participants categorized as either low or high restraint on the basis of cognitive dietary restraint score with subgroup analyses based on gender, spinal cord injury level and function

		n	Low Restraint[a] (≤ 11)	High Restraint (≥12)	p-value[b]
Gender					
	Male	24	12 (50%)	12 (50%)	0.657
	Female	8	4 (50%)	4 (50%)	
Spinal Cord Injury - Level					
	Paraplegia	12	5 (42%)	7 (58%)	0.358
	Tetraplegia	20	11 (55%)	9 (45%)	
Spinal Cord Injury - Function					
	Complete	20	10 (50%)	10 (50%)	0.642
	Incomplete	12	6 (50%)	6 (50%)	

[a] Individuals were classified as low or high restraint based on the median score (11.5) for the Three-Factor Eating Questionnaire cognitive dietary restraint scale.

[b] Fisher's Exact test was used to test for differences in the percentages of low and high restraint between groups. p-value < 0.05 was considered significant. (2x2 cross table)

Results of anthropometric and dietary intakes as well as the scores for each of the scales from the TFEQ and YEPQ were compared with the group stratified based on cognitive dietary restraint scores, as shown in **Table 3.8**. No differences in BMI scores or the sum of four upper skinfold measurements between low or high restraint groups were detected, although those with high restraint tended to have a slightly greater sum of skinfolds. No differences in any of the absolute parameters of dietary intake reported based on restraint were detected although the higher restraint group had protein intakes account for a greater proportion of total energy. No difference was detected in the percentages of calories from carbohydrate or fat intake. By design, the high restraint group had a significantly higher cognitive dietary restraint score compared to the low restraint group and those with higher restraint scores also had a relatively higher disinhibition score. No differences based on the hunger scale were detected between the groups. A comparison of the YEPQ scale scores between low and high restraint groups revealed differences for the dieting and satiation – guilty subscales as those in the high restraint group scored higher for both of those traits.

Table 3.8 Comparison of anthropometrics, dietary intake and eating patterns scores between those with low and high cognitive dietary restraint scores

	Low Restraint (n=16)	High Restraint (n=16)	p-value
Anthropometrics			
BMI (kg·m^{-2})	20.9 ± 3.3[a]	21.7 ± 3.6	0.511
Sum of Skinfolds (mm)	45.0 ± 19.1	57.2 ± 20.9	0.095
Dietary Intake			
Energy (kcal)	2210 ± 375	2020 ± 452	0.207
Carbohydrate (g)	296.2 ± 49.6	274.0 ± 62.9	0.276
Fat (g)	72.9 ± 18.5	62.8 ± 18.2	0.130
Protein (g)	92.8 ± 17.5	92.8 ± 25.6	0.997
Fibre (g)	19.3 ± 3.7	20.4 ± 5.1	0.462
% Energy from carbohydrate	53.9 ± 3.9	54.6 ± 5.5	0.697
% Energy from fat	29.6 ± 3.8	27.8 ± 4.6	0.248
% Energy from protein	**16.9 ± 2.0**	**18.4 ± 2.1**	**0.042**
Calcium (mg)	793 ± 173	914 ± 385	0.267
Vitamin D (IU)	166.1 ± 44.9	162.4 ± 41.8	0.814
Three-Factor Eating Questionnaire			
Cognitive Dietary Restraint	**6.8 ± 3.0**	**14.7 ± 2.1**	**<0.001**
Disinhibition	**2.1 ± 1.7**	**3.5 ± 1.6**	**0.019**
Hunger	2.8 ± 1.9	3.4 ± 2.4	0.430
Yale Eating Patterns Questionnaire			
Uninhibited	22.6 ± 3.6	20.4 ± 3.7	0.092
Oversnacking	26.1 ± 6.2	25.1 ± 3.3	0.553
Binging	29.3 ± 5.4	30.4 ± 4.0	0.486
Dieting	**9.9 ± 2.3**	**12.5 ± 2.7**	**0.007**
Satiation – Full	14.9 ± 2.3	15.4 ± 2.4	0.606
Satiation – Nausea	17.1 ± 4.3	16.0 ± 4.1	0.456
Satiation – Guilty	**10.4 ± 2.5**	**13.6 ± 2.8**	**0.002**
Attributes – Physical	18.9 ± 6.4	17.5 ± 2.4	0.425
Attributes – Emotional	3.7 ± 1.6	4.0 ± 1.0	0.505

Abbreviations: BMI, body mass index; kcal, kilocalorie; IU, International Units

[a] mean ± standard deviation

Low and High restraint group divided on the basis of group median score of 11.5.

Comparison between sub-groups done using student's t-test for independent samples.

p-value <0.05 considered significant and indicated in bold font.

Sum of skinfolds from four upper body sites: bicep, tricep, subscapular, iliac crest

3.3.6 Correlation between TFEQ and YEPQ subscales with anthropometrics and selected nutrients

The potential association between each of the three subscales for TFEQ was tested against anthropometric and dietary intake variables. As presented in **Table 3.9**, no significant correlations were detected between cognitive dietary restraint and any of the anthropometric or selected nutrient intake variables. A moderate positive association was detected between disinhibition and the sum of skinfolds. The hunger scores were moderately associated with a number of the dietary intake variables including energy, carbohydrate and protein.

Table 3.9 Association of cognitive restraint, disinhibition and hunger with anthropometric and dietary intake

(Group N=32)	Cognitive Dietary Restraint		Disinhibition		Hunger	
	r	p-value	r	p-value	r	p-value
Anthropometrics						
BMI ($kg \cdot m^{-2}$)	0.281	0.120	0.268	0.138	0.297	0.099
Sum of Skinfolds (mm)	0.349	0.050	**0.513**	**0.003**	0.248	0.171
Dietary Intake						
Energy (kcal)	-0.248	0.171	0.044	0.810	**0.354**	**0.047**
Carbohydrate (g)	-0.235	0.196	-0.011	0.954	**0.361**	**0.042**
Fat (g)	-0.246	0.175	0.077	0.674	0.240	0.185
Protein (g)	-0.010	0.955	0.158	0.388	**0.456**	**0.009**

Abbreviations: BMI, Body mass index; kcal, kilocalorie; IU, International Units; r, Pearson's product moment correlation coefficient

correlation with p-value <0.05 considered significant and in bold font

Sum of skinfolds are from four upper body sites: bicep, tricep, subscapular, iliac crest.

Pearson's product moment correlations between each of the nine subscales of the YEPQ and anthropometrics or selected were examined. Results presented in **Table 3.10** are limited to the two subscales of the YEPQ in which a statistically significant association with at least one of the anthropometric or dietary variables was detected. Correlation data for subscales with no association to anthropometric or dietary intake variables are not shown. A moderate positive association between the sum of skinfolds and the satiation-guilty subscale was detected but no correlation with BMI was detected for any of the subscales. The dieting subscale was detected to have a moderate positive association with protein intake.

Table 3.10 Correlation of selected scales from Yale Eating Patterns Questionnaire with anthropometrics and dietary intake

	Dieting		Satiation - Guilty	
	r	p-value	r	p-value
Anthropometrics				
BMI (kg·m^{-2})	0.053	0.772	0.242	0.183
Sum of Skinfolds (mm)	0.178	0.329	**0.382**	**0.031**
Dietary Intakes				
Energy (kcal)	0.264	0.145	-0.355	0.046
Carbohydrate (g)	0.145	0.427	**-0.376**	**0.034**
Fat (g)	0.336	0.060	-0.234	0.198
Protein (g)	**0.418**	**0.017**	-0.226	0.213

Abbreviations: BMI, Body mass index; mm; millimetre; kcal, kilocalorie; r, Pearson's product moment correlation coefficient; g, gram; k, kilogram
p-value < 0.05 considered significant and in bold font
Data from scales of the Yale Eating Patterns Questionnaire without any significant correlation not presented.
Sum of skinfolds are from four upper body sites: bicep, tricep, subscapular, iliac crest.

3.4 Discussion

The assessment of the psychological constructs of cognitive dietary restraint, disinhibition and hunger in athletes with SCI contributes novel information to this body of literature. While significant differences were not detected based on gender or level of SCI for any of the three scales within the TFEQ, the cognitive dietary restraint scores for the men in the group were considerably higher than expected with a mean score of 11.1 ± 5.0. In comparison, a sample of 60 adult males reported a mean restraint score 6.7 ± 3.7 (32). Another sample of obese men in a weight reduction study reported baseline restraint scores of 5.0 ± 3.7, which increased to 10.0 ± 4.1 during the energy restriction phase and then returned to 7.0 ± 4.3 at the end of the maintenance phase of the intervention (56). The mean restraint scores for the female athletes with SCI in this study were similar to scores of many other studies of college aged women, which ranged from 6.4 ± 4.8 for vegetarian women (24) to 11.0 ± 5.4 for female runners with stress fractures (22) with many studies reporting a mean or median score between 8 and 10 (23, 25, 26).

The disinhibition scores in this group of athletes were slightly lower than anticipated, with a mean value of 2.8 ± 1.8, compared to typical scores for both men and women between 5 and 7 out of a possible 16 (20, 22, 23, 29, 32, 56, 57). Hunger scores are also typically higher in able-bodied populations in the range of 5 to 7 out of a possible 14 (22, 23, 32, 56, 57) compared to the mean hunger score of 3.1 ± 2.2 in this group of athletes with SCI. The stronger expression of cognitive dietary restraint with weaker expression of disinhibition and hunger traits identifies a unique pattern of eating behaviours and attitudes in these athletes, especially the men. The profile of eating behaviours assessed by the TFEQ can be described as the purposeful monitoring and perhaps intentional limiting of food intake to maintain body composition without an associated loss of control with intake of certain foods and low susceptibility to hunger cues. Even among SCI athletes with high restraint, scores for disinhibition were still lower than population norms. As a group, these athletes appear to be monitoring and potentially restricting their dietary intake but with an attenuated sense of disinhibition and weaker hunger and satiety cues.

When the athletes were categorized based on a median split of cognitive dietary restraint scores, no differences in the energy, macronutrient or micronutrient intakes were detected. Many studies have compared dietary intakes within groups on the basis of restraint scores (20, 34, 36, 39, 42, 43, 58) with a tendency for those with higher levels of dietary restraint to report lower energy intakes (20, 34-36, 38-40). The percentage of energy from protein tends to be higher (20, 39, 42, 58) while the proportion of energy from fat tends to be less (20, 34, 42). While significant differences in the absolute macronutrient intakes were not detected between those with high and low restraint, a significant difference was detected in the percentage of energy from protein. This may reflect an athlete's desire or attempt to maintain an adequate protein intake within a limited energy intake.

Significant correlations were not detected between the scores for cognitive dietary restraint and any of the anthropometric or dietary intake data. A moderate positive correlation was detected between the scores for disinhibition and the sum of skinfolds, although BMI was not associated with disinhibition. The literature confirms that disinhibition scores are more likely to be associated with measures of body composition and weight than are scores for cognitive dietary restraint (28), although the relationship is influenced by the strength and presence of other eating behaviours and attitudes (29, 59, 60). These results illustrate that although dietary intake and body composition were similar between those with low and high dietary restraint, the athletes had very different ways of thinking about the relationship between food intake and body size.

The results from each of the nine subscales from the YEPQ were presented for this group of athletes with SCI. Unfortunately, a very limited number of studies exist for comparative purposes. In comparison to the original population of college students this instrument was developed with, the athletes in this study scored higher on the dieting scale (11.2 ± 2.8 vs. 7.6 ± 1.6), scored similar on the scales for satiation-full (15.2 ± 2.3 vs. 16.5 ± 3.9), satiation-guilty (12.0 ± 3.1 vs. 14.8 ± 5.2) and scored lower on the remaining scales of uninhibited (21.5 ± 3.8 vs. 25.2 ± 4.9), oversnacking (25.6 ± 4.9 vs. 34.2 ± 6.3), binging (29.8 ± 4.7 vs. 40.0 ± 7.3), satiation-nausea (16.6 ± 4.2 vs. 23.6 ± 10.5), attribution of overweight to physical factors (18.2 ± 4.8 vs. 27.8 ± 7.3) and attribution of overweight to emotional factors (3.8 ± 1.3 vs. 6.8 ± 2.2). A subjective profile of the eating behaviours and attitudes of the athletes as assessed by the YEPQ is subjectively similar to the profile observed on the TFEQ. Similar characteristics include an emphasis on the importance of dieting with some tendency towards the uninhibited eating of foods for enjoyment and eating to satiety with some guilt associated with when to stop eating. Tendencies towards oversnacking and binging were low and any attribution of physical or emotional causes of weight gains were also low. While the YEPQ offers great potential as a psychometric instrument to measure food and eating related behaviours and attitudes in the general population, this tool has yet to withstand validation in a variety of populations. Studies that have used this tool are quite limited and often only the binging and oversnacking subscales have been used in obesity or bulimia related studies.

3.4.1 Strengths and limitations

The strengths of this study include the choice of psychometric instrument used to assess eating behaviours and the strategies used to improve the accuracy of the self-reported food diaries. The TFEQ is widely recognized as a robust instrument used to assess the construct of cognitive dietary restraint with extensive studies using this tool as a primary method of assessment. The validity of the restraint scale of the TFEQ has good internal consistency (Cronbach's alpha 0.80) (55) with good test-retest reliability (18). The psychometric properties of the restraint scale of the TFEQ were tested in a population of college aged women of differing ethnic background and found good temporal stability over a 5 month period (61). Bond et al. found strong intercorrelations among the original TFEQ scales and the subscales tested in the study (correlation of 0.69 – 0.87) (62). As with most psychometric instruments, there is some debate over the validity of the constructs that the tool is intended to measure and the clinical relevance or application of the findings (55, 61-63). Over time, all tools tend to evolve and change but at the present time the TFEQ is considered to be a robust tool to assess cognitive dietary restraint in a variety of populations.

A second strength of this study was the repeated measurement of the self-reported three-day food records to capture usual intakes while at home as well as when athletes were with the team. The accuracy of the dietary reporting was enhanced by a number of methods including a detailed tutorial provided to athletes by a Registered Dietitian, having that same individual present during meals while at training camp to observe intakes and to answer any questions or provide clarity on how to record intake.

This study was exploratory in nature with a key objective to assess the eating behaviours and attitudes in a population of elite Canadian athletes with SCI. As a result of the study design, there are a number of limitations that the reader should be aware of, and accordingly, the results should be interpreted with caution. The primary objective of this study was to measure and evaluate the dietary adequacy of athlete with SCI (presented in detail in **Chapter 2**). While significant differences were not detected between groups with differing cognitive dietary restraint scores, this study was not powered adequately to detect differences on the basis of restraint scores. While the number of women in this study was not adequate for independent analyses, the most interesting finding of higher than expected dietary restraint scores was detected among the men which had a reasonable group size.

3.4.2 Future directions

The presence of a strong tendency towards dietary restraint in athletes with SCI has not been reported in the literature, and thus, hypotheses regarding why restraint may be elevated or the potential physiological impacts of chronically high dietary restraint behaviours have not been established or tested. It has been previously well documented that high dietary restraint is associated with elevated urinary and salivary cortisol concentrations (20-22) and potential effects on bone mineral density (23, 25, 27). The stimulation of the hypothalamic-pituitary-adrenal axis may further affect an already tenuous bone density situation in those with SCI (64). If the same relationship holds true between cognitive dietary restraint and elevated cortisol concentration, the impact on bone health may be significant as this population is already at great risk for reduced bone mineral content (65-67).

It is purely speculative at this point as to why a relatively high cognitive dietary restraint score was observed in this group of athletes. One may hypothesize that appetite and dietary intake may be influenced as a result of the SCI secondary to altered autonomic control, changes to hormonal regulation or simply that energy requirements are significantly less following SCI. Perhaps the cognitive control of dietary intake is a necessity for these athletes in order to avoid weight gain and obesity as a consequence of the reduced energy requirements following SCI. These athletes may be actively regulating their dietary intakes to maintain or achieve a desired body composition specific to the needs of the sport to contribute to their athletic successes. The observation of elevated cognitive dietary restraint in athletes with SCI offers many potential hypotheses to be developed and tested in order to better understand this phenomenon.

3.4.3 Conclusions

It has been previously established that energy requirements for adults with SCI are less than predicted and energy intakes are often considerably less than expected based on body mass and physical activity level (12, 68-70). The most common rationale for this reduced energy requirement has been related to the reduction in lean tissue following SCI (8-11). In athletes with SCI, the balance between energy intake, energy requirements and energy expenditure for physical training creates an interesting paradigm of energy balance. Added to this picture, is now the additional influence of eating behaviours and attitudes. These athletes may be purposefully monitoring or limiting dietary intake to avoid the high prevalence of obesity associated with SCI (7, 8, 10) or perhaps to maintain an ideal body composition for their sport performance. It would be interesting to further investigate this observation and test if the presence of a stronger cognitive dietary restraint trait is repeated in other groups with SCI. Future studies investigating the hormonal influence and regulation of appetite and energy intake in those with SCI would benefit from including an assessment of eating behaviours and attitudes. Many questions remain unanswered but it would be prudent for coaches, sport scientists and Registered Dietitians working with these athletes to explore eating behaviours and attitudes, especially in those athletes who appear to have a very limited dietary intake.

3.5 References

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Chapter 4: Conclusion

4.1 General discussion

Athletes with spinal cord injury (SCI) are training with increased frequency and intensity, looking for a competitive edge in order to achieve their athletic goals. Often, performance nutrition is included in the arsenal of weapons available to optimize training, recovery and ultimately performance. While there is a wealth of information to assist able-bodied athletes in adjusting their dietary intake to support training, there is very limited information on what athletes with SCI are consuming, and virtually no evidence to support altering intakes. Thus, the primary goal of this study was to better understand the usual dietary intakes of elite Canadian athletes with SCI as a step towards enhancing the current state of knowledge.

This chapter summarizes and synthesizes the information related to, and obtained from the study. It begins with an overview of previous literature on the metabolic and physiological changes associated with SCI including a brief summary of the limited number of published studies on the dietary intakes of this population. Next, the general conclusions of the study are presented with reference to the research objectives. An evaluation of the strengths and limitations of the study is then presented along with some suggested avenues for further research on this topic. This chapter then finishes with some practical applications of the findings from the study.

4.2 Summary of the current state of knowledge

SCI is associated with many significant metabolic and physiological changes, both of which may influence dietary intakes. Those with SCI are at greater risk of glucose intolerance (1-4) with resistance to the action of insulin in mediating glucose uptake by peripheral tissues (4-6). Lipid metabolism is also altered with lower concentrations of high density lipoprotein (HDL) cholesterol (7) and elevated low density lipoprotein (LDL) cholesterol concentrations in approximately 25% of individuals (8, 9). Increased physical activity and improved cardiovascular fitness improves the HDL cholesterol concentrations (9-13). The level of neurological impairment is associated with the degree to which glucose and lipid metabolism are affected, as those with complete tetraplegia are most at risk for hyperinsulinemia (14) and depressed HDL cholesterol concentrations (2, 15).

Many changes to body composition are also observed following SCI. Spungen et al. (16) found that those with SCI have a much higher total fat mass and percent body fat with increased prevalence of abdominal obesity (17-20). There is a decrease in total body lean tissue mass (16, 21, 22) while the amount of lean tissue in the regions above the level of injury are similar compared to matched controls (23). Body composition in athletes with SCI has been assessed in a relatively limited number of studies and the effect of physical training on body composition remains somewhat inconclusive. While training improves measures of fitness (24), the effect on body composition is not as apparent with a tendency towards a reduced percent body fat above the level of neurological impairment but not a systemic reduction in percentage of body fat (24-28).

Resting energy expenditure in adults with SCI is considerably less than in matched able-bodied controls (29-32). In most cases, this reduced resting energy expenditure can be explained by a decrease in lean tissue (29-37) which is the best predictor of resting metabolic rate in those with paraplegia (30). The studies have typically measured resting energy expenditures in sedentary adults with SCI and the impact of high intensity, high frequency physical activity on the total energy expenditure in athletes with SCI has not yet been measured.

The dietary intakes of community living adults with SCI have been studied with a sufficient level of detail in four studies to date (19, 38-40). As resting energy expenditure is reduced following SCI, it is not surprising that the reported energy intakes are less than predicted (19, 38-40). Within this reduced energy intake, the distribution of macronutrients generally falls within the recommended ranges with the exception of consistently low fibre intakes. The intakes of several micronutrients are cause for concern with mean intakes of folate, vitamin C and magnesium identified as being suboptimal. Mean intakes of calcium and vitamin D are consistently below the recommended intake level for healthy adults. The dietary intakes of athletes with SCI have been studied by three groups (41-43). Energy intakes were reduced with an appropriate macronutrient distribution and some indication of micronutrient inadequacies. Potvin et al. (41) reported mean micronutrient intakes compared to a reference standard. In this small group of marathoners, micronutrient intakes were above the cut-point with the exception of vitamin E and zinc. Interestingly, this group reported mean calcium and vitamin D intakes which were above the recommended amount. The studies by Lally et al. (42) and Ribeiro et al. (43) did not systematically assess or report mean intakes of micronutrients.

Many gaps in the literature are apparent. There is sufficient evidence that energy intakes are below those of able-bodied individuals yet there is limited information on the overall quality or adequacy of the diets of those individuals with SCI within this reduced energy. A considerable prevalence of suboptimal nutrient intakes has been identified in community living adults with SCI (19, 40). A very limited number of reports suggest that athletes with SCI consume similar amounts of energy as compared to non-athletes with SCI but suggest there may be differences in the micronutrient intakes and prevalence of inadequacy.

4.3 General conclusions

This study contributes to the current body of knowledge as it relates to the dietary intakes of athletes with SCI by assessing the current dietary intakes of a varied population of elite Canadian athletes with SCI. Dietary intakes representative of the individuals' usual or home diets in addition to dietary intakes while the athletes were at a national team event were assessed. This study assessed several of the factors which influence dietary intakes such as nutrition knowledge, supplement usage, activity level and behaviours or attitudes associated with eating.

The specific objectives and key findings from this study are summarized in **Table 4.1**. The assessment of dietary adequacy was comparable to the results in a sample of community living adults with SCI as reported by Walters et al. (40). There was a relatively low energy intake, macronutrient intakes generally fell within the Acceptable Macronutrient Distribution Range (AMDR) and there was a high prevalence of mean micronutrient intakes below the Estimated Average Requirement (EAR) or Adequate Intake (AI) (44). A comparison of the results between the Walters et al. (40) report and the findings of this study suggest that the athletes in this study have not made significant alterations to the nutrient density of their dietary choices to enhance intakes.

While at the national team event, the energy intakes of the athletes differed slightly with a tendency to consume more calories. The slightly increased energy intake may be related to an increased training volume (492 ± 266 minutes vs. 366 ± 172 minutes, $p<0.05$) while at training camp. More likely, the tendency towards increased energy intake is secondary to the food choices available and the reliance on restaurant type meals. If the food available included nutrient dense, lower calorie foods one would assume that the prevalence of nutrient inadequacy would be less with the increased volume of food consumed. Despite the increased energy intake, a greater proportion of athletes had nutrient intakes below the EAR while at training camp. The women in this study were able to maintain consistency in their diets between home and training environments without significant differences in mean intakes or the proportion of women with intakes below the EAR. A subjective comparison of the intakes of the athletes and the dietary intakes of Canadians (45) showed that the nutrient intakes between the two groups were similar. Canadian men consumed approximately 600 kcal greater per day compared to the male athletes with SCI, while the energy intakes of the women were similar. Overall, the patterns of dietary inadequacies of micronutrients were similar between the athletes with SCI and Canadians across the country.

The assessment of the psychological constructs of cognitive dietary restraint, disinhibition and hunger in athletes with SCI contributes novel information to this body of literature. The cognitive dietary restraint scores for the men in the group were higher than expected while the disinhibition and hunger scores were lower than the norms presented in the literature. The pattern of a relatively high cognitive dietary restraint with low disinhibition and hunger was observed in both men and women. The stronger expression of cognitive dietary restraint with weaker expression of disinhibition and hunger traits identifies a unique pattern of eating behaviours and attitudes in these athletes, especially the men. The profile of eating behaviours assessed by the Three-Factor Eating

Questionnaire (46) can be described as the purposeful monitoring and perhaps intentional limiting of food intake to maintain body composition without an associated loss of control with intake of certain foods and low susceptibility to hunger cues. Similar to the findings with the TFEQ, the results of the Yale Eating Pattern Questionnaire (47) describe the eating attitudes of the athletes to be concerned with dieting with some tendency towards the uninhibited eating of foods for enjoyment and eating to satiety with some guilt associated with when to stop eating. There was a low tendency towards oversnacking and binging, similar to the disinhibition scale of the TFEQ.

Table 4.1 Summary of key results with regards to specific objectives

Chapter 2	Chapter 2
Specific objective	Summary of key results
1. Evaluate the dietary adequacy of macronutrient and micronutrient intakes of elite athletes with a spinal cord injury using the Dietary Reference Intakes for macronutrients (48), vitamins and elements (49-53) as comparative tools.	• The prevalence of nutrient inadequacy was significant for men while at training camp with greater than 25% of men reporting mean intakes below the EAR for riboflavin, folate, vitamin B12, magnesium and zinc. At home, the prevalence of nutrient inadequacy for men decreased as greater than 25% of men reported mean intakes below the EAR for only folate, magnesium and zinc. • For men, mean intakes of calcium (775 ± 206 mg) and vitamin D (86.9 ± 65.5 IU) were poor. Women had mean intakes above the AI for calcium (1089 ± 419 mg) but not vitamin D (165.6 ± 130.1 IU). • Only 17% of men and 13% of women reported intakes above the AI for vitamin D, whereas 21% of men and 50% of women had mean calcium intakes above the AI. • The macronutrient intakes were within the AMDRs for men (55.6% carbohydrate, 28.1% fat, 17.9% protein) and women (53.3% carbohydrate, 28.9% fat, 17.9% protein), and most individuals had intakes within the AMDRs. • The predictive equations for EER developed by the IOM did not accurately reflect reported energy intake, even when the coefficients for sedentary or low activity levels were used.
2. Assess the usage of supplemental vitamins and minerals and evaluate the impact on dietary adequacy.	• At home, 44% of athletes consumed a nutritional supplement. At training camp, this decreased to 34% of athletes. • For men, the additional nutrients improved the proportion with mean intakes above the AI for vitamin D (29%) and increased the mean intake of vitamin D to 176.8 ± 200.1 IU. For almost all other nutrients, the mean intake was significantly increased but the proportion of men with intakes below the EAR did not improve. • For women, the additional nutrients did not significantly increase the mean intakes or change the proportion of women with intakes above the AI or below the EAR.

Chapter 2	Chapter 2
Specific objective	Summary of key results
3. Compare and contrast the energy and nutrient intakes of athletes while training at home and at a national team event.	• Athletes consumed a slightly greater energy intake while at training camp. This was statistically significant for men (2285 ± 540 kcal vs. 2028 ± 528 kcal, $p<0.05$), rugby athletes (2213 ± 556 kcal vs. 1899 ± 566 kcal) and those with incomplete SCI (2279 ± 481 kcal vs. 1910 ± 494 kcal, $p<0.05$). • While at home, men had a greater intake of riboflavin (1.8 ± 0.6 mg vs. 1.4 ± 0.5 mg, $p<0.05$), thiamin (1.7 ± 0.6 mg vs. 1.4 ± 0.4 mg, $p<0.05$), calcium (856 ± 330 mg vs. 693 ± 204 mg, $p<0.05$) and vitamin D (160.1 ± 133.4 IU vs. 38.5 ± 78.3 IU, $p<0.05$), despite their lower energy intakes. • No differences were detected between home and training camp intakes for women.
4. Assess athletes' understanding of nutrition knowledge and recommendations using a nutrition knowledge questionnaire (54).	• Women achieved a total score of 76.1 ± 7.9 (out of a possible 110) which was higher than the score 66.7 ± 10.8 achieved by men ($p<0.05$). The women scored higher on determining the food sources of nutrients ($p<0.05$). No differences were detected between groups on the basis of sport or SCI. • The total score on the nutrition knowledge questionnaire was similar to the results from a Canadian population with an average score of 71 (55).
5. Compare and contrast the energy and nutrient intakes of elite athletes with a spinal cord injury to the Canadian population (45).	• Energy intakes of male athletes with SCI were considerably less than Canadian men (2156 kcal vs. 2737 kcal). Energy intakes of female athletes were comparable to Canadian women (1991 kcal vs. 1902 kcal). • Athletes with SCI and adult Canadians had similar proportions of individuals with intakes below the EAR for riboflavin, thiamin, vitamin B12, vitamin C, phosphorus and magnesium above the AI for calcium and vitamin D. • Similar to Canadians, mean sodium intakes for men (4142 ± 1159 mg) and women (3368 ± 11085 mg) were well above the AI. • Athletes with SCI had a greater proportion of individuals with intakes below the EAR for folate (men only), niacin and zinc as compared to Canadians. • Overall, the patterns of dietary inadequacies of micronutrients were similar between the athletes with SCI and Canadians across the country.

Chapter 3	**Chapter 3**
Specific objective	Summary of key results
1. Describe food related attitudes and behaviours as measured by the Three-Factor Eating (46) and Yale Eating Patterns Questionnaires (47).	• The scores for the cognitive dietary restraint scale from the TFEQ were higher than expected for men (11.1 ± 5.0) while the scores for women (9.8 ± 4.0) were comparable to able-bodied groups. • The group score for disinhibition (2.8 ± 1.8) and hunger (3.1 ± 2.2) were lower than able-bodied populations. • The scores of the YEPQ subscales showed athletes with SCI scored higher on the dieting scale, scored similar on the scales for uninhibited, satiation-full, satiation-guilty and scored lower on the remaining scales of oversnacking, binging, satiation-nausea, attribute-physical and attribute-emotion as compared to an able-bodied population.
2. Explore cognitive dietary restraint scores and associations with dietary intake, anthropometrics and SCI characteristics.	• Athletes with higher cognitive dietary restraint scores had a greater percentage of energy from protein (18.4 ± 2.1% vs. 16.9 ± 2.0%) but no other differences in dietary intake or anthropometrics were detected. • Athletes with higher cognitive dietary restraint scores also scored higher on dieting (12.5 ± 2.7 vs. 9.9 ± 2.3, $p<0.01$) and satiation-guilty (13.6 ± 2.8 vs. 10.4 ± 2.5, $p<0.01$) subscales of the YEPQ. • Cognitive dietary restraint scores were not significantly correlated with dietary intakes or anthropometric measures. Disinhibition scores showed a moderate positive correlation to the sum of skinfolds ($r=0.513$, $p=0.003$).

Abbreviations: AI, Adequate Intake; AMDR, Acceptable Macronutrient Distribution Range; EAR, Estimated Average Requirement; EER, estimated energy requirement; kcal, kilocalorie; IOM, Institute of Medicine; mg, milligram; IU, International Units; SCI, spinal cord injury; TFEQ, Three-Factor Eating Questionnaire; UL, Tolerable Upper Limit; YEPQ, Yale Eating Patterns Questionnaire

4.4 Strengths and limitations

This cross-sectional study was designed to enhance the understanding of the dietary intakes of elite athletes with SCI and also to explore some of the factors which might influence those dietary choices. A strength of this study is the athletes who agreed to participate. Of the athletes approached in person to participate, 83% consented to participate and 78% completed all aspects of the study including a second food and activity diary which was completed once the athlete returned home. The athletes who completed all aspects of the study provided detailed and accurate information as all questions were answered with no missing data.

Many influencing factors were assessed including physical activity for the same days food intake was reported with detailed information on the time participating in an activity as well as a rating of perceived exertion. Nutrition knowledge, eating attitudes and behaviours were also assessed as these are key factors which may influence dietary intake. Nutrient adequacy was determined using the framework established by the Institute of Medicine (44) which allowed for the assessment of the prevalence of nutrient inadequacy in a group.

This study did have some limitations. Of the participants who completed the study, most were male (75%) and had a SCI resulting in tetraplegia (63%). This sample was not representative of elite athletes competing in Canada as the number of athletes in wheelchair athletics and female athletes were under represented. The coaches were generally interested in supporting this research study. However, the athletes' training and competition schedules were such that it was not possible to identify a team event at which data collection could take place. The distribution of athletes based on sport and gender made statistical comparisons between groups difficult and subtle differences based on sport may not have been detected.

A second limitation with this study was the reliance on self reporting of dietary intake and activity and the risk of inaccurate reporting. The inherent risks in collecting data in this manner were minimized using a number of methods including providing all participants with a detailed explanation of how to accurately record food intake, having a researcher present for the first three days, observation of food intake and clarification of recorded items as needed. It is the author's impression that the athletes were motivated to provide accurate data based on the level of detail in the food records for most diaries and the fact that 94% of participants completed the second set of food records. While this study did have some limitations, the primary objective was to collect preliminary data on dietary intakes and assess overall adequacy which was achieved.

4.5 Future directions

While the exploratory nature of this study meant that definitive answers were not obtained, several exciting directions for future research were identified. Reported energy intakes were typically quite low given the athletes' level of activity. It would be valuable to validate the estimated energy requirements of these athletes using the doubly labeled water method. This would be a more accurate measure of energy expenditure with the potential to develop a predictive equation to estimate energy requirements specific to this population. The development of a valid and reliable prediction equation would be an important tool to assist with individual nutrition assessment, meal planning and nutrition education of the athletes.

As these are high performance athletes, the goal is to train and use the most energy efficient metabolic systems for athletic performance. Preliminary work has shown alterations in substrate use during exercise in those with SCI with a greater reliance on carbohydrate as the primary substrate (56). Spendiff and Campbell studied the effect of carbohydrate ingestion during exercise and found improved performance with the use of an 8% glucose drink (57-59). However, impact of this additional carbohydrate load in the context of the athlete's total diet has yet to be evaluated. The consumption of 500 ml of a typical glucose drink (6% carbohydrate) at 10 training sessions per week could contribute an additional 1200 kcal per week. This could lead to increased weight gains or displace more nutrient dense foods, thereby contributing to nutrient inadequacies. If athletes with SCI are using metabolic systems differently than able-bodied athletes, perhaps macronutrient intakes in differing amounts would positively affect performance.

The prevalence of nutrient inadequacy was determined using the EAR and AI as the reference values. These requirements were established with data typically from healthy able-bodied adults. The requirement distribution for micronutrients is unknown for adults with SCI. Perhaps the established AI and EAR reference values do not accurately reflect the true needs of adults with SCI and the proportion of individuals with inadequate intakes is over estimated. Perhaps with some nutrients, the requirements are increased with SCI and perhaps the percentage of individuals below the requirement amount is actually less than estimated with the current reference values.

The presence of a relatively strong tendency towards cognitive dietary restraint is intriguing and leads to many questions. It would be interesting to assess the association between dietary restraint and cortisol excretion as cortisol is one parameter within the hypothalamic-pituitary-adrenal axis and may potentially impact bone density. Appetite and dietary intake may be influenced by the reduction in total muscle mass or they may be affected by altered autonomic control, changes to hormonal regulation or intentional attempts to limit intake to maintain a desirable body weight to contribute to athletic success. Regulation and control of appetite and dietary intake involve incredibly complex processes. Injury to the spinal cord, high performance athletics, reduced energy intake and now cognitive restraint add many layers of complexity to this puzzle.

4.6 Applications

This research identified that while athletes with SCI are consuming a diet with macronutrient intakes that fall within the AMDR, the energy intakes are lower than anticipated given the frequency of physical training. Within this energy reduced diet, a higher than anticipated prevalence of micronutrient inadequacies was observed. When the athletes were at training camp, the occurrence of suboptimal micronutrient intakes increased, particularly among the male athletes. Coaches, administrators and Registered Dietitians working with these teams and athletes can apply this knowledge to work to improve the dietary intakes of athletes.

The provision of food services while athletes are away with their respective national team ranges dramatically from athletes fully responsible for the procurement of all food and meals to fully customized and catered meals and snacks. The food choices are often dictated by factors outside the control of athletes such as access to grocery stores, access to refrigerators and microwaves, types of restaurants nearby, cost and training schedules which may not allow sufficient time for meals. The provision of meals and snacks that are lower in fat and energy but nutrient dense would likely improve the nutrient quality of food choices, the overall nutrient density and micronutrient intakes. Alternately, if it is not possible to provide meals and snacks directly to the athletes, ongoing nutrition education may help athletes acquire the skills and knowledge to improve their dietary choices. Athletes could benefit from practical skills and information related to making better meal choices when eating out, grocery store options, travel safe foods and portable meal options to name a few.

Nutrition knowledge scores in this group of athletes were comparable to other Canadians, and suggest athletes had a reasonable understanding of general diet recommendations. However, knowledge related to food sources of nutrients and strategies to choose everyday foods were two topics which were identified as potential areas to improve knowledge. If athletes, in particular men, were more aware of foods that contain the micronutrients they may be lacking in their diet the nutrient density may improve. The basic nutrition information should also be tailored to meet the demanding lifestyles of elite athletes with the added challenges of frequent travel, time constraints, food preparation abilities and potential financial constraints.

In this study, vitamin and mineral supplements were consumed by slightly less than half of all athletes. A variety of supplements were consumed with multivitamins consumed most often. Female athletes may benefit from a more tailored approach to micronutrient supplementation targeting vitamins and minerals that are marginal as the overall dietary adequacy was reasonable. While for the male athletes, considerable improvements to the overall quality of their diets should be the initial focus and then after careful reassessment of dietary adequacy micronutrient supplementation may be warranted.

The assessment of eating behaviours and attitudes provides us with an additional consideration when evaluating the dietary intakes of athletes with SCI. Many questions remain unanswered but it would be prudent for coaches, sport scientists and Registered Dietitians working with these athletes to explore eating behaviours and attitudes, especially in those athletes who appear to have a very limited dietary intake.

This exploratory study of the nutrient intakes of elite Canadian athletes with SCI established baseline information on the intakes and dietary adequacy in this novel population. Many aspects of dietary intake, activity, supplement use, details of the SCI and the attitudes associated with eating were explored. The key findings of this study suggest that there is significant potential for athletes with a spinal cord injury to improve the micronutrient density of their diets.

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Appendix 1: University of British Columbia Behavioural Research Board ethics approval certificates

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL - MINIMAL RISK

PRINCIPAL INVESTIGATOR:	I~NSTITUTION / DEPARTMENT:	I~BC BREB NUMBER:
Susan I. Barr	USC/Land and Food Systems	H07-00011

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
USC	Point Grey Site

Other locations where the research will be conducted:
Research will be conducted during national team training sessions, locations will be Vancouver (Lower Mainland), Calgary, Edmonton, Montreal, Toronto. Facilities will be preselected by sport administrators and coaches to meet the needs of the athletes.

CO-INVESTIGATOR(S):
Jennifer Krempien

SPONSORING AGENCIES:
N/A

PROJECT TITLE:
Nutrient Intakes of Elite Canadian Athletes with a Spinal Cord Injury

CERTIFICATE EXPIRY DATE: April 4, 2008

DOCUMENTS INCLUDED IN THIS APPROVAL: ~ATE APPROVED: pri14,2007

Document Name	Version	Date
Protocol:		
Research Proposal	1	March 7, 2007
Consent Forms:		
Consent Form	02	March 26, 2007
Questionnaire, Questionnaire Cover Letter, Tests:		
Activity Diary	1	February 5, 2007
Anthropometrics	1	February 5, 2007
Food Diary	1	February 5, 2007
Physical Activity Scale	1	February 5, 2007
Participant Information Questionnaire	1	February 5, 2007
Three Factor Eating Questionnaire	1	February 5, 2007
Participant Information Questionnaire Page 2	1	February 5, 2007
Yale Eating Patterns Questionnaire	1	February 5, 2007
Nutrition Knowledge Questionnaire	1	February 5, 2007
Letter of Initial Contact:		
Letter of Invitation	1	February 5, 2007

The application for ethical review and the document(s) listed above have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board
and signed electronically by one of the following:

Dr. Peter Suedfeld, Chair
Dr. Jim Rupert, Associate Chair
Dr. Arminee Kazanjian, Associate Chair
Dr. M. Judith Lynam, Associate Chair
Dr. Laurie Ford, Associate Chair

https://rise.ubc.ca/rise/Doc/0/CPT24ND356RKR94F7UC86QJDD2/fromString.html

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL- MINIMAL RISK RENEWAL

PRINCIPAL INVESTIGATOR:	DEPARTMENT:	UBC BREB NUMBER:
Susan I. Barr	UBC/Land and Food Systems/Human Nutrition	H07-00011

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
UBC	Vancouver (excludes UBC Hospital)

Other locations where the research will be conducted:
Research will be conducted during national team training sessions, locations will be Vancouver (Lower Mainland), Calgary, Edmonton, Montreal, Toronto. Facilities will be preselected by sport administrators and coaches to meet the needs of the athletes.

CO-INVESTIGATOR(S):
William Sheel
Jennifer Krempien
Andrei V. Krassioukov

SPONSORING AGENCIES:
N/A

PROJECT TITLE:
Nutrient Intakes of Elite Canadian Athletes with a Spinal Cord Injury

EXPIRY DATE OF THIS APPROVAL: March 31, 2009

APPROVAL DATE: March 31, 2008

The Annual Renewal for Study have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board
Dr. M. Judith Lynam, Chair
Dr. Ken Craig, Chair
Dr. Jim Rupert, Associate Chair
Dr. Laurie Ford, Associate Chair
Dr. Daniel Salhani, Associate Chair
Dr. Anita Ho, Associate Chair

The University of British Columbia
Office of Research Services
Behavioural Research Ethics Board
Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

CERTIFICATE OF APPROVAL- MINIMAL RISK RENEWAL

PRINCIPAL INVESTIGATOR:	DEPARTMENT:	UBC BREB NUMBER:
Susan I. Barr	UBC/Land and Food Systems/Human and Animal Nutrition	H07-00011

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
UBC	Vancouver (excludes UBC Hospital)

Other locations where the research will be conducted:
Research will be conducted during national team training sessions, locations will be Vancouver (Lower Mainland), Calgary, Edmonton, Montreal, Toronto. Facilities will be preselected by sport administrators and coaches to meet the needs of the athletes.

CO-INVESTIGATOR(S):
William Sheel
Jennifer Krempien
Andrei V. Krassioukov

SPONSORING AGENCIES:
N/A

PROJECT TITLE:
Nutrient Intakes of Elite Canadian Athletes with a Spinal Cord Injury

EXPIRY DATE OF THIS APPROVAL: February 3, 2010

APPROVAL DATE: February 3, 2009

The Annual Renewal for Study have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval is issued on behalf of the Behavioural Research Ethics Board

Dr. M. Judith Lynam, Chair
Dr. Ken Craig, Chair
Dr. Jim Rupert, Associate Chair
Dr. Laurie Ford, Associate Chair
Dr. Daniel Salhani, Associate Chair
Dr. Anita Ho, Associate Chair

Appendix 2: Consent form

THE UNIVERSITY OF BRITISH COLUMBIA

Department of Food, Nutrition and Health
Faculty of Land and Food Systems
244 – 2205 East Mall
Vancouver, B.C., Canada V6T 1Z4

CONSENT FORM

Title of Study: Nutrient Intakes of Elite Canadian Athletes with a Spinal Cord Injury

Principal Investigator:

Susan I. Barr, PhD, RD, FACSM FDC	Professor, Food, Nutrition and Health University of British Columbia

Co-Investigators:

Jennifer Krempien, BSc (Nutrition), RD	Graduate Student, Human Nutrition University of British Columbia
William Sheel, PhD	Associate Professor, Human Kinetics University of British Columbia
Andrei Krassioukov, MD PhD	Associate Professor, School of Rehabilitation, Department of Medicine University of British Columbia ICORD

Introduction:

This research project relates to the foods consumed by athletes with a spinal cord injury and what factors may influence those food choices. You are being invited to participate in this research study because you 1) are an athlete who is competing at a national or international level and 2) have a spinal cord injury (SCI).

It is entirely up to you whether you want to take part in this study or not. The coaching and training support you usually receive will not be affected in any way by the choice you make about taking part in this study. Your status or participation on the team, or in your sport, will not be affected in any way by taking part in this study. You can change your mind and withdraw from this study at any time.

Background:

Nutrition is an important part of training and performance for athletes who compete at a national or international level. Optimal nutrition may help athletes train harder, more often and improve their results. Many studies have shown this to be true in able-bodied athletes. In athletes with a SCI, how nutrition may affect training and performance is not well understood.

Previous studies have shown that athletes with a SCI eat fewer calories than able-bodied athletes. This study is designed to better understand what foods athletes are eating, why athletes may choose certain foods, and how the level of spinal cord injury itself may influence the amount of food eaten.

Purpose:

The purpose of this project is to better understand the amounts and types of foods and nutrition supplements consumed by athletes with a SCI and what factors may influence those food choices.

Who can participate?

You are being invited to participate because you are a 1) a national caliber athlete, 2) have a spinal cord injury, 3) are currently training 12 or more hours a week, 4) are 19 years or older and meet <u>one of</u> the following criteria:

- a current member of a senior national team
- receiving funding from the Athletes Assistance Program of Sport Canada
- ranked in the top 3 for your sport/discipline in Canada
- ranked in the top 5 for your sport/discipline in the World

Who should not participate?

If you cannot understand written and spoken English, you should not participate.

What does the study involve?

<u>Overview of the Study</u>

This study will take place during a training camp or national team event in Canada. The study involves recording everything you eat and drink for three days and your training activities while you are at the training camp and then once more when you are at home. The study involves completing a booklet of questionnaires asking about your usual daily activities, spinal cord injury, sport, nutrition knowledge and some of your attitudes and beliefs about eating and food.

Your height, weight, skin fold thicknesses and ability to move your arms and legs will also be measured.

<u>Time Requirement</u>

The total time to participate in this study is 3 ½ to 4 hours spread over 6 days, 3 days during the national team event and 3 days when you are at home. It is anticipated that 2 ½ to 3 hours of your time will be required during the national team event and 1 hour when you are at home.

<u>Study Procedures</u>

If you agree to take part in this study, the procedures you can expect will include the following:

Initial Group Meeting:

There will be an initial group meeting to explain and describe the study procedures. If you agree to take part in the study, then a short (30 minute) session will begin describing in more detail the study procedures.

An important part of this study requires you to record everything you eat and drink for a total of 6 days (3 days during training camp and 3 days at home). Detailed and accurate information is very important to this study, so during this initial meeting the student researcher will provide you with some strategies and methods to complete these food diaries.

At this initial meeting, you will be asked to complete a series of questionnaires. The questionnaires will ask questions about your usual activity level, spinal cord injury, training practices, nutrition knowledge and your attitudes and beliefs about food.

The initial meeting and completion of questionnaires is anticipated to take between 60 and 75 minutes.

Food & Activity Diaries:

For three days during training camp, you are requested to record all foods, beverages and supplements that you consume. You are requested to complete a second set of food diaries when you are at home. The student researcher may need to contact you at home after the second set of food diaries to clarify any items.

You are also requested to complete an activity diary for the same days that you record your food diaries. It is anticipated that filling in the activity and food diaries will take 20 minutes each day.

Frequency of your Spasms:

You are requested to assess the number of spasms you experience for one day while you are at the training camp or national team event. At the end of a one hour period, you are asked to rate the number of spasms on a scale of 0 – 4. This will be repeated three times over one day. It is anticipated that this will take a total of 5 minutes.

Measurements:

Your height and weight will be measured. Your body fat will also be measured using skin fold calipers. Four locations on your upper body will be tested by pinching a sample of skin and the fat beneath the skin and the thickness measured using skin fold calipers.

The ability to move your arms and legs will also be observed to better understand your spinal cord injury. You will be asked to move your arms and/or legs against slight pressure to test the strength in your extremities.

The measurements will be taken in a private setting. If you would feel more comfortable, you may have a coach, staff member or fellow athlete with you while the measurements are taken. The measurements will take 30 minutes.

Further Body Composition Assessment:

You may be approached in the future to ask if you are interested in participating in a more detailed assessment of your body composition using dual-energy x-ray absorptiometry. At that time the risks and benefits would be explained in detail, and your written informed consent would be obtained should you choose to participate in this additional assessment of your body composition.

Risk and Potential Benefits:

There are no potential risks associated with participating in this study. There may be a slight pinching sensation with the skinfold measurement. Also, there may be some questions in the questionnaires that you might not want to answer. You can refuse to answer any questions if you wish to do so.

There is likely to be no direct benefit to you associated with taking part in this research. If desired, a detailed analysis of the composition of your diet based on your food diaries will be provided to you.

Consent:

It is entirely up to you whether you want to take part in this study or not. The coaching and training support that you usually get will not be changed in any way by the choice you make about taking part in this study. Your status on the team or within your sport will not be affected by taking part in this study or not. You can change your mind and withdraw from this study at any time without providing any reasons for your decision. By signing this consent form, you are agreeing to participate in this study and acknowledge that you have received a copy of this consent form for your own records. By signing this consent form, you do not waive any of your legal rights against the sponsor, investigators, or anyone else.

Study Costs:

There are no costs associated with this study. A self addressed envelope will be provided to you to return your activity and food diaries. You will not be paid for participating in this study.

Confidentiality:

Your confidentiality will be respected. No information that discloses your identity will be released or published without your specific consent to the disclosure. However, research records identifying you may be inspected in the presence of the Investigator or his or her designate by representatives of the UBC Research Ethics Board for the purpose of monitoring the research or by the graduate student's Thesis committee. Data collected will be stored in the principal investigator's office in a locked cabinet to maintain confidentiality. However, no records which identify you by name or initials will be allowed to leave the Investigators' offices.

If you have any questions regarding this study or desire further information you may contact the principal investigator, Susan Bar

If you have any concerns about your rights as a research subject and/or your experiences while participating in this study, you may contact the 'Research Subject Information Line' at the University of British Columbia, Office of Research Services at 604-822-8598.

I have read the above information and I have had a chance to ask any questions about the study and my involvement. I understand what I have to do and what will happen if I take part in this study. I freely choose to take part in this study and I have a signed and dated copy of the consent form.

Printed name of subject	Signature of subject
Principal Investigator or designate	Signature of PI or designate
Date	

Would you like to receive the results of this study by mail?

- ☐ Yes, I would like to receive the results of this study
- ☐ No, I would not like to receive the results of this study

Signature of subject	Date

Appendix 3: Letter of invitation

THE UNIVERSITY OF BRITISH COLUMBIA

Department of Food, Nutrition and Health
Faculty of Land and Food Systems
244 – 2205 East Mall
Vancouver, BC Canada V6T 1Z4

Mr. Joe Smith
Head Coach, Sport
Address
City, Postal Code

Date

Dear Mr. Smith,

I am writing to request your permission to contact athletes involved with your program to participate in a study on "Nutrient Intakes of Elite Canadian Athletes with a Spinal Cord Injury." The study is being conducted as a component of the requirements for a Masters of Science (Human Nutrition) degree at the University of British Columbia.

To conduct this study, we are requesting permission for the graduate student investigator (Jennifer Krempien) to attend a national team event such as a training or selection camp. Recruitment of athletes and data collection would take place during an event when the team is together. It is important for Jennifer to have direct contact with the athletes to collect data and complete this study. There will be no additional cost to your program or the athletes.

A brief description of the study procedures is enclosed for your consideration.

If you are interested in facilitating your athletes' participating in this study or would like to learn more, please contact the graduate student investigator, Jennifer Krempien by telephone at Jennifer will try to contact you directly within the next week or two to discuss the possibility of recruiting athletes in your program to this study.

Thank you for considering this request.

Sincerely,

Susan Barr, PhD, RD

Jennifer Krempien, B.Sc., RD

Version 1: 2007/02/05

Nutrient Intakes of Elite Canadian Athletes with a Spinal Cord Injury

We are inviting athletes with a spinal cord injury (SCI) who are 19 years of age or older and competing at a national or international level to participate in this research study.
The study is being conducted by Dr. Susan Barr, Professor of Nutrition at the University of British Columbia, and Ms. Jennifer Krempien, Registered Dietitian and graduate student in the Human Nutrition program at UBC.

The **purpose of this study** is to understand the amount and types of foods and supplements national team athletes with a spinal cord injury are consuming and what factors may be influencing those choices.

What does the study involves? Approximately 3 ½ - 4 hours per athlete spread over 6 days.

If an athlete chooses to be involved in this study, he or she will be asked to record all foods and nutrition supplements consumed during three consecutive days during the training camp or national team event. The athlete will also be asked to record all activity for those same three days.

During the training camp or national team event, measurements of height, weight and four upper body skinfold sites will be measured for each athlete. The ability to move arms and legs against slight resistance will also be tested to better describe the athlete's SCI.

Athletes who choose to be involved in the study will be asked to complete a series of questionnaires that will ask questions about the athlete's usual activity level, spinal cord injury, training practices, nutrition knowledge and their attitudes and beliefs about food.

These activities will require approximately 2 ½ - 3 hours of each athlete's time spread over the duration of the training camp. The athletes' schedule and team commitments will be honoured and every effort will be made to ensure participation in the study does not detract from the team event.

When the athlete returns home, he or she will be requested to complete a second set of three day food and activity records and return them to the student researcher by mail, email or fax. This will take an additional 60 minutes spread over 3 days.

After completing the study, each athlete will be provided with a detailed nutrient analysis of the food records.

If you are interested in facilitating your athletes' participation in this study or would like to learn more, please contact the graduate student investigator **Jennifer Krempien** by telephone at **(778) 772-2217 or** by email at **jkrempien@gmail.com.**

All forms and responses will be kept completely confidential.

Version 1: 2007/02/05

Appendix 4: Details of recruitment

Sport	Eligibility [a]		Coach Response		Athlete Contact			
	Y/N	Comments	Contact Method	Reason for not participating in study.	Potential Athletes	Met in person	Agreed to participate	Completed study
Summer Sports								
Archery	N	Did not meet sport eligibility requirements.						
Athletics	Y		email phone	most athletes training out of country	20	2	2	2
Boccia	N	No athletes with SCI						
Cycling	Y	Recently added SCI class (Athens 2004)	email phone	only one potential athlete	1	0	0	0
Equestrian	N	Did not meet sport eligibility requirements						
Goalball	N	No athletes with SCI						
Judo	N	No athletes with SCI						
Powerlifting	N	Did not meet sport eligibility requirements						
Rowing	Y		email phone	national team event scheduling	1	0	0	0
Sailing	N	Did not meet sport eligibility requirements						
Shooting	N	Did not meet sport eligibility requirements						
Sitting Volleyball	N	No athletes with SCI						

Sport	Eligibility [a]		Coach Response		Athlete Contact			
	Y/N	Comments	Contact Method	Reason for not participating in study.	Potential Athletes	Met in person	Agreed to participate	Completed study
Summer Sports								
Swimming	Y		email phone	No athletes with SCI	0	0	0	0
Table Tennis	N	Did not meet sport eligibility requirements						
Wheelchair Basketball	Y		email phone		12	12	8	7
Wheelchair Fencing	N	Did not meet sport eligibility requirements						
Wheelchair Rugby	Y		email person		24	24	21	20
Wheelchair Tennis	Y		email person	athletes not at domestic NT event together	5	0	0	0
Winter Sports								
Alpine Skiing	Y		email phone		3	3	3	3
Biathlon & Cross-Country Skiing	Y	contacted as one sport	email phone	No reason provided	4	0	0	0
Sledge Hockey	Y		email phone	conflict with World Championships preparation	3	0	0	0
Wheelchair Curling	Y		email phone	did not want athletes over burdened	3	0	0	0
				Totals:	76	41	34	32

[a] Sports were not eligible if minimum physical training of 12 hours per week was not a sport requirement

Notes:

54% (41/76) of potential athletes with SCI were approached in person to participate in the study

78% (32/41) of athletes met in person completed all required components of the study

Appendix 5: Participant questionnaire

PARTICIPANT INFORMATION

Age: _____ Gender: ☐ Female ☐ Male

City of Primary Residence: ____

Province of Primary Residence: ____

Mailing Address: ____

Email Address: ____

Phone Number: ____

Sport Information

Sport: ____

Discipline/Event: ____

Are you funded by Sport Canada AAP? ☐ Yes ☐ No

How many years have you been on the senior National team? ______________________

How many Paralympic Games have you participated in? ___________________________

How many World Championships have you participated in? ________________________

What is your current International ranking?__________________________________

Training Information

How many hours per week do you, on average, engage in physical training for your sport: ___
Of that time:

1. How many hours per week do you engage in aerobic conditioning? ______________
2. How many hours per week do you engage in strength training? _________________
3. How many hours per week do you engage in sport specific training? ____________

Do you competitively or recreationally participate in other sports? ☐ Yes ☐ No
(If yes, which sports?)

____
____
____
____
____

Version 2: 2007/04/26

Nutrition Goals

Are you currently following a modified diet or nutrition plan prescribed by a physician, dietitian, coach or trainer? ☐ Yes ☐ No

If yes, please describe.

____
____
____
____
____

Are you currently trying to change your body weight or composition: ☐ Yes ☐ No

If yes, are you trying to: (tick all that apply)

☐ gain weight
☐ lose weight
☐ gain muscle mass
☐ decrease muscle mass
☐ gain fat mass
☐ lose fat mass
☐ other ____
____
____
____
____

Version 2: 2007/04/26

Spinal Cord Injury Details

Year of Injury: ______________________

Level of SCI: ______________________

Please circle the phrase which best describes your SCI:

complete quadriplegic | incomplete quadriplegic

complete paraplegic | incomplete paraplegic

What is your sport classification: ______________________________

Cause of SCI: (tick one)

☐ congenital (e.g. Spina Bifida) ☐ other ☐ trauma (e.g. motor vehicle accident)

Have you had an ASIA assessment performed by a physician in the last 2 years?

☐ Yes ☐ No If yes, what was your score? ______________________

Do you have any other medical conditions?

Diabetes ☐ Yes ☐ No

Thyroid Condition ☐ Yes ☐ No

Do you take any medications: (if yes, list) ☐ Yes ☐ No

____

____

____

Version 2: 2007/04/26

Appendix 6: Physical activity log with rate of perceived exertion scale

Note: Instruction sheet and sample of one day of activity log included in appendix. Athletes provided with 3 days of activity logs to record activity.

Instructions for Keeping Your Activity Log

We request that you keep detailed activity logs for the same days that you keep your food diary. For each training activity, please record the time involved in the activity, your perceived rate of exertion and a brief description of the activity.

For each day, please record all physical activity that you participate in. This includes all planned and structured workouts such as team practice, strength workout or any type of cross training. While doing any physical activity, we want you to rate your perception of exertion. It may be necessary to divide the training session into shorter time periods. For example, warm-up activities will have a different rate of perceived exertion than sprints.

For game related activities, please estimate your time engaged in the activity. For example, if you played in a game which lasted 60 minutes and you were on the court competing for 25 minutes you would enter 25 minutes of activity at your perceived level of exertion.

This feeling should reflect how heavy and strenuous the exercise feels to you, combining all sensations and feelings of physical stress, effort, and fatigue. Do not concern yourself with any one factor such as arm pain or shortness of breath, but try to focus on your total feeling of exertion.

Look at the rating scale below while you are engaging in an activity; it ranges from 6 to 20, where 6 means, "no exertion at all" and 20 means "maximal exertion". Choose the number from below that best describes your level of exertion. This will give you a good idea of the intensity level of your activity.

Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Your own feeling of effort and exertion is important, not how it compares to others. Look at the scales and the expressions and then give a number.

6 no exertion at all
7 extremely light (7.5)
8
9 very light
10
11 light
12
13 somewhat hard
14
15 hard (heavy)
16
17 very hard
18
19 extremely hard
20 maximal exertion

Explanation of Scales and Expressions

9 on the scale is "very light" exercise. For a healthy person, it is like wheeling slowly at his or her own pace for some minutes.

13 on the scale is "somewhat hard" exercise, but it still feels OK to continue.

17 "Very hard" is very strenuous. A healthy person can still go on, but he or she really has to push him or herself. It feels very heavy, and the person is very tired.

19 on the scale is an extremely strenuous exercise level. For most people this is the most strenuous exercise they have ever experienced.

(sample)

Time (minutes)	Rate of Perceived Exertion	Activity Description
15 min	10	warm up for practice, light wheeling, shooting and dynamic stretching
90 min	14	basketball practice: scrimmage and high intensity shooting drills
10 min	9	cool down, wheeling and stretching
30 min	17	interval wheeling (1 minute and 30 second working sets)

Subject Code: ____________ Name: ________________________________

Activity Log Date: ________________________ Day One

Time	Rate of Perceived Exertion	Activity Description

Version 1: 2007/02/05 Page 1 of 4

Appendix 7: Physical Activity Scale for Individuals with a Physical Disability

Physical Activity Scale for Persons with Physical Disabilities

This questionnaire is about your current level of physical activity and exercise. Please remember there are no right or wrong answers. We simply need to assess your current level of activity.

Leisure Time Activity

1. During the past 7 days how often did you engage in *stationary* activities such as reading, watching T.V., computer games, or doing handcrafts?
   - ☐ Never (go to question #2)
   - ☐ Seldom (1 – 2 days)
   - ☐ Sometimes (3 – 4 days)
   - ☐ Often (5 – 7 days)

   What were these activities? ______________________________

   On average, how many hours per day did you spend in these *stationary* activities?
   - ☐ Less than 1 hour
   - ☐ 1 but less than 2 hours
   - ☐ 2 – 4 hours
   - ☐ More than 4 hours

2. During the past 7 days, how often did you *walk, wheel, push outside* your home *other than specifically for exercise*. For example: getting to work or class, walking the dog, shopping, or other errands
   - ☐ Never (go to question #3)
   - ☐ Seldom (1 – 2 days)
   - ☐ Sometimes (3 – 4 days)
   - ☐ Often (5 – 7 days)

   What were these activities? ______________________________

   On average, how many hours per day did you spend wheeling or pushing outside your home?
   - ☐ Less than 1 hour
   - ☐ 1 but less than 2 hours
   - ☐ 2 – 4 hours
   - ☐ More than 4 hours

3. During the past 7 days, how often did you engage in *light sport or recreational* activities such as bowling, golf with a cart, hunting or fishing, darts, billiards or pool, therapeutic exercise (physical or occupational therapy, stretching, use of a standing frame) or other similar activities?
   - ☐ Never (go to question #4)
   - ☐ Seldom (1 – 2 days)
   - ☐ Sometimes (3 – 4 days)
   - ☐ Often (5 – 7 days)

   What were these activities? ______________________________

   On average, how many hours per day did you spend in these *light sport or recreational* activities?
   - ☐ Less than 1 hour
   - ☐ 1 but less than 2 hours
   - ☐ 2 – 4 hours
   - ☐ More than 4 hours

4. During the past 7 days, how often did you engage in *moderate sport and recreational* activities such as doubles tennis, softball, golf without a cart, ballroom dancing, wheeling or pushing for pleasure or other similar activities?

- ☐ Never (go to question #5)
- ☐ Seldom (1 – 2 days)
- ☐ Sometimes (3 – 4 days)
- ☐ Often (5 – 7 days)

What were these activities? ______________________

On average, how many hours per day did you spend in these *moderate sport and recreational* activities?

- ☐ Less than 1 hour
- ☐ 1 but less than 2 hours
- ☐ 2 – 4 hours
- ☐ More than 4 hours

5. During the past 7 days, how often did you engage in *strenuous sport and recreational* activities such as jogging, wheelchair racing (training), off-road pushing, swimming, aerobic dance, arm cranking, cycling (hand or leg), singles tennis, rugby, basketball, walking with crutches and braces, or other similar activities?

- ☐ Never (go to question #6)
- ☐ Seldom (1 – 2 days)
- ☐ Sometimes (3 – 4 days)
- ☐ Often (5 – 7 days)

What were these activities? ______________________

On average, how many hours per day did you spend in these *strenuous sport or recreational* activities?

- ☐ Less than 1 hour
- ☐ 1 but less than 2 hours
- ☐ 2 – 4 hours
- ☐ More than 4 hours

6. During the past 7 days, how often did you do any exercise specifically to *increase muscle strength and endurance* such as lifting weights, push-ups, pull-ups, dips, or wheelchair push-ups, etc?

- ☐ Never (go to question #7)
- ☐ Seldom (1 – 2 days)
- ☐ Sometimes (3 – 4 days)
- ☐ Often (5 – 7 days)

What were these activities? ______________________

On average, how many hours per day did you spend in these *increase muscle strength and endurance*?

- ☐ Less than 1 hour
- ☐ 1 but less than 2 hours
- ☐ 2 – 4 hours
- ☐ More than 4 hours

Household Activity

7. During the past 7 days, how often have you done any *light housework*, such as dusting, sweeping floors or washing dishes?

- ☐ Never (go to question #8)
- ☐ Seldom (1 – 2 days)
- ☐ Sometimes (3 – 4 days)
- ☐ Often (5 – 7 days)

What were these activities? ______________________

On average, how many hours per day did you spend doing *light housework*?

- ☐ Less than 1 hour
- ☐ 1 but less than 2 hours
- ☐ 2 – 4 hours
- ☐ More than 4 hours

8. During the past 7 days, how often have you done any *heavy housework or chores*, such as vacuuming, scrubbing floors, washing windows, washing walls, etc?

- ☐ Never (go to question #9)
- ☐ Seldom (1 – 2 days)
- ☐ Sometimes (3 – 4 days)
- ☐ Often (5 – 7 days)

What were these activities? ______________________________

On average, how many hours per day did you spend doing *heavy housework or chores*?

- ☐ Less than 1 hour
- ☐ 1 but less than 2 hours
- ☐ 2 – 4 hours
- ☐ More than 4 hours

9. During the past 7 days, how often have you done *home repairs* like carpentry, painting, furniture refinishing, electrical work, etc.?

- ☐ Never (go to question #10)
- ☐ Seldom (1 – 2 days)
- ☐ Sometimes (3 – 4 days)
- ☐ Often (5 – 7 days)

What were these activities? ______________________________

On average, how many hours per day did you spend doing *home repairs*?

- ☐ Less than 1 hour
- ☐ 1 but less than 2 hours
- ☐ 2 – 4 hours
- ☐ More than 4 hours

10. During the past 7 days, how often have you done *lawn work or yard care* including mowing, leaf or snow removal, tree or bush trimming, or wood chopping, etc?

- ☐ Never (go to question #11)
- ☐ Seldom (1 – 2 days)
- ☐ Sometimes (3 – 4 days)
- ☐ Often (5 – 7 days)

What were these activities? ______________________________

On average, how many hours per day did you spend doing *lawn work*?

- ☐ Less than 1 hour
- ☐ 1 but less than 2 hours
- ☐ 2 – 4 hours
- ☐ More than 4 hours

11. During the past 7 days, how often have you done outdoor gardening such as planting seeds, weeding, etc?

- ☐ Never (go to question #12)
- ☐ Seldom (1 – 2 days)
- ☐ Sometimes (3 – 4 days)
- ☐ Often (5 – 7 days)

What were these activities? ____________________

On average, how many hours per day did you spend doing *outdoor gardening*?

- ☐ Less than 1 hour
- ☐ 1 but less than 2 hours
- ☐ 2 – 4 hours
- ☐ More than 4 hours

12. During the past 7 days, how often did you *care for another person*, such as children, a dependent spouse, or another adult?

- ☐ Never (go to question #13)
- ☐ Seldom (1 – 2 days)
- ☐ Sometimes (3 – 4 days)
- ☐ Often (5 – 7 days)

What were these activities? ____________________

On average, how many hours per day did you spend *caring for another person*?

- ☐ Less than 1 hour
- ☐ 1 but less than 2 hours
- ☐ 2 – 4 hours
- ☐ More than 4 hours

Work-Related Activity

13. During the past 7 days, how often did you *work physically for pay or as a volunteer*? (Exclude work that mainly involved sitting with slight arm movement such as light office work, computer work, light assembly line work, driving bus or van, etc.)

- ☐ Never (go to end)
- ☐ Seldom (1 – 2 days)
- ☐ Sometimes (3 – 4 days)
- ☐ Often (5 – 7 days)

What were these activities? ____________________

On average, how many hours per day did you spend *working physically for pay or as a volunteer?*

- ☐ Less than 1 hour
- ☐ 1 but less than 2 hours
- ☐ 5 but less than 8 hours
- ☐ 8 hours or more

Adapted From: Washburn RA, Zhu W, McAuley E, Frogley M, Figoni SF. The Physical Activity Scale for Individuals with Physical Disabilities: development and evaluation. Arch Phys Med Rehabil 2002;83:193-200.

Appendix 8: Food diary with instructions

Note: Instruction sheet with portion estimation guide and of one day of food diary is included in this appendix. Athletes provided with 3 days of food diaries to record intake.

Subject Code: ________ Name: ________________________

Instructions for Keeping Accurate Food Intake Records

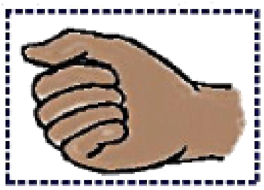
Analysis of your dietary intake is an important component of this study. It is important to continue to eat in your usual manner. Please do not adjust the amounts or types of foods you would typically consume during the day.

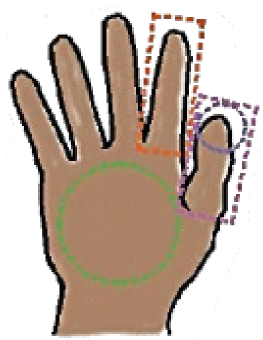
To assist you with keeping accurate food intake records, some instructions are included below.

- Record everything you eat and drink for three consecutive days.
- For accuracy, it is best to record each meal or snack immediately after it is eaten.
- Be sure to include beverages: water, coffee, tea, soda, milk, juice.
- If additional space is required for the same day, continue onto the back of the page.
- Record brand names of products, if known.
- If eating out, record foods eaten as accurately as possible, including the name of the establishment and name of menu item.
- Specify the method of preparation. Examples include: baked, broiled, deep fried, grilled, BBQ, steamed, pan-fried, etc.
- Describe all foods as fully as possible. Example: peanut butter sandwich (2 slices 100% whole wheat bread, 1 ½ TBSP smooth peanut butter, ½ banana sliced).
- List all ingredients for sandwiches, casseroles, and other mixed dishes.
- Record exact amounts when known. Specify weight, volume or dimensions. Example: 1 piece banana bread, 1" by 2" by 4"
- Use household measuring cups or spoons to estimate portions.
- Include all additions to food at the table, such as salt, sugar, or milk.
- Record all dietary supplements (vitamins, minerals, etc.) and nutritional supplements (protein powders, carbohydrate gels, sports drinks or powders, etc.). Record brand names and amounts. Attach product label if possible.

- **FINGER Length**
- the diameter of a medium sized piece of fruit

- **FIST Volume**
- 1 cup (1 cup cooked or raw vegetables, 1 cup of cooked pasta)





- **THUMB Tip**
- 1 tsp or 5 ml (1 tsp of margarine)

- **THUMB Volume**
- 2 tbsp, 30 ml or 1 ounce (2 tbsp of peanut butter)

- **PALM**
- 100 g (3 ounces of meat, fish or poultry
  30 g of nuts, snack chips (the amount that fits in your palm)

"Handy" Ways to Estimate your Portions

To help you accurately complete your food diary, we have provided you with this handy reference to be able to consistently estimate how much of a food you are consuming.

Your fist, palm of your hand, thumb, and thumb-tip volume, and finger length act as handy references.

Here are some examples on how to use your hand to estimate portions:

- 15 grams of ½ ounce of cheese is about the size of your thumb
- your fist, about one cup is 1 cup cooked vegetables, cooked pasta or cold cereals
- your full thumb is about 30 ml or 2 Tbsp of cream cheese, peanut butter
- your thumb tip, is 1 tsp or a serving of butter or margarine
- a medium sized fresh fruit can be held in your hand, like a tennis ball, with a diameter about the length of your index finger
- A hamburger patty, or other meats, fish or poultry pieces that fit in the palm of your hand are 100g, or the size of a deck of cards
- Cover your palm with nuts or potato chips to estimate 30 grams

Adapted from: Dr. Barracos, Jane Kirby, RD.
http://www.ahs.uwaterloo.ca/˜kh346/html/handy.htm

Subject Code: ______________ Name: ______________________

Food Diary Date: ____________________ **Day One**

Time	Amount	Food/Drink	Description

Supplements, Vitamins, Minerals

Time	Amount	Description

Appendix 9: Nutrition Knowledge Questionnaire

Nutrition Knowledge Survey

This is a survey, not a test. Your answers will help identify which dietary advice people find confusing.

- It is important that you complete it by yourself.
- Your answers will remain confidential.
- If you do not know the answer, mark "not sure" rather than guess.

The first few items are about what advice you think experts are giving us.

1. Do you think health experts recommend that people should be eating more, the same amount, or less of the following foods? (tick one box per food)

	More	Same	Less	Not Sure
vegetables............................				
sugary foods........................				
meat......................................				
starchy foods........................				
fatty foods............................				
high fibre foods....................				
fruit..				
salty foods............................				

2. How many servings of fruit and vegetables a day do you think experts are advising people to eat? (one serving could be, for example, an apple or a handful of chopped carrots)

____

3. Which fat do experts say is most important for people to cut down on? (tick one)

☐ monounsaturated fat ☐ polyunsaturated fat ☐ saturated fat ☐ not sure

4. What version of dairy foods do experts say people should eat? (tick one)

☐ full fat ☐ lower fat ☐ mixture of full fat and lower fat

☐ neither full or lower fat, dairy foods should be cut out ☐ not sure

Foods are often classified into groups or categories. We are interested to see whether people are aware of what foods fit into these groups.

1. Do you think these are high or low in added sugar? (tick one box per food)

	High	Low	Not Sure
bananas................................			
unflavoured yogurt...............			
ice-cream..............................			
orange soda..........................			
tomato ketchup.....................			
canned fruit in juice.............			

2. Do you think these are high or low in **fat**? (tick one box per food)

	High	Low	Not Sure
pasta (without sauce)...........			
baked beans..........................			
luncheon meat.......................			
caesar salad..........................			
honey......................................			
boiled egg..............................			
nuts...			
bread......................................			
cottage cheese......................			
soft-tub margarine................			

3. Do you think these foods fit into the **grains and cereals** group? (tick one box per food)

	Yes	No	Not Sure
cheese....................................			
pasta......................................			
butter.....................................			
nuts..			
rice...			
porridge..................................			

4. Do you think these are high or low in **salt**? (tick one box per food)

	High	Low	Not Sure
sausages................................			
pasta......................................			
deli meat................................			
red meat.................................			
frozen vegetables..................			
cheese....................................			

5. Do you think these are high or low in **protein**? (tick one box per food)

	High	Low	Not Sure
chicken..................................			
cheese....................................			
fruit...			
baked beans..........................			
butter.....................................			
cream.....................................			

6. Do you think these are high or low in **fibre or roughage**? (tick one box per food)

	High	Low	Not Sure
cornflakes..............................			
bananas.................................			
eggs.......................................			
red meat.................................			
broccoli..................................			
nuts..			
fish...			
baked potato with skin.........			
chicken..................................			
baked beans..........................			

7. Do you think these fatty foods are high or low in saturated fat? (tick one box per food)

	High	Low	Not Sure
salmon..................................			
whole milk............................			
olive oil.................................			
red meat...............................			
soft-tub margarine...............			
chocolate..............................			

8. Some foods contain a lot of fat but no cholesterol. (tick one)

☐agree ☐disagree ☐not sure

9. Do you think these foods are a healthy alternative to red meat? (tick one box per food)

	Yes	No	Not Sure
liver pate...............................			
luncheon meat......................			
baked beans.........................			
nuts.......................................			
low fat cheese.....................			
quiche...................................			

10. A glass of unsweetened fruit juice counts as a serving of fruit. (tick one)

☐agree ☐disagree ☐not sure

11. Saturated fats are mainly found in: (tick one)

☐vegetable oils ☐dairy products ☐both vegetable oils and dairy products ☐not sure

12. Brown sugar is a healthy alternative to white sugar. (tick one)

☐agree ☐disagree ☐not sure

13. There is more protein in a glass of whole milk than in a glass of skimmed milk. (tick one)

☐agree ☐disagree ☐not sure

14. Polyunsaturated margarine contains less fat than butter. (tick one)

☐agree ☐disagree ☐not sure

15. Which of these breads contain the most vitamins and minerals? (tick one)

☐white ☐brown ☐wholegrain ☐not sure

16. Which do you think is higher in calories: butter or regular margarine? (tick one)

☐butter ☐regular margarine ☐both the same ☐not sure

17. A type of oil which contains mostly monounsaturated fat is: (tick one)

☐coconut oil ☐sunflower oil ☐olive oil ☐palm oil ☐not sure

18. There is more calcium in a glass of whole milk than a glass of skimmed milk. (tick one)

☐agree ☐disagree ☐not sure

19. Which one of the following has the most calories for the same weight? (tick one)

☐sugar ☐starchy foods ☐fibre or roughage ☐fat ☐not sure

20. Harder fats contain more: (tick one)

☐monounsaturates ☐polyunsaturates ☐saturates ☐not sure

21. Polyunsaturated fats are mainly found in: (tick one)

☐vegetable oils ☐dairy products ☐both vegetable oils and dairy products ☐not sure

The next few items are about choosing foods. Please answer what is being asked and not whether you like or dislike the food! For example, suppose you were asked. . . . 'If a person wanted to cut down on fat, which cheese would be best to eat?' (a) cheddar cheese (b) camembert (c) cream cheese (d) cottage cheese
If you didn't like cottage cheese, but knew it was the right answer, you would still tick cottage cheese.

1. Which would be the best choice for a low fat, high fibre snack? (tick one)

☐light strawberry yogurt ☐raisins ☐granola bar ☐whole wheat crackers & cheddar cheese ☐not sure

2. Which would be the best choice for a low fat, high fibre light meal? (tick one)

☐grilled chicken ☐cheese on whole wheat toast ☐beans on whole wheat toast ☐quiche ☐not sure

3. Which kind of sandwich do you think is healthier: (tick one)

☐two **thick** slices of bread with a **thin** slice of cheddar cheese ☐not sure

☐two **thin** slices of bread with a **thick** slice of cheddar cheese

4. Many people eat spaghetti Bolognese (pasta with a tomato and meat sauce). Which do you think is healthier? (tick one)

☐a **large** amount of pasta with a **little** sauce on top ☐not sure

☐a **small** amount of pasta with a **lot** of sauce on top

5. If a person wanted to reduce the amount of fat in their diet, which would be the best choice? (tick one)

☐steak, grilled ☐sausages, grilled ☐turkey, grilled ☐pork chop, grilled ☐not sure

6. If a person wanted to reduce the amount of fat in their diet, but didn't want to give up French fries, which one would be the best choice? (tick one)

☐thick cut fires ☐thin cut fries ☐crinkle cut fries ☐not sure

7. If a person felt like something sweet, but was trying to cut down on added sugar, which would be the best choice? (tick one)

☐ honey on toast ☐ a cereal snack bar ☐ plain digestive cookie ☐ banana with plain yogurt ☐ not sure

8. Which of these would be the healthiest dessert? (tick one)

☐ baked apple pie ☐ wholegrain crackers & cheddar cheese

☐ carrot cake with cream cheese topping ☐ strawberry yogurt ☐ not sure

9. Which cheese would be the best choice as a lower fat option?

☐ plain cream cheese ☐ edam ☐ cheddar ☐ swiss ☐ not sure

10. If a person wanted to reduce the amount of salt in their diet, which would be the best choice?

☐ ready made frozen dinner ☐ baked ham with vegetables ☐ not sure

☐ mushroom omelet ☐ stir fry vegetables with soy sauce

This section is about health problems or diseases

1. Are you aware of any major health problems or diseases that are related to a low intake of fruit and vegetables?

☐ yes ☐ no ☐ not sure

If yes, what diseases or health problems do you think are related to a low intake of fruit and vegetables?

___

2. Are you aware of any major health problems or diseases that are related to a low intake of fibre?

☐ yes ☐ no ☐ not sure

If yes, what disease or health problems do you think are related to fibre?

___

3. Are you aware of any major health problems or diseases that are related to how much sugar people eat?

☐ yes ☐ no ☐ not sure

If yes, what diseases or health problems do you think are related to sugar?

___

4. Are you aware of any major health problems or diseases that are related to how much salt or sodium people eat?

☐ yes ☐ no ☐ not sure

If yes, what diseases or health problems do you think are related to salt?

___

5. Are you aware of any major health problems or diseases that are related to the amount of fat people eat:

☐yes ☐no ☐not sure

If yes, what diseases or health problems do you think are related to fat?

6. Do you think these help to reduce the chances of getting certain kinds of cancer? (answer each one)

	Yes	No	Not Sure
eating more fibre..			
eating less sugar..			
eating less fruit...			
eating less salt..			
eating more fruit and vegetables.............			
eating less preservatives/additives.........			

7. Do you think these help prevent heart disease? (answer each one)

	Yes	No	Not Sure
eating more fibre..			
eating less saturated fat............................			
eating less salt..			
eating more fruit and vegetables..............			
eating less preservatives/additives.........			

8. Which one of these is more likely to raise people's blood cholesterol level? (tick one)

☐antioxidants ☐polyunsaturated fats ☐saturated fats ☐cholesterol in the diet ☐not sure

9. Have you heard of antioxidant vitamins?

☐yes ☐no

10. If YES to question 9, do you think these are antioxidant vitamins? (answer each one)

	Yes	No	Not Sure
Vitamin A...............................			
B Complex Vitamins............			
Vitamin C...............................			
Vitamin D...............................			
Vitamin E...............................			
Vitamin K...............................			

THE END

Adapted From: Parmenter K, Wardle J. Development of a General Nutrition Knowledge Questionnaire for Adults. Eur J Clin Nutr 1999;53:2980308

Appendix 10: Canadian Community Health Survey – summary tables

Nutrient Intakes from Food, Canadian Population Data

Canadian Community Health Survey Cycle 2.2, Nutrition (2004)
Canada excluding territories

		Men		Women	
		19 - 30 yr n=1804	31 - 50 yr n=2596	19 - 30 yr n=1854	31 - 50 yr n=2686
Macronutrients	**Units**				
Total energy intake	kcal/d	2737 (47)	2510 (42)	1902 (34)	1850 (30)
Total energy intake from fat	%	31.2 (0.4)	31.6 (0.4)	30.5 (0.4)	32.2 (0.3)
% within AMDR	%(SE)	81.7 (4.5)	71.2 (3.4)	88.4 (4.1)	71.7 (3.4)
Fat	g/d	97 (2)	92 (2)	67 (2)	69 (2)
Total energy intake from protein	%	15.6 (0.2)	16.9 (0.2)	15.5 (0.2)	16.6 (0.3)
% within AMDR	%(SE)	99.1 (0.6)	99.8 (0.2)	99.2 (0.5)	99.3 (0.4)
Protein	g/d	107 (2)	105 (2)	73 (2)	76 (2)
Total energy intake from carbohydrate	%	49.6 (0.5)	47.8 (0.5)	52.0 (0.5)	48.6 (0.5)
% within AMDR	%(SE)	76.4 (3.2)	64.6 (3.4)	90.9 (2.9)	70.3 (3.2)
Carbohydrate	g/d	339 (6)	301 (6)	247 (5)	225 (4)
% less than EAR	%(SE)	<3	<3	<3	1.5 (0.4) E
Total dietary fibre	g/d	19.4 (0.5)	19.1 (0.4)	14.5 (0.3)	15.7 (0.3)
%>AI	%(SE)	<3	2.0 (0.6)	F	8.7 (1.5)

Data source: Statistics Canada, Canadian Community Health Survey, Cycle 2.2, Nutrition (2004) - Share File

Symbol Legend

E Data with a coefficient of variation (CV) from 16.6% to 33.3%; interpret with caution.

<3 Data with a coefficient of variation (CV) greater than 33.3% with a 95% confidence interval entirely between 0 and 3%; interpret with caution.

F Data with a coefficient of variation (CV) greater than 33.3% with a 95% confidence interval not entirely between 0 and 3%; suppressed due to extreme sampling variability.

Nutrient Intakes from Food, Canadian Population Data

Canadian Community Health Survey Cycle 2.2, Nutrition (2004)

Canada excluding territories

		Men		Women	
		19 - 30 yr n=1804	31 - 50 yr n=2596	19 - 30 yr n=1854	31 - 50 yr n=2686
Vitamins					
Vitamin C	mg/d	158 (7)	127 (4)	133 (5)	117 (4)
% less than EAR	%(SE)	13.7 (3.2) E	24.4 (3.0)	10.8 (2.5) E	19.9 (2.2)
Folate	DFE/d	587 (14)	528 (11)	415 (10)	423 (9)
% less than EAR	%(SE)	<3	F	18.8 (3.7) E	19.6 (3.3) E
Niacin	NE/d	49.7 (1.1)	48.4 (0.9)	33.1 (0.7)	36.0 (0.8)
% less than EAR	%(SE)	<3	0.0 (0.0)	<3	<3
Riboflavin	mg/d	2.41 (0.06)	2.24 (0.05)	1.72 (0.04)	1.74 (0.03)
% less than EAR	%(SE)	<3	1.7 (0.6) E	F	2.8 (0.7) E
Thiamin	mg/d	2.14 (0.05)	2.04 (0.05)	1.48 (0.03)	1.48 (0.03)
% less than EAR	%(SE)	F	F	F	7.9 (1.5) E
Vitamin B6	mg/d	2.29 (0.06)	2.23 (0.05)	1.59 (0.04)	1.65 (0.03)
% less than EAR	%(SE)	F	F	9.6 (3.2) E	15.9 (1.9)
Vitamin B12	mcg/d	5.4 (0.3)	5.3 (0.2)	3.4 (0.2)	3.9 (0.3)
% less than EAR	%(SE)	F	F	F	13.7 (3.2) E
Vitamin D	mcg/d	5.9 (0.2)	5.8 (0.2)	4.7 (0.2)	5.2 (0.3)
%>AI	%(SE)	53.0 (4.2)	52.0 (4.0)	36.0 (3.5)	42.0 (4.4)

Data source: Statistics Canada, Canadian Community Health Survey, Cycle 2.2, Nutrition (2004) - Share File

Symbol Legend

E Data with a coefficient of variation (CV) from 16.6% to 33.3%; interpret with caution.

<3 Data with a coefficient of variation (CV) greater than 33.3% with a 95% confidence interval entirely between 0 and 3%; interpret with caution.

F Data with a coefficient of variation (CV) greater than 33.3% with a 95% confidence interval not entirely between 0 and 3%; suppressed due to extreme sampling variability.

Nutrient Intakes from Food, Canadian Population Data

Canadian Community Health Survey Cycle 2.2, Nutrition (2004)

Canada excluding territories

			Men		Women	
			19 - 30 yr n=1804	31 - 50 yr n=2596	19 - 30 yr n=1854	31 - 50 yr n=2686
Elements						
Calcium		mg/d	1107 (35)	938 (22)	867 (27)	827 (19)
	%>AI	%(SE)	52.9 (3.7)	38.4 (2.6)	30.4 (3.2)	27.2 (2.4)
Sodium		mg/d	4083 (112)	3634 (81)	2743 (71)	2778 (55)
	%>AI	%(SE)	100.0 (0.0)	99.5 (0.3)	99.1 (0.7)	96.9 (1.0)
Potassium		mg/d	3552 (76)	3534 (58)	2674 (50)	2874 (41)
	%>AI	%(SE)	13.8 (2.5) E	13.4 (1.9)	<3	3.4 (0.8) E
Iron		mg/d	17.6 (0.4)	16.7 (0.3)	12.4 (0.3)	12.4 (0.2)
	% Inadequacy	%(SE)	<3	<3	16.8 (1.5)	18.3 (1.1)
Magnesium		mg/d	380 (8)	372 (6)	284 (6)	306 (5)
	% less than EAR	%(SE)	34.8 (3.2)	45.7 (2.7)	36.6 (3.7)	36.4 (2.1)
Phosphorus		mg/d	1659 (34)	1560 (27)	1192 (25)	1229 (23)
	% less than EAR	%(SE)	<3	<3	<3	1.8 (0.5) E
Zinc		mg/d	14.2 (0.3)	13.9 (0.3)	9.5 (0.2)	9.9 (0.2)
	% less than EAR	%(SE)	F	13.3 (2.3) E	14.7 (3.3) E	14.2 (2.1)

Data source: Statistics Canada, Canadian Community Health Survey, Cycle 2.2, Nutrition (2004) - Share File

Symbol Legend

E Data with a coefficient of variation (CV) from 16.6% to 33.3%; interpret with caution.

<3 Data with a coefficient of variation (CV) greater than 33.3% with a 95% confidence interval entirely between 0 and 3%; interpret with caution.

F Data with a coefficient of variation (CV) greater than 33.3% with a 95% confidence interval not entirely between 0 and 3%; suppressed due to extreme sampling variability.

Appendix 11: Three-Factor Eating Questionnaire

Three-Factor Eating Questionnaire

Part I

Directions: Circle the response that is appropriate to you. True (T) or False (F)

1.	When I smell my favourite food, I find it very difficult to keep from eating, even if I have just finished a meal	T	F
2.	I usually eat too much at social occasions, like parties and picnics	T	F
3.	I am usually so hungry that I eat more than three times a day	T	F
4.	When I have eaten my quota of calories, I am usually good about not eating any more	T	F
5.	Dieting is so hard for me because I just get too hungry	T	F
6.	I deliberately take small helpings as a means of controlling my weight	T	F
7.	Sometimes things just taste so good that I keep on eating even when I am no longer hungry	T	F
8.	Since I am often hungry, I sometimes wish that while I am eating, an expert would tell me that I have had enough or that I can have something more to eat	T	F
9.	When I feel anxious, I find myself eating	T	F
10.	Life is too short to worry about dieting	T	F
11.	Since my weight goes up and down, I have gone on reducing diets more than once	T	F
12.	I often feel so hungry that I just have to eat something	T	F
13.	When I am with someone who is overeating, I usually overeat too	T	F
14.	I have a pretty good idea of the number of calories in common food	T	F
15.	Sometimes when I start eating, I just can't seem to stop	T	F
16.	It is not difficult for me to leave something on my plate	T	F
17.	At certain times of the day, I get hungry because I have gotten used to eating then	T	F
18.	While on a diet, if I eat food that is not allowed, I consciously eat less for a period of time to make up for it	T	F
19.	Being with someone who is eating often makes me hungry enough to eat also	T	F
20.	When I feel blue, I often overeat	T	F
21.	I enjoy eating too much to spoil it by counting calories and watching my weight	T	F
22.	When I see a real delicacy, I often get so hungry that I have to eat right away.	T	F
23.	I often stop eating before I am really full as a conscious means of limiting the amount that I eat.	T	F
24.	I get so hungry that my stomach often seems like a bottomless pit	T	F
25.	My weight has hardly changed at all in the last two years	T	F
26.	I am always hungry so it is hard for me to stop eating before I finish the food on my plate	T	F
27.	When I feel lonely, I console myself by eating	T	F
28.	I consciously hold back at meals in order not to gain weight	T	F
29.	I sometimes get very hungry late in the evening or at night	T	F
30.	I eat anything I want, any time I want	T	F
31.	Without even thinking about it, I take a long time to eat	T	F
32.	I count calories as a conscious means of controlling my weight	T	F
33.	I do not eat some foods because they make me fat	T	F
34.	I am always hungry enough to eat at any time	T	F
35.	I pay a great deal of attention to changes in my figure	T	F
36.	While on a diet, if I eat a food that is not allowed, I often then splurge and eat other high calorie foods	T	F

From: Stunkard AJ, Messick S. The Three-Factor Eating Questionnaire to Measure Dietary Restraint, Disinhibition and Hunger. Journal of Psychosomatic Research 1985;29:71-83.

Version 1: 2007/02/05

Part II Directions: Please answer the following questions by circling the number before the response that is appropriate to you.

37. How often are you dieting in a conscious effort to control your weight?
1 rarely 2 sometimes 3 usually 4 always

38. Would a weight fluctuation of 5 lbs affect the way you live your life?
1 not at all 2 slightly 3 moderately 4 very much

39. How often do you feel hungry?
1 only at mealtimes 2 sometimes between meals 3 often between meals 4 almost always

40. Do your feelings of guilt about overeating help you to control your food intake?
1 never 2 rarely 3 often 4 always

41. How difficult would it be for you to stop eating halfway through dinner and not eat for the next four hours?
1 easy 2 slightly difficult 3 moderately 4 very difficult

42. How conscious are you of what you are eating?
1 not at all 2 slightly 3 moderately 4 extremely

43. How frequently do you avoid 'stocking up' on tempting foods?
1 almost never 2 seldom 3 usually 4 almost always

44. How likely are you to shop for low calorie foods?
1 unlikely 2 slightly unlikely 3 moderately likely 4 very likely

45. Do you eat sensibly in front of others and splurge alone?
1 never 2 rarely 3 often 4 always

46. How likely are you to consciously eat slowly in order to cut down on how much you eat?
1 unlikely 2 slight likely 3 moderately likely 4 very likely

47. How frequently do you skip dessert because you are no longer hungry?
1 almost never 2 seldom 3 at least once a week 4 almost very day

48. How likely are you to consciously eat less than you want?
1 unlikely 2 slightly likely 3 moderately likely 4 very likely

49. Do you go on eating binges though you are not hungry?
1 never 2 rarely 3 sometimes 4 at least once a week

50. On a scale of 0 to 5, where 0 means no restraint in eating (eating whatever you want, whenever you want it) and 5 means total restraint (constantly limiting food intake and never 'giving in'), what number would you give yourself?
0 eat whatever you want, whenever you want it
1 usually eat whatever you want, whenever you want it
2 often eat whatever you want, whenever you want it
3 often limit food intake, but often 'give in'
4 usually limit food intake, rarely 'give in'
5 constantly limiting food intake, never 'giving in'

51. To what extent does this statement describe your eating behaviour? 'I start dieting in the morning, but because of any number of things that happen during the day, by evening I have given up and eat what I want, promising myself to start dieting again tomorrow.'
1 not like me
2 little like me
3 pretty good description of me
4 describes me perfectly

Version 1: 2007/02/05

Appendix 12: Yale Eating Patterns Questionnaire

Yale Eating Patterns Questionnaire

Please answer each question to the best of your ability. There are no correct or incorrect answers.

		Never	Seldom	Sometimes	Often	Very Often
1.	I have late night snacks					
2.	Eating keeps me feeling better emotionally					
3.	I consciously restrain my eating					
4.	I'm willing to make a special trip to the store or bake something to satisfy my cravings					
5.	When small meals are put in front of me, I am satisfied without second helpings					
6.	When the afternoon comes, my stomach growls					
7.	When I don't eat (or if dieting) I become nervous and anxious					
8.	I feel dizzy and faint when I go without food					
9.	I buy refreshments at movies, ball games, etc.					
10.	I snack or nibble when watching TV					
11.	I open the refrigerator door to look even though I do not take out any food					
12.	I have late night snacks					
13.	I eat more on weekends than on weekdays					
14.	Watching other people eat makes me hungry					
15.	I crave sweets more than other foods					
16.	I am more likely to overeat between lunch and dinner					
17.	I am more likely to overeat after dinner					
18.	When I am bored I eat for something to do					
19.	Snacking is a big problem for me					
20.	I'm likely to eat too much if I'm doing something else at the same time (watching TV, reading)					
21.	I eat more when I'm alone					
22.	I snack and nibble when preparing meals					
23.	I eat more on holidays and vacations than usual					
24.	I have an uncontrollable urge to eat even to the point of making myself sick					
25.	I eat food even when it doesn't taste very good					
26.	I think about and look forward to each meal					
27.	I am more likely to overeat at dinner					
28.	I eat when I'm not really hungry, just because food is available					
29.	I just seem to crave food					
30.	I finish whatever is put in front of me					
31.	I think about food when I am not actually eating or preparing it					
32.	I like to celebrate important events by going out to eat					
33.	I find eating is the most pleasurable activity of the day					
34.	I overeat when I'm angry or depressed					
35.	I have never attempted to follow a regular dietary program					
36.	I have dieted successfully in the past but I seem to gain back what I lose					

	Never	Seldom	Sometimes	Often	Very Often
37. I can picture what I will look like when I am thinner than I am now					
38. I am familiar with the caloric values of most foods					
39. I often eat most when I have already eaten a lot					
40. Dinner: My stomach is stuffed					
41. Afternoon: My stomach is comfortably full					
42. Afternoon: I have a satisfied feeling					
43. Evening: My stomach is stuffed					
44. Evening: My stomach is comfortably full					
45. Dinner: There is no more food in the serving bowls					
46. Dinner: One more bite would make me feel nauseous					
47. Dinner: There is no more food at all					
48. Dinner: I feel nauseous					
49. Dinner: If I eat more I'll feel bad physically (gas, indigestion, etc.)					
50. Evening: There is no more food					
51. Evening: I feel nauseous					
52. Evening: If I eat more I'll feel bad physically (gas, indigestion, etc.)					
53. Dinner: I've eaten enough calories					
54. Dinner: I feel guilty					
55. Dinner: There is no more food on the plate					
56. Evening: I feel guilty					
57. Evening: People will think I'm a pig if I eat more					
58. Evening: I'll feel bloated in the morning					

How important are the following factors in weight problems?

	Very Important	Quite Important	Not Very Important	Not At All Important
1. Hereditary factors				
2. Physiological factors (metabolism, thyroid, etc.)				
3. Lack of knowledge about which foods I should and should not eat				
4. Lack of knowledge about specific techniques to use in controlling my eating				
5. Lack of encouragement from family and/or friends				
6. Insufficient time to shop and/or prepare food correctly				
7. Large body frame				
8. Too little exercise				
9. Poor eating habits				
10. Lack of motivation				

How important are the following factors in weight problems?

	Very Important	Quite Important	Not Very Important	Not At All Important
1. Anxiety or stress				
2. Depression				

From: Kristeller JL, Rodin J. Identifying Eating Patterns in Male and Female Undergraduates Using Cluster Analysis. Addictive Behaviors 1989;14:631-42.
Version 1: 2007/02/05

Appendix 13: Summary of results for participants

Nutrient Intakes of Elite Canadian Athletes with a Spinal Cord Injury
Participant Results Summary

Background: Canadian athletes with a spinal cord injury (SCI) are training at intensities, durations and frequencies that rival those of their Olympic colleagues. While there is a large body of nutrition research to support able-bodied athletes in achieving their training and competitive goals, very little data exists to support optimizing nutrition in athletes with SCI.

Participants/Methods: Thirty-two athletes (24 men, 8 women) completed all components of this study. The group consisted of 20 rugby, 7 basketball and 5 athletes from a variety of sports. Within the group, there was 20 athletes with complete SCI, 12 with incomplete SCI, 20 with tetraplegia and 12 with paraplegia. The average age was 30.5 years with 13.5 years elapsed since the onset of SCI. This was an exploratory cross-sectional study using self-reported 3 day food diaries, activity logs and questionnaires to measure training practices, nutrition knowledge, food behaviours and eating attitudes.

Results: Men reported consuming an average of 2150 kcal per day which is much less than the predicted intake of 2990 kcal using the estimated energy requirement (EER) and less than 2735 kcal per day reported by able bodied Canadians. Many of the men reported suboptimal intakes (intakes below the estimated average requirement or EAR) for magnesium (50%), zinc (46%), and folate (46%). The percentage of men with intakes above the adequate intake (AI) for calcium (21%), vitamin D (17%), and fibre (0%) was also less than ideal. There were no statistically significant differences based on sport, level of SCI or training practices.

Women reported consuming an average of 1990 kcal per day which was also less than the predicted intake of 2380 kcal but similar to Canadian women with intakes of 1900 kcal. Most women had diets with vitamins and minerals in acceptable amounts with the exception of magnesium (63% below EAR), folate (38%) and zinc (25%). The percentage of women with intakes above the AI for calcium (50%), vitamin D (12.5%) and fibre (25%) indicates they are likely meeting their nutrient requirements.

The scores of the nutrition knowledge questionnaire (67% for men, 76% for women) were on par with other populations with SCI. The scores of the food attitude and behaviour questionnaires uncovered novel and unexpected findings. This population can be described as 'restrained eaters' or trying to manage body size or shape by food intake. The participants in this study scored very low on the hunger scale which means food intake is not as tightly controlled by the body's hunger and satiety cues.

Conclusions: This study confirms that elite athletes with SCI are consuming fewer calories than would be predicted for an able-bodied individual with an active lifestyle. This lower energy intake was expected, given the lower amounts of lean muscle mass and fewer large muscle groups used during training and activity. The lower energy intakes are a reflection of lower energy expenditure and athletes should not strive to increase calorie intake.

Version 1: 2009/11/16

The lower daily energy intake and prevalence of vitamin and mineral inadequacies reaffirms the need for athletes to make sound nutrition choices to optimize their diet. The diets consumed had an acceptable proportion of calories from fat, protein and carbohydrate. Women were able to maintain diets with fewer micronutrient inadequacies at home and training camps. Men were at greater risk of dietary vitamin and mineral inadequacies, with their diet at training camp at greater risk of inadequacies. The nutrients that were low in the athletes' diets (magnesium, zinc, folate, calcium, vitamin D and fibre) are also low in the diets of many Canadians. Good food sources of the nutrients are included in this summary for your information.

Acknowledgements: I would like to extend a tremendous thank you to everyone who participated in this study. Your willing participation, with thoughtful and complete responses greatly enhanced the results of this study.

Food Sources of Selected Nutrients	
Calcium	fluid milk, cheese, yogurt, fortified rice or soy beverage, fortified orange juice
Vitamin D	fluid milk, fortified rice or soy beverage, fortified orange juice, fortified margarine, salmon, sardines, trout or herring, mackerel
Magnesium	whole grains, legumes, dark leafy green vegetables, cooked halibut, nuts (almonds, cashews, peanuts), bran cereals, oatmeal
Zinc	oysters, beef, crab meat, pork, chicken, yogurt, fortified breakfast cereal, cheese, milk, chickpeas
Folate	chicken or beef liver, beans, leafy green vegetables, enriched pastas and breads, orange juice, asparagus, wheat germ
Fibre	bran cereals, whole wheat pasta, oatmeal, brown rice, beans, legumes, corn, peas, spinach, broccoli, banana, pear, berries, apple