The Dietary Intakes of Calcium and Bone Health Related Nutrients Among Individuals with and without Spinal Cord Injury

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Abstract: *Objectives*: The purposes of this observational study were to: 1) describe and compare the intakes of nutrients related to bone health among a group of individuals with traumatic spinal cord injury (SCI) versus a group of age, gender and weight matched non–SCI peers; and 2) contrast the participant's nutrient intakes against current dietary reference intakes (DRIs).

Methods: Consenting participants included: 87 individuals with SCI (C2-T10 AIS A-D) aged 18-68 years and 85 non-SCI individuals. Participants' nutrient intakes were determined using a 24-hour dietary recall. Participants were grouped by gender, age (19-30yrs, 31-50yrs, 51-68yrs), and impairment (SCI and non-SCI). Additionally, the nutrient intakes were contrasted with the DRIsparameters.

Results: The range for mean calcium intakes across all age strata was 870-1087mg/day for SCI men and 848-1087mg/day for SCI women. The range for mean calcium intakes of the non-SCI participants were similar (men: 900-909mg/day; women: 796-1160mg/day). The majority of SCI and non-SCI men (64 - 86% of participants) in all age groups and SCI and non-SCI women in the 52-68 yrs group (72 and 73% of participants) did not meet the DRIs recommendation for calcium.. Additionally many participants did not meet the DRIs recommendation for magnesium (38-55%) and potassium (71-95%) regardless of gender and impairment. The majority (60-70%) of participants consumed excessive amounts of sodium with the exception of non-SCI women.

Conclusions: Dietary calcium intakes among SCI and non-SCI participants were not significantly different from each other. However, the dietary calcium intakes of both impairment groups were less than the recommended DRIs; SCI men and women are a target for nutritional interventions based on their calcium, magnesium potassium and sodium intakes.

Keywords: Calcium, 24 hour recall, spinal cord injury, dietary assessment, osteoporosis.

INTRODUCTION

Patients with motor complete spinal cord injury (SCI) experience a rapid 3%-4% per month decline in regional bone mass of the hip and knee region within the first 12-16 months after injury [1-5]. This decline in bone mineral density (BMD) of the hip and knee region is predominantly peri-articular with relative preservation of cortical bone and reduced trabecular volume due to endosteal resorption [6-8]. During the period of excessive bone resorption early after SCI, specific metabolic alterations occur including increased urinary calcium, nitrogen, hydroxyproline, and zinc excretion. Hypercalciuria (urinary calcium excretion of >250mg/day for women or >300mg/day for men) [9], is a metabolic disorder that contributes to calcium stone formation in people with SCI [10], and may be

associated with the early rapid decline in bone mass [11 12]. These regional changes in BMD and bone architecture result in sublesional osteoporosis (SLOP) and an increased lifetime propensity for lower extremity fragility fracture when compared to their age and gender matched non-SCI peers [13]. Approximately 25-46% of SCI individuals develop lower extremity fragility fractures[14-19] Plausible risk factors for development of SLOP after SCI include: hormonal changes [20-22], immobility [23], abnormalities in blood circulation [24 25], autoimmune reactions, vitamin D deficiency, low calcium intake and inadequate nutrition.

Nutrition plays a key role in the pathogenesis, prevention and treatment of osteoporosis in the aging able-bodied (Non-SCI) population with primary and secondary osteoporosis [26-32]. Nutrients essential for maintaining bone health include protein, calcium, phosphorous, magnesium, potassium, and copper, and vitamins C, D and K. Amongst these nutrients, calcium by far is the most important dietary constituent for

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maintaining bone mass [27 33]. Excessive intakes of animal protein, dietary fiber, free fatty acids, caffeine and phosphorus may possibly have adverse effects on bone mass, by decreasing calcium absorption. Studies have shown a strong correlation between bone mass and calcium intake across all age groups of the able-bodied population [33-37]. Individuals with long term inadequate calcium intakes have low bone mass and are at risk of developing osteoporosis [37]. An optimal calcium intake is thought to prevent osteoporosis development and to be a key component of osteoporosis treatment for all ages within the able-bodied population [33-37]. To ensure adequate calcium intake, both the Dietary Reference Intakes (DRIs) and Osteoporosis Canada (OC) recommend a calcium intake of 1000mg of calcium per day for men and women aged 19 to 50 years, and 1200 mg calcium per day for individuals aged over 51 years of age [38 39].

There are many myths and considerable clinical equipoise regarding the ideal calcium intake acutely, sub-acutely (after discharge from inpatient rehabilitation), and long term (>2 years post injury) after SCI. In order to prevent SLOP among individuals with SCI, an adequate but not excessive intake of calcium and other nutrients relating to bone health are recommended. There are currently no evidence based recommendations for calcium intake after SCI. There is little evidence describing how much calcium individuals with SCI require. To date, five studies have investigated the dietary calcium intake of patients with chronic SCI [40-44] However, their generalizability is limited by the relatively small sample sizes [40 44] and restriction of the sample to young active paraplegic men [41 42]. Recently, the inadequate dietary intakes among men and women with chronic SCI among a large sample of Ontarians was reported [43]. They reported that the mean usual intakes of vitamin D and calcium were well below the DRI recommendation for adult men and women. Although the study did not include a non-SCI comparator group, it was methodologically rigorous. Understanding the current intake of calcium and other bone health related nutrients of people after SCI is the first step in beginning to formulate dietary prescriptions and nutritional interventions for the prevention and treatment of the SLOP after SCI.

The aims of this study were to: 1) describe and compare the intakes of bone health related nutrients including calcium of individuals with traumatic SCI with a cohort of age, gender and weight matched non–SCI peers; and 2) contrast the participants' intakes of bone

health related nutrients with the north American dietary reference intakes (DRIs) parameters. We hypothesized that nutrient intakes in subjects with SCI would be insufficient compared with the non-SCI peers since people with SCI would have limited ability to shop and prepare meals.

METHOD

Participants

Participants included 87 consenting adults, aged 18-68 years, with acute or chronic traumatic SCI C1-T10, AIS A-D affiliated with the SCI in- or outpatient services at Toronto Rehab, Lyndhurst Centre. Thirty paraplegics and 57 tetraplegics, mean SCI duration of 9.1±5.6 years, were recruited *via* a poster campaign and SCI program staff. Eighty-five participants without SCI, aged 18-66 years matched for age, gender and where possible BMI, were recruited as the control participants from the staff at Lyndhurst Centre, and friends of the authors. The study data were collected between January and October1999.

Participants were given a brief description of the purpose of this study, and asked to provide written informed consent prior to completing the study procedures. Participants did not receive remuneration. SCI participant weight was measured using a Stathmos-Lindell self-indicating platform scale (Model 513-417, Stathmos Scale Manufacturing Limited, Milliken, ON). SCI participants were instructed to wear light clothing and no shoes. Weight of the able-bodied non-SCI participants and heights of all participants were self-reported. This study was approved by the Research Ethics Board of Toronto Rehab, and we certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed.

Interview

The 24-hour recall was administered on one occasion by a Registered Dietitian (EL or AB) The interview lasted 30-45 minutes. During the 24-hour recall, participants were probed to report all foods and beverages consumed as part of a meal and/or snack, as well as food preparation methods and brand names (where possible), in the previous 24 hours. Portion sizes were reported in household measures. Calcium, other nutrients and energy intakes from the 24-hour recall were calculated using Fuel Nutrition Software (version 2.1, 1998, Sillery, Quebec, Canada), updated with the 1997 Canadian Nutrient File.

Total energy intake, macronutrients (protein, fat and carbohydrate), and selected micronutrient intakes (vitamin C, calcium, phosphorous, magnesium, potassium, iron, and sodium) were assessed. Each participant's dietary values were compared with the dietary reference intakes (DRIs) [38] to assess whether their intakes were appropriate. The measured nutrient intakes were compared with the DRIs. For the DRI's, the estimated average requirement (EAR), the adequate intake (AI), the tolerable upper intake level (UL) and the acceptable macronutrient distribution range (AMDR) were used. EAR is the value set to meet the needs of 50% of individuals in a group. It is usually used to assess the adequacy of population intake. EAR was used as the reference value for determining adequacy of the protein, carbohydrate, Vitamin C, magnesium, phosphorus, and iron intakes. AI is the value set to meet the needs of almost all (97 to 98%) of individuals in a group. Thus, AI is a higher and stricter threshold than EAR. The AI value was used to assess the adequacy of participant intake of calcium and potassium because these nutrients do not have an established EAR. The UL is the maximal level of daily nutrient intake unlikely to pose any risk of adverse effects. The UL was used for the phosphorus and sodium intakes because they inhibit the absorption of calcium if their intakes are excessive. AMDR is the range of intake for the particular energy source that is associated with risks of the chronic disease while providing intakes of essential nutrients for the macronutrient energy. The AMDR was used as the adequate energy range from protein, fat and carbohydrate. Intakes of vitamins D and E are not reported due to incomplete food composition data.

The DRIs for calcium (AI value) were assumed to be the age-gender ideal daily calcium intake [38]; 1000mg/day for 19-50 year olds and 1200mg/day for those >51 years of age. A priori, 67% AI for calcium intake (670mg for 19-50yrs, 1005mg for 51-70yrs) was defined as the minimum requirement for dietary calcium intake.

Analysis

All analyses were gender specific. Additionally, for the analysis of calcium intake, each gender was divided into three age categories (19-30yrs, 31-50yrs, 51-68yrs).

Descriptive data and selected nutrients were presented as the mean and standard deviation for each group. The percentage of participants who did not meet the recommendation of DRIs parameters was also described. The calcium intake was presented as the mean and range for each age and impairment group. The percentage of participants consuming less than both the AI and minimum requirement (67% AI) calcium intake were also described. Quintiles were used for categorization of participants by calcium intake level.

The mean values of demographic data, daily energy intake, macronutrients and selected nutrients were compared between individuals with and without SCI using the t-test. Calcium intake in paraplegics and tetraplegics was also compared using the t-test. Two-way analysis of variance (ANOVA) was used to assess the effect of age (19-30yrs, 31-50yrs, 51-68yrs) and impairment status (SCI, Non-SCI) on calcium intake. A significance level of $p<0.05$ was used.

RESULTS

Demographic characteristics of the participants are displayed in Table **1**. There were no significant differences in age, weight and BMI between the SCI and non-SCI participants, nor was there a difference in the between group distribution of men and women. Daily intakes of energy, macronutrients and selected nutrients relevant to calcium absorption are described in Table **2**. There were no significant differences between the SCI and non-SCI participants, with the exception of the vitamin C intake (Table **2**). The percentage of participants not meeting the recommended intakes of energy, macronutrients and selected micronutrients relevant to bone health amongst the SCI and the non-SCI participants is reported (Table **3**). Most participants met the recommended calorie intake for protein, fat and carbohydrate and the recommended amounts of protein carbohydrate, phosphorus and iron (Table **3**). In non-SCI men, the percentage of participants with an excessive calorie intake from fat and a deficient calorie intake from carbohydrate was higher (29% versus 25%, respectively) than those in the SCI men. In all groups, a majority of participants did not meet the recommended intakes of calcium (48-73%), magnesium (40-55%), and potassium (71-95%) (Table **3**). The majority, 60 to 70% of participants consumed excessive amounts of sodium with the exception of non-SCI women (Table **3**). There was a tendency toward a lower percentage of participants with insufficient vitamin C intake in the male and female SCI participants versus non-SCIpeers.

The ANOVA showed no significant effects of age (men: $p=0.581$, women: $p=0.977$) or impairment (men:

Table 1:   Demographic Characteristics of SCI and Non-SCI Participants

Variables	Men		Women	
	SCI (n=66)	**Non-SCI (n=65)**	**SCI (n=21)**	**Non-SCI (n=20)**
Demographic variables (Mean+SD)				
Age (year)	37.0 ± 12.6	37.5 ± 13.3	39.0 ± 13.9	40.0 ± 12.9
Weight (kg)	74.9 ± 14.6	80.0 ± 14.0	62.2 ± 10.9	67.2 ± 13.7
BMI (kg/m^2)	23.5 ± 4.2	25.6 ± 3.9	22.7 ± 4.3	24.6 ± 5.1
Impairment (n, %)				
Paraplegia	22 (33.3)	-	8 (38.1)	-
Tetraplegia	44 (66.7)	-	13 (61.9)	-

SCI: spinal cord injury participants, Non-SCI; gender age-matched able bodied peers.

Table 2:   Daily Intakes of Energy, Macronutrients and Micronutrients Relevant to Bone Health and Percentage of DRI Recommendations

Nutrient		*Men*		*Women*	
		SCI	**Non-SCI**	**SCI**	**Non-SCI**
Total energy (kcal)		2468 ± 813	2406 ± 735	1925 ± 545	1833 ± 451
Protein	Intake (g)	95.7 ± 34.4	104.7 ± 38.8	80.1 ± 24.3	79.4 ± 25.4.
	% EAR (%)	(202 ± 89)	(202 ± 80)	(197 ± 59)	(186 ± 70)
%Kcal from protein	Intake (%)	15.5 ± 3.1	17.7 ± 4.6	16.9 ± 3.1	17.4 ± 3.6
	AMDR (%)	(10 - 35)	(10 - 35)	(10 - 35)	(10 - 35)
Total Fat	Intake (g)	76.8 ± 36.1	83.7 ± 42.3	60.6 ± 24.9	60 ± 19.8
%Kcal from fat	Intake (%)	27.5 ± 7.4	30.3 ± 8.9	28 ± 6.5	29.3 ± 7.1
	AMDR (%)	(20 - 35)	(20 - 35)	(20 - 35)	(20 - 35)
Carbohydorate	Intake (%)	355.5 ± 109.4	305.4 ± 90.9	268 ± 79.7	273.5 ± 71.1
	% EAR (%)	(356 ± 109)	(305 ± 91)	(269 ± 79)	(273 ± 136)
%Kcal from Carbohydrate	Intake (%)	56.7 ± 8.6	50.4 ± 8.7	55.8 ± 8.5	51.5 ± 9.3
	AMDR (%)	(45 - 65)	(45 - 65)	(45 - 65)	(45 - 65)
Calcium	Intake (mg)	941.4 ± 658.5	904.3 ± 458.3	1006 ± 414	939.1 ± 486.4
	%AI (%)	(91 ± 62)	(87 ± 45)	(96 ± 40)	(90 ± 47)
Vitamin C	Intake (mg)	232.8 ± 147.9[*]	168 ± 131.3	246.1 ± 110.4 [*]	129.9 ± 112.6
	%EAR (%)	(310 ± 197)	(224 ± 175)	(410 ± 184)	(242 ± 188)
Magnesium	Intake (mg)	345.8 ± 129.5	368.8 ± 140	328.3 ± 117.8	304 ± 117
	%EAR (%)	(99 ± 35)	(106 ± 39)	(123 ± 45)	(116 ± 45)
Phosphorus	Intake (mg)	1439 ± 528	1456 ± 622	1259 ± 389	1248 ± 464
	%EAR (%)	(251 ± 107)	(248 ± 91)	(217 ± 69)	(215 ± 80)
Potassium	Intake (mg)	3725 ± 1315	3683 ± 1382	3649 ± 1098	3116 ± 1313
	%AI (%)	(79 ± 28)	(78 ± 29)	(78 ± 23	(66 ± 28)
Iron	Intake (mg)	16.1 ± 5.9	16.4 ± 5.7	14.9 ± 6.7	13.7 ± 6.5
	%EAR (%)	(268 ± 98)	(273 ± 95)	(208 ± 128)	(197 ± 110)
Sodium	Intake (mg)	3049 ± 1594	2979 ± 1432	2701 ± 897	2181 ± 1065
	%UL (%)	(133 ± 69)	(130 ± 62)	(117 ± 38)	(95 ± 46)

SCI: spinal cord injury participants, Non-SCI; gender age-matched able bodied peers.
Data are group mean ± SD.
AMDR: Acceptable Macronutrient Distribution Ranges, EAR: Estimated Average Requirements, UL: Tolerable Upper Intake Levels, AI: Adequate Intake.
[*]p<0.05 vs Non-SCI group.

Table 3: **Percentage of Participants Not Meeting the DRIs Recommendations of Energy, Macronutrients and Selected Micronutrients Relevant to Bone Health**

		Men		Women	
		SCI (66)	Non-SCI (65)	SCI (21)	Non-SCI (20)
		%	%	%	%
%Kcal from protein	: <AMDR	6	2	0	0
	: >AMDR	0	0	0	0
%Kcal from fat	: <AMDR	14	11	10	0
	: >AMDR	12	29	10	10
%Kcal from Carbohydrate	: <AMDR	11	25	10	15
	: >AMDR	14	3	5	0
Protein (g)	: <EAR	3	3	5	0
Carbohydrate (g)	: <EAR	0	0	0	0
Vitamin C (mg)	: <EAR	14	25	10	25
Magnesium (mg)	: <EAR	55	51	38	40
Phosphorus (mg)	: <EAR	0	6	0	5
	: >UL	0	0	0	0
Calcium (mg)	: <AI	73	72	48	60
Potassium (mg)	: <AI	71	75	85	95
Iron (mg)	: <EAR	2	2	5	15
Fiber (g)	: <67%AI	0	0	0	0
Caffeine (mg)		0	0	0	0
Sodium (mg)	: >UL	62	60	71	25

Table 4: **Calcium Intake by Age Group for SCI Participants vs Non-SCI Participants**

Men					
Age (yr)	SCI (mg)		n	Non-SCI (mg)		n
19-30	870.4	(291.5-2870.1)	21	909.4	(161.2-2443.6)	23
31-50	933.8	(253.2-2447.0)	33	900.4	(202.7-2240.6)	28
51-68	1087.0	(225.3-3390.0)	12	904.0	(273.1-1334.2)	14
Women						
Age (yr)	SCI (mg)		n	Non-SCI (mg)		n
19-30	848.1	(123.7-1227.1)	6	1159.8	(621.7-1695.7)	5
31-50	1086.9	(342.3-1583.6)	9	795.9	(282.3-1616.7)	10
51-68	1038.5	(574.0-1749.5)	6	1004.8	(511.6-1866.2)	5

SCI: spinal cord injury participants, Non-SCI; gender age-matched able bodied peers.
Data are group mean (range).

p=0.755, women: p=0.880) on calcium intake (Table **4**). The majority (63.6 to 85.7%) of the men did not meet the recommended level of calcium intake regardless of age and impairment (Figure **1**). Many women (66.7 and 80.0% of participants) in the 51-68yrs age group (SCI and non-SCI) did not meet the AI level for calcium (Figure **1**). There were no prominent differences in the proportion of SCI and non-SCI participants falling below the minimum calcium requirements (67% AI), except for the women in the 31-
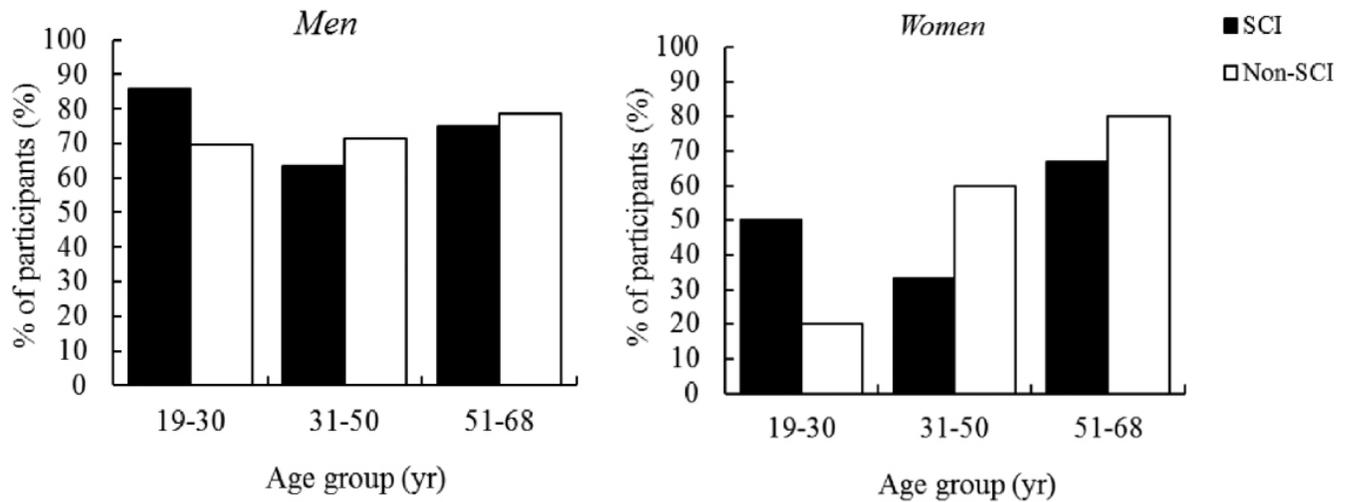
Figure 1: Percentage of participants consuming under the AI for calcium by age group for SCI and Non-SCI participants.

50yr age groups (Figure **2**). There was a tendency toward a higher proportion of participants with insufficient calcium intake in the male SCI participants versus able-bodied peers. Figure **3** illustrates the distribution of calcium intakes for the SCI and non-SCI participants. About two thirds (60%) of all participants had a calcium intake of <1000mg per day (SCI: 63.2%, non-SCI: 66.1%). The majority of participants with SCI (39.1%) and non-SCI (47.1) had calcium intakes of >500 and ≦ 1000mg per day. It should be noted that about one quarter (24.1%) of individuals with SCI had a calcium intake of <500mg per day.

In Table **5**, the calcium intake between paraplegic and tetraplegic participants was compared. There were no significant differences in the calcium intake between the two impairment groups.

DISCUSSION

We found that the levels of the calcium and other nutrient intakes of individuals with SCI were not significantly different from their age and gender matched, able-bodied controls. The majority of SCI and non-SCI participants did not meet the DRIs recommendation for calcium. In particular, the majority (63.6 to 85.7% of participants) of men did not meet the DRIs recommendation for calcium in all age and impairment groups. Additionally, a majority (66.7 and 80.0% of participants) of 51-68yr age women (SCI and non-SCI) did not meet the DRIs recommendation. Moreover, it should be noted that the percentage of participants who consumed calcium below the minimum requirement (<67% AI) was higher in SCI men compared with Non-SCI men across all age groups (Figure **2**). Individuals with SCI have a much
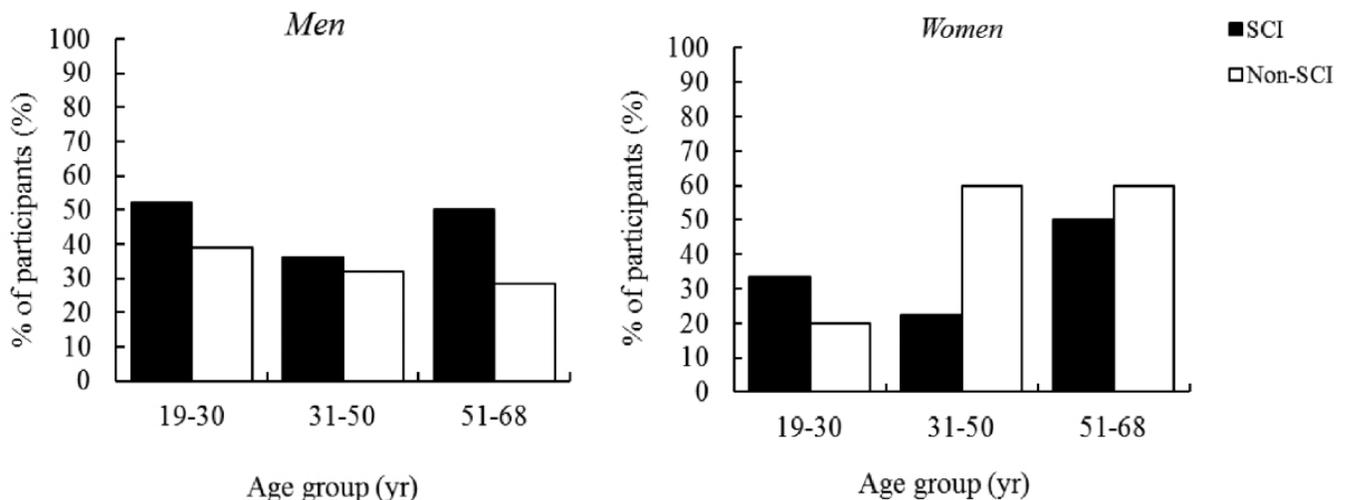
Figure 2: Percentage of participants consuming under 67%AI for calcium by age group for SCI and Non-SCI participants.
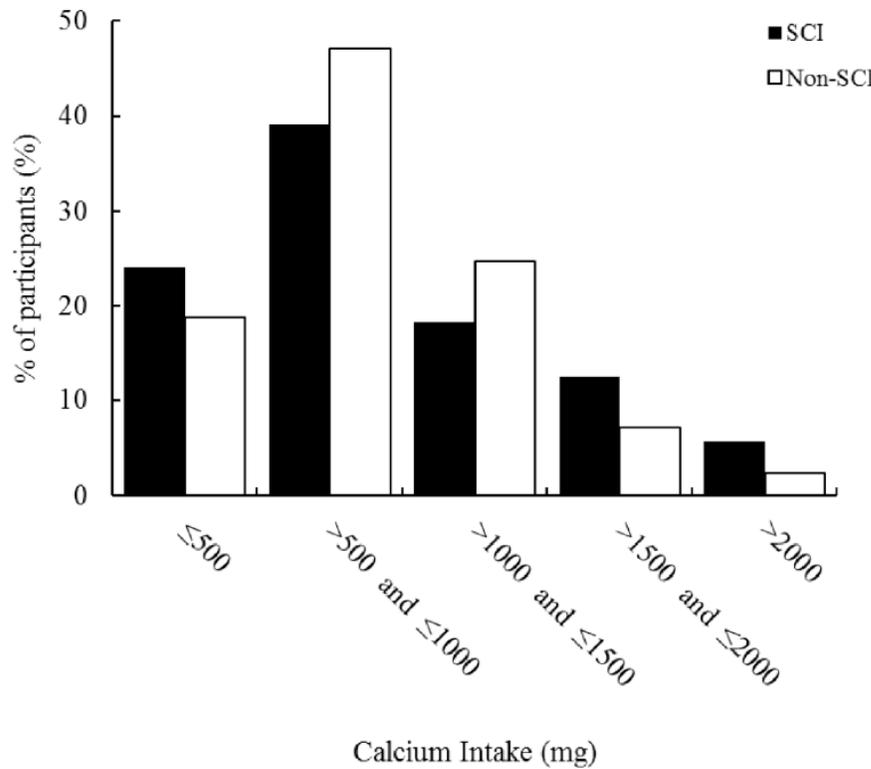
Figure 3: The distribution of SCI and Non-SCI participants to the classified calcium intakes.

Table 5:   Comparison of the Calcium Intake between Paraplegic and Tetraplegic Participants and Percentage of Participants Consuming under the DRIs Recommendation (<AI value) and <67% AI

Men				
	Calcium Intake (mg)		**< AI (%)**	**<67% AI (%)**
Paraplegia (n=22)	972.4	(288.6-2447.0)	72.7	36.4
Teraplegia (n=44)	926.0	(255.3-3390.0)	72.7	50.0
Women				
	Calcium Intake (mg)		**< AI (%)**	**<67% AI (%)**
Paraplegia (n=8)	952.6	(574.1-1454.0)	62.5	25.0
Teraplegia (n=13)	1037.0	(123.7-1749.5)	46.2	38.4

Calcium intake data are group mean (range).

higher risk of lower extremity fragility fractures and high fracture related mortality [45]. Therefore, they require lifestyle interventions to help prevent further declines in bone mass [46]. This is especially true in the 51-68yr age groups, which have a high risk of osteoporosis, greater incidence of fragility fractures, and the most insufficient calcium intakes.

Reports have indicated that a sufficient calcium intake prevents loss of bone mass in able-bodied individuals [33-37 47]. Baran *et al*. reported that premenopausal able-bodied women who had an average dietary calcium intake of 900mg lost bone

mass from the lumbar spine at a rate of 1% per year, while the group supplemented with calcium intakes up to 1500mg a day, maintained their bone mass [34] . Dawson-Hughes *et al*. have indicated that dietary supplementation with calcium (500mg) and vitamin D (700IU) reduced bone loss over the three-year study period and reduced the incidence of non-vertebral fractures in men and women 65 years of age or older [47].

A calcium intake above the recommended level is not necessarily beneficial and may be harmful, while

maintaining a sufficient intake is strongly recommended for able-bodied individuals. Osteoporosis Canada states that calcium is a threshold nutrient, i.e. the intake below a certain threshold level will result in a calcium deficiency, while increased calcium intake above the threshold level does not result in increased skeletal protection or benefit [48]. Therefore, it is suggested that calcium intake meets the recommended level. SCI individuals should be encouraged to maintain a sufficient intake of calcium; however, the DRIs are only available for able-bodied individuals. Excessive dietary calcium intake can precipitate renal or bladder stones post- SCI in persons with hypercalciuria or can exacerbate constipation [49-51]. Asymptomatic renal and bladder stones are frequently identified during routine renal and bladder ultrasounds or cystoscopy in patients with SCI. Symptomatic stones present as shale or blood in the urine or as urosepsis and renal failure in the event of ureter obstruction [52]. Further investigation is necessary to determine the ideal calcium intake level for the SCI population.

Three previous studies reported the calcium intake among individuals with chronic SCI [40 42 43]. Walters *et al*. (2009) reported that the range of median calcium intakes across all age strata with SCI was 631.8-810.4mg and 631.8- 873mg per day for men and women, respectively [43]. Levin *et al*. reported 550.0±268.3mg and 525.0±262.9mg per day for men and women with SCI, respectively [40]. Tomey *et al*. reported 755±268.3mg per day for men with chronic SCI [42]. The participants in the present study had greater calcium intakes than reported previously (Men: 941.4±658.5.8mg, Women: 1005.8±414.0mg). However, this difference was likely attributable to the male participants' lower energy intake. If the calcium intake is normalized per 1000 kilocalories, the differences in calcium intake become negligible (Walters: 352mg/1000kcal [mean value of median values in all age group], Levine *et al*.: 327mg/1000kcal, Tomey *et al*.: 332mg/1000kcal, the present study: 377mg/1000kcal) among male participants. Additionally, Tomey *et al*. has reported that 43% of SCI men did not meet the minimum calcium requirements. This percentage was similar to that of the present study (49%).

Calcium intake alone is insufficient to augment bone health, adequate intakes of other nutrients is also necessary. Other important nutrients for maintaining bone health include protein, phosphorous, magnesium, potassium, copper, vitamins C, D and K. Nutrients that should not be taken excessively include animal protein, dietary fiber, free fatty acids, caffeine and phosphorus. In the present study, we demonstrated that the total and percentage of energy macronutrient intakes and nutrient intakes are sufficient in both SCI and non-SCI participants. However, many participants in the SCI and non-SCI groups did not meet the recommended magnesium and potassium intake levels, and consumed excessive amounts of sodium. Previous studies have emphasized the importance of adequate dietary magnesium and potassium and low sodium intake to maintain or increase bone mineral density (BMD) [26 32]. Little research has been done regarding these nutrients in the SCI population [40 42 43]. Regarding magnesium intake, these results concur with prior studies. Levine *et al*. have reported 217mg per day and 242mg per day magnesium intake, in SCI men and women, respectively [40]. These intakes appear lower than observed intakes in the present study, however when the magnesium intake is normalized (per 1000 kilocalories), the difference is minimal (Levine *et al*.: 129mg/1000kcal in men, 188mg/1000kcal in women, the present study: 143mg/1000kcal in men, 173mg/1000kcal in women). Walters *et al*. reported that the percentage of SCI men and women with magnesium intake below the EAR were 89% and 71%, respectively [43]. These percentages were similar to the present study (Men: 71%, Women: 85%). With regards to potassium, the participants of the present study were higher than that of the previous studies (Men: 3728±1315mg, Women: 3116±1313mg). Levine *et al*. has reported 1975mg and 1828mg per day potassium intake, among SCI men and women, respectively [40] . Walters *et al*. reported that the range of the median calcium intakes across all age strata was 2399-2761mg for men and 2323-2703mg per day for women with chronic SCI [43]. The difference between the results of the present study and previous results remains similar after normalizing the values per 1000 kilocalories (Levine *et al*.: 1378mg/1000kcal in men, 1351mg/1000kcal in women, Walter *et al*.: 1206mg/1000kcal in men, 1488mg/1000kcal in women [mean value of median values in all age group], the present study: 1582mg/1000kcal in men, 1973mg/1000kcal in women). Regarding the sodium intake, the participants of the present study consumed excessed sodium (2949±1457mg) as in the general Canadian population [53]. Additionally, the intakes in the present study were similar to previous reports in the SCI population. Walters *et al*. reported 2804mg sodium intake in the SCI men [mean value of median values in all age group] [43]. Tomey *et al*. reported 3058±1171.8mg sodium intake in their sample of SCI men with two

thirds of participants consuming excess sodium [42]. Additionally, Levin *et al*. [40] reported that sodium intake in the SCI participants was 2594mg and 1949mg for men and women, respectively, which was less than we observed in prior reports from Walters *et al* and Tomey *et al*. Again, when the sodium intake is normalized per 1000 kilocalories, the differences become quite minimal (Levine *et al*.: 1569mg/1000kcal in men, 1470mg/1000kcal in women, Tomey *et al*.: 1348/1000kcal in men, the present study: 1243 mg/1000kcal in men, 1528mg/1000kcal in women). Together with these previous studies, the present study highlights the urgent necessity to educate individuals with SCI to improve their nutrient intake to facilitate calcium absorption and help maintain bone mass. Many individuals with SCI are dependent on others for assistance with grocery shopping and meal preparation. This may result in legitimate reason for their inappropriate dietary intake. Opperman *et al*. reported dietary supplement use in the SCI population [54]. They reported 20% of participants consumed a calcium supplement to maintain bone mass. For patients with insufficient calcium intakes, calcium absorption can be enhanced by taking supplements in divided doses, no more than 400-500mg at a time [13]. Given that the majority of people with SCI did not meet the recommended calcium intake and the fact 25 to 46% of persons living with chronic SCI develop lower extremity fragility fractures [14-19], more people with chronic SCI may need to try supplementation with calcium and bone related nutrients to ensure adequate nutrient intakes. However, it is known that calcium supplements increase the risk of nephrolithiasis and may cause mild gastrointestinal upset [55]. Additionally, although it is inconsistent and inconclusive, there is evidence that calcium supplements increase the risk of both coronary and cerebrovascular events [55]. These conditions are already problematic and typically occur at an earlier age in individuals with SCI [56-58]. Clinicians and other healthcare providers, should promote adequate dietary calcium as a means to achieve the daily intake recommendation and reserve supplements for those who are unable or unwilling to achieve adequate dietary intake [55].

This study has limitations that require caution when interpreting and considering the generalizability of the findings reported herein. First, supplement use was not taken into account when calculating dietary intakes. Second, the vitamin D intake of the participants was not assessed. Vitamin D is an equally important nutrient as calcium with respect to bone health. Third, the nutrient analysis software (Fuel Nutrition Software,

version 2.1, 1998, Sillery, Quebec, Canada) which was used for the data analysis is now out dated. However, although the software is now out dated, we believe that use of the old software is appropriate as it coincided with the average Canadian diet at the time of data collection. Fourth, although the 24 hour recall method was feasibie; a one-time nutrient assessment likely does not necessary reflect the complete spectrum of dietary habits. Therefore, it is not clear if the enclosed data is a fair representation of the subjects' dietary habits. The one week recall method for dietary assessment is a better option to evaluate subjects' dietary habits. Last, the influence of nutrient intakes and/or the urinary excretion of nutrients on actual bone health (i.e. bone density or fracture risk) were not assessed; nor were clinical risk factors for osteoporosis and fragility fracture including mobility status, physical activity level, alcohol intake, family history of fracture etc. recorded. Future prospective studies should try to relate the observed nutrient intakes to the subjects state of bone health.

CONCLUSIONS

Dietary calcium intake and selected nutrients relating to bone health after SCI were surveyed and compared with that of age-matched able-bodied non-SCI individuals; both groups had equally insufficient nutrient intakes although their fracture risk is presumed to be quite different. A particular focus on individuals with SCI is needed due to their high risk of lower extremity fragility fractures. Similar to other authors, the present results revealed that nutrient intake insufficiency is prevalent among individuals with SCI. As an adequate calcium intake is a prerequisite for bone health and many related pharmacologic treatments, we strongly recommend introduction of interventions to ensure adequate but not excessive intakes of bone health related nutrients, particularly among men with spinal cord injury.

ACKNOWLEDGEMENT

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