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Review Article

Nutrient and Dietary Supplement Intake and Measures of Lean Mass, Fat Free Mass Index and Strength in Community-Dwelling Adults 70 Years and Older With High Socioeconomic Status

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INTRODUCTION

Nutrition is an important determinant of health in older adults. As humans age, they experience a decrease in caloric requirements while the need for protein (g/kg body mass) and the recommended dietary allowance (RDA) for micronutrients (e.g. vitamins (vit) and minerals) remain the same or increase (e.g. vit B-6, vit D, and calcium) [1-3]. If nutritional requirements are not met through food consumption, dietary supplement use may be required to ensure that older adults meet their RDA [4]. Knowledge of nutrient intake from food and dietary supplements in the oldest age category of the dietary reference intakes (DRI's), defined as individuals >70 years of age, is growing but requires additional research [2,5]. Estimates of nutrient intake representative of the Canadian population have been collected in the Canadian Community Health Survey (CCHS) [6]. Inadequate dietary intake of vit A, C, D, E, and calcium, folic acid, potassium, and magnesium have been reported [6,7]. This data reflects the average Canadian senior (65 plus years of age), with an annual income of $31,600 [8]. Research has demonstrated that higher socioeconomic status (SES; annual income and education level) is related to healthier food choices in adult populations [9]. However, it is unknown whether populations of older adults with higher SES experience nutrient inadequacies similar to that of the average Canadian older adult. This is of interest since many of the participants volunteering for aging research at the University of Guelph [10,11] are from this demographic. For this reason, we have selected to examine a population of older adults residing in the Village by the Arboretum, an active adult lifestyle community in Guelph, Ontario.

Another area of expanding research in older adult populations is the relationship between nutrition and physical changes. One of the most noticeable physical changes is the reduction in lean body mass (skeletal muscle and bone) and the increase in fat mass [12]. A low muscle mass, known as sarcopenia, and/or a high fat mass may result in decreased physical strength and mobility. This may lead to physical disability and contribute to and exacerbate various chronic diseases (cardiovascular, cancers, diabetes, and osteoporosis) [12-15]. Ultimately, low muscle mass results in a decreased quality of life (QOL), and an increased rate of transition from independent living to assisted living [16]. Quantifying and monitoring an individual's lean muscle mass may be an important strategy in order to implement therapies to prevent the reduction in QOL and loss of independence [16]. Various indices have been proposed to quantify the amount of lean muscle mass and estimate the threshold amount needed to support daily activities. One such index, the fat free mass index (FFMI; fat free mass (kg)/height (m)^2) has been previously examined in the same population as this paper [11]. In addition to FFMI, handgrip strength, which correlates well with overall physical strength, has been shown to be an important indicator of mobility and physical function [17]. Research investigating the relationship between nutrient intake (prevalence of inadequate dietary intake from food, use of dietary supplements, etc.), lean muscle mass (e.g. FFMI) and strength (e.g. hand grip strength) in the DRI oldest age category is of importance to optimize QOL and independence in community-dwelling adults.

Seniors represent the fastest growing age cohort in Canada [18], thus research into the nutrition and physical profile of

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diverse socioeconomic groups is essential to understand the needs of each group. Understanding these relationships is essential for the management of the ongoing health of Canadian seniors. Therefore, the aims of this study were to: 1) measure the dietary intake and prevalence of multivitamin multimineral (MVMM) and other supplement use; 2) determine if MVMM consumers have a healthier diet than non-users; 3) determine if relationships existed between dietary intake parameters (total energy intake, protein, calcium, vit D) and lean mass (LM), FFMI, and combined handgrip strength (CGS). To this end, we assessed the dietary intake and physical measures of lean mass and strength of 62 community-dwelling older adults >70 years of age with a high SES. A subset of this data was previously reported in a study that developed a predictive measurement tool to estimate normalized FFMI, a means of identifying sarcopenia, in community-dwelling older adults (McIntosh, Smale, & Vallis, 2013).

METHODS

Recruitment and inclusion

We recruited 31 females and 31 males from the community of Guelph, Ontario, Canada. Adults who were 71 years of age or older and with good cognitive status, as determined by a score above 25 (out of a possible 30) on the Mini Mental State Exam were included [19]. Following ethics approval from the University of Guelph, both oral and written informed consent was obtained from all participants.

Physical measures and determining FFMI

The protocols outlined in the Canadian Physical Activity, Fitness and Lifestyle Approach (CPAFLA) document for body mass (BM), height (Ht), and waist circumference (WC) were used in this study [20]. Ht was measured to the nearest 0.1 cm using a vertical metric wall tape and a horizontal flat edge. BM was measured to the nearest 0.1 kg on a calibrated digital scale. WC was measured to the nearest 0.5 cm, and was taken at the top of the iliac crests using an anthropometric tape. A WC of <102 cm for males and <88 cm for females was considered healthy (Health Canada, 2003). Body mass index (BMI) was calculated as BM/Ht^2. A BMI of <25 kg/m^2 was considered healthy, 25 to 30 kg/m^2 was considered overweight, and >30 kg/m^2 was considered obese [21].

Body composition of fat mass and fat-free mass or lean mass was estimated using Bioelectrical Impedance Analysis (BIA; model 1500, Bodystat, Douglas, Isle of Man) as previously described [11]. A FM of <30% for males and <42% for females was considered healthy [22]. Healthy cut-points for LM were >70% for males and >58% for females. FFMI was calculated using fat free mass and standardizing for height (fat free mass (kg)/ height^2 (m^2)). Participants were classified as sarcopenic if possessing a FFMI less than 2 standard deviations below the normative value of a young adult reference population [23]. A participant was considered to have a normal muscle mass if possessing a value above the sarcopenia cut-off values of 16.3 kg/m^2 for males and 13.1 kg/m^2 for females [23].

Isometric handgrip strength was measured using a digital hand-held dynamometer (Vernier; 60 Hz; Oregon, USA). Three measurements per hand were taken, and the highest measurement for each hand was added together to achieve the CGS score. Since healthy CGS cut-points for adults >70 years of age have not be established, we used the healthy cut-point for adults 60-69 years. A CGS of ≥73 kg for males and ≥41 kg was considered healthy [20].

Questionnaires

The participants completed a demographic and a health behaviour and conditions questionnaire to collect information on participant education, marital status, and living arrangements. The participants also completed the Physical Activity Scale for the Elderly (PASE) questionnaire, designed to measure the amount of physical activity completed in the past 7 days, with higher scores indicative of greater amounts of daily activity [24].

Assessment of energy and nutrient intake

The participants recorded their 24-hour food and beverage consumption using a multiple-day food record (version 3; Fred Hutchinson, WA, USA) on three consecutive days, which included two weekdays and one weekend day. Detailed training was provided to the participants to ensure accurate recording of dietary intake. The dietary information was then entered into the Food Processor SQL-ESHA database version 10.8.0 (ESHA Research, Salem, OR, USA). The brand of multivitamin was entered into the participant's nutrient intake (Centrum Silver, Usana, Life Spectrum, One A Day). If the brand was not specified, intake from multivitamin-multimineral (MVMM) supplements was calculated using a default nutrient profile based on Centrum Silver (Pfizer Consumer Healthcare, Mississauga, ON), since this was the most commonly used MVMM among the current cohort.

Estimating Prevalence of Inadequacy

The estimated average requirement (EAR) is the daily intake amount of a nutrient estimated to meet the needs of half of the healthy individuals in an age and sex group [25]. The prevalence of inadequate dietary intake for nutrients was estimated as the proportion of respondents with intakes below the EAR of nutrients for which the EAR has been established [25]. The EAR cut-point method was used to determine the proportion of the population with inadequate intake [25]. The tolerable upper limit (UL) is the highest recommended daily intake level of a nutrient likely to pose no risk of adverse health effects, and was used to assess the potential risk of excessive intake.

Statistical analysis

Data were reported as mean + standard error (*M + SE*), unless indicated otherwise. Non-normal data was log transformed; however, since transformations to normalize skewed distributions did not generally change the inferences, the untransformed results were reported. Independent samples *t*-tests were used to determine whether significant relationships existed between nutrient intake from food for supplement users and supplement non-users. Pearson's bivariate correlations were implemented to assess the relationship between dietary nutrient status and LM, FFMI, and CGS. If significant relationships were found, stepwise multivariable linear regressions examined the combination of the nutrients that could significantly predict LM, FFMI, and CGS after controlling for predictor variables (sex, age, BMI). The residuals of the final regression models were normally distributed (Shapiro-Wilk test) and the variance inflation factors (VIF) of each variable was less than 1.2. All statistics were computed using SPSS Statistics 20.0.1 for Windows (SPSS, Chicago, IL). Statistical significance was accepted as *p (2-tailed)* < 0.05 for all tests unless otherwise indicated.

RESULTS

Participant characteristics

The mean age of the participants was 77 + 4.7 years (4.7) (Table 1). The majority of the participants completed post-secondary education (69%), were married (81%), and lived with others (86%). The mean BMIs were close to 25 (Table 1), however, 16 of 31 males and 14 of 31 females fell in the overweight category. Similarly, the mean WC for males was in the healthy range but 10 of 31 men had unhealthy values. For females, the mean WC was above the healthy cut-point, with 16 of 31 having an unhealthy WC value. Research has suggested that the healthy WC cut-off of 88 cm may be too low for older female adults, and may potentially be increased to a cut-off of 99 cm [26]. This higher cut-off is associated with a high risk of adverse health outcomes (pain, mobility limitations, incontinence, knee osteoarthritis, cardiovascular disease, and diabetes) [26]. If 99 cm is used as the healthy cut-point, the mean WC is in the healthy range and only 4 of 31 females have unhealthy values.

Total energy intake for males was indicative of a low to moderate level of daily activity, and for females implied an active lifestyle [27]. The mean physical activity level of our cohort, as measured by the PASE score (133.7 males; 138.0 females) (Table 1), was far above the normative mean, stratified by age and sex (102.4 males, 62.3 females) [24]. In fact, only 8 males and 6 females were below the normative cut-off values for physical activity level. The average CGS of the males was below the healthy cut-point (≥73 kg), and only 13 of 31 males scored above this value. The mean value for females was above the healthy cut-point, with 26 of 31 having a healthy CGS. The mean FFMI for both males and females were above the saropenia cut-off values of 16.3 kg/m^2 for males and 13.1 kg/m^2 [23]. Using these values, only 3 males and 3 females were considered sarcopenic.

In comparison to similar aged cohorts [28,29], the present cohort has a higher education level and a greater percentage of married individuals (Table 1). The present cohort, in comparison to Logan et al. [29], had mean values for the males that were higher for LM and lower for BMI, WC, and CGS. For the females, the present cohort had mean values that were similar for LM, lower for BMI and WC, and higher for CGS. In addition, the current

Table 1: Participant characteristics of male and female community-dwelling adults in comparison to values of similar aged cohorts.

Characteristics	All (*n*=62)	Chad et al. [28] (*n* = 351, 77.2 % female)	Male (*n*=31)	PEOPL data [29] Male (*n* = 72)	Female (*n*=31)	PEOPL data [29] Female (*n* = 90)
Age (years)	77 (4.7)	65 - 79	79 (4.6)	77 (3.2)	76 (4.5)	77 (4.3)
Mini Mental State Exam (/30)	29 (1.0)	ND	28 (1.1)	ND	29 (1.0)	ND
Education (Highest Level Completed)						
Elementary	1.6 (1)	15.7 (55)	3.2 (1)	19.4 (14)	0	21.2 (19)
Secondary	29.0 (18)	38.2 (134)+	16.1 (5)	33.3 (24)	41.9 (13)	43.3 (39)
Post-Secondary	69.3 (43)	43.6 (153)+	80.6 (25)	33.3 (24)	58.1 (18)	34.4 (31)
Missing	0	2.6 (9)	0	13.9 (10)	0	1.1 (1)
Marital Status						
Married	80.6 (50)	41.9 (147)	83.9 (26)	86.1 (62)	77.4 (24)	47.8 (43)
Widowed	8.1 (5)	39.0 (137)	3.2 (1)	9.7 (7)	12.9 (4)	42.2 (38)
Separated/Divorced	9.7 (6)	7.7 (27)	9.7 (3)	1.4 (1)	9.7 (3)	2.2 (2)
Never Married	1.6 (1)	10.8 (38)	3.2 (1)	1.4 (1)	0	7.8 (7)
Missing	0	0.6 (2)	0	0	0	0
Living Arrangements						
Live Alone	14.5 (9)	38.5 (135)	6.5 (2)	15.3 (11)	22.5 (7)	50.0 (45)
Live With Others	85.5 (53)	37.6 (132)	93.5 (29)	84.7 (61)	77.4 (24)	48.9 (44)
Missing	0	23.9 (84)	0	0	0	1.1 (1)
Total Energy Intake (kcal/d)	2088 (624.7)	ND	2173.8 (627.5)	ND	2002.6 (617.9)	ND
PASE Score	135.9 (62.1)	128.2 (65.7)	133.7 (52.5)	162.5 (71.9)	138.0 (71.3)	119.3 (47.3)
Height (cm)	167.7 (10.0)	ND	175.5 (5.4)	173.2 (7.0)	159.9 (6.8)	160.6 (6.6)
Body Mass (kg)	71.4 (13.6)	ND	79.9 (11.1)	83.3 (12.0)	63.0 (10.3)	67.4 (11.7)
Lean Mass (%)	66.0 (8.0)	ND	72.8 (4.0)	69.9 (3.5)	59.4 (4.4)	59.3 (8.0)
Body Mass Index (kg/m^2)	25.4 (3.7)	ND	25.8 (3.5)	27.8 (3.4)	24.9 (3.8)	26.1 (4.1)
Waist Circumference (cm)	93.4 (10.3)	ND	97.8 (9.3)	101.4 (8.9)	89.1 (9.5)	101.4 (8.9)
Combined Hand Grip Strength (kg)	59.1 (16.3)	ND	70.0 (16.9)	75.7 (15.6)	51.5 (12.1)	44.1 (9.0)
Fat Free Mass Index (FFMI)	16.65 (2.72)	ND	18.8 (1.8)	18.5 (4.4)	14.5 (1.5)	14.4 (4.2)

Data are means and standard deviations or percentage of individuals with number of participants in brackets. +Completed some or all secondary and post-secondary education; ND = not determined. PEOPL data from Logan et al. [29]

cohort had a similar activity level as measured by the PASE score as the Chad et al. [28] cohort and PEOPL cohort [29] (Table 1).

Prevalence of supplement use

Dietary supplement use was 56% (52% males, 61% females), of which 31% (29% males, 32% females) took a multivitamin-multimineral (MVMM) (Table 2). Vit D was the most commonly consumed supplement (18%), followed by vit C (16%), calcium (15%) and B-complex (15%), omega-3 fatty acids (13%), magnesium (8%), and vit E (7%). More females (61%) consumed supplements than males (52%), except vit E and omega-3 where usage was equal between the sexes. Males and females also consumed equal amounts of 'other' supplements (13%), which included supplements that are not required in the diet (no current DRI) (saw palmetto, probiotics, methylsulfonalmethane, glucosamine, and coenzyme Q10) (Table 2).

Nutrient adequacy

For the total cohort, the majority of males had insufficient intake of vit A (53%), D (90%), E (90%), and calcium (61%), magnesium (61%), and zinc (58%) from food alone (Table 3). When the males were separated into supplement users and non-users, there were no significant differences in mean intake or in mean intake below the EAR from food alone. However, for most nutrients (with the exception of calcium, magnesium, and folate) a greater percentage of supplement users were below the EAR than non-users (Table 3). When dietary supplement values were added to intake from food alone, all supplement users met their EAR value.

For the females, the majority of the cohort had insufficient intake of vit D (84%) and E (84%), and calcium (71%) (Table 4). When the females were separated into supplement users and non-users, there was a significant difference in mean intake for calcium, with the supplement users consuming higher mean intakes from food (965 ± 86) than the non-users (749 ± 66). However, there were no significant differences in mean intake amount below the EAR from food alone (Table 4). When dietary supplement values were added to intake from food alone, all supplement users met their EAR value.

The nutrient intake from food alone exceeded the tolerable upper limit (UL) for vit B-3 (10%), folate (6%), and magnesium (39%) for males (Table 3); and vit B-3 (3%) and magnesium (29%) for females (Table 4). When considering nutrient intake from both food and supplement use, the proportion of the cohort above the UL increased greatly for niacin (46% males, 85% females), folate (15% males and females), and magnesium (62% males, 54% females) (Tables 3 and 4). In addition, sodium intake was high in this cohort, with 55% of males and 29% of females exceeding the UL of 2300 mg/day (data not shown).

In comparison to Canadian population data (Health Canada, 2005) the current cohort had higher mean intakes of vit C, calcium, magnesium, and total energy and carbohydrate intake (Tables 3 and 4). For females, the present cohort had higher mean intakes of vit A, B-2, B-6, B-12, and folate, similar mean intakes of vit B-1 and D, and lower mean intakes for vit B-3 and zinc with respect to the CCHS female data (Table 4). In contrast to the females, the current male cohort had more nutrients with lower mean intake amounts for vit A, B-2, B-3, B-12, D, and folate and zinc, and similar intakes of vit B-2 and B-6 to the CCHS males (Table 3).

A smaller proportion of the current cohort had inadequate intake as determined by a lower percentage below the EAR for vit A, B-6, and folate (females only), magnesium, and carbohydrate in comparison to the CCHS data (Tables 3 and 4). A greater percentage of the current cohort was below the EAR for vit B-3, B-12 (females only), C (females only), and folate (males only) and zinc (males only) in comparison to the CCHS data. A similar risk of inadequate intake of vit C was observed for both cohorts (Table 3). Intake above the UL for many micronutrients with established ULs were not reported in the CCHS data, making it difficult to compare the present cohort's data. However, for most nutrients, none of the population or a very small percentage was above the UL for the nutrient in question in the CCHS and for those analyzed, our data was similar.

Table 2: Prevalence of dietary supplement use for male and female community-dwelling older adults. Vitamin and mineral supplement intake is independent of daily multivitamin-multimineral (MVMM) intake.

Dietary Supplement	All Participants (*n* = 62)	Male (*n* = 31)	Female (*n* = 31)
Supplement Use	56.4 (35)	51.6 (16)	61.3 (19)
MVMM	30.6 (19)	29.0 (9)	32.3 (10)
B complex	14.5 (9)	12.9 (4)	16.1 (5)
B complex + MVMM	3.2 (2)	0	6.5 (2)
Vitamin C	16.1 (10)	12.9 (4)	19.4 (6)
Vitamin C + MVMM	9.7 (6)	6.5 (2)	12.9 (4)
Vitamin D	17.7 (11)	12.9 (4)	22.5 (7)
Vitamin D + MVMM	16.1 (3)	3.2 (1)	6.5 (2)
Vitamin E	6.5 (4)	6.5 (2)	6.5 (2)
Vitamin E + MVMM	0	0	0
Calcium	14.5 (9)	12.9 (4)	16.1 (5)
Calcium + MVMM	3.2 (2)	3.2 (1)	3.2 (1)
Magnesium	4.8 (3)	3.2 (1)	12.9 (4)
Magnesium + MVMM	1.6 (1)	0	3.2 (1)
Omega-3 Fish Oil	12.9 (8)	12.9 (4)	12.9 (4)
Other	12.9 (8)	12.9 (4)	12.9 (4)

Data are percentage of individuals with numbers in brackets. The 'other' category refers to botanical supplements and supplements without daily recommended intake (DRI) value

Table 3: Male nutrient intake and percent below the estimated average requirement (EAR) and above the tolerable upper limit (UL) for the current cohort and the CHSS (n= 734) cohort.

Nutrient Intake	*n*	*M ± SE*[a]	CHMS, *M ± SE*[a]	Median	25th, 75th Quartiles	EAR	% < EAR	CCHS, % < EAR	UL	% > UL	CCHS , % > UL
Vitamin A RAE[b] (μ /d)											
All participants: Food only	31	577 ± 45	655 ± 54	538	387, 774	650	53 52	61	3000	0	ND
Non-users: Food only	22	597 ± 57		570	378, 807		56				
Users: Food only	9	529 ± 73		485	248, 739		0				
Users: Food + Supplements	9	1362 ± 55		1319	1235, 1511					0	
Thiamine (B_1) (mg/d)											
All participants: Food only	31	1.6 ± 0.1	1.7 ± 0.03	1.4	1.1, 2.1	1.0	16	ND	ND		
Non-users: Food only	18	1.6 ± 0.2		1.4	1.1, 2.3		11				
Users: Food only	13	1.5 ± 0.2		1.4	1.0, 1.9		23				
Users: Food + Supplements	13	3.0 ± 0.2		2.9	2.5, 3.4		0				
Riboflavin (B_2) (mg/d)											
All participants: Food only	31	1.8 ± 0.1	1.8 ± 0.04	1.7	1.3, 2.0	1.1	6	12	ND		
Non-users: Food only	18	1.9 ± 0.2		1.8	1.5, 2.6		6[d]				
Users: Food only	13	1.5 ± 0.1		1.4	1.3, 1.8		8[d]				
Users: Food + Supplements	13	3.6 ± 0.2		3.7	3.0, 4.0		0				
Niacin (B_3) (mg/d)											
All participants: Food only	31	19 ± 2	34 ± 0.8	17	14, 22	12	16	<3	35	10	ND
Non-users: Food only	18	22 ± 2		19	16, 26		11			23	
Users: Food only	13	17 ± 1		15	13, 21		23			0	
Users: Food + Supplements	13	37 ± 1		35	33, 41		0			46	
Vitamin B_6 (mg/d)											
All participants: Food only	31	1.8 ± 0.1	1.8 ± 0.04	1.8	1.2, 2.3	1.4	35	21	100	0	0
Non-users: Food only	18	1.9 ± 0.2		1.8	1.3, 2.5		28				
Users: Food only	13	1.6 ± 0.2		1.6	1.0, 2.0		46				
Users: Food + Supplements	13	4.6 ± 0.2		4.6	4.0, 5.0		0			0	
Vitamin B_{12} (μ g/d)											
All participants: Food only	31	3.1 ± 0.3	4.2 ± 0.4	2.8	2.0, 3.6	2.0	23	ND	ND		
Non-users: Food only	18	3.5 ± 0.5		2.9	1.9, 4.6		28				
Users: Food only	13	2.7 ± 0.3		2.8	2.3, 3.5		15				
Users: Food + Supplements	13	27.6 ± 0.3		27.8	27.3, 28.5		0				
Folate DFE[c] (μ /d)											
All participants: Food only	31	379 ± 34	421 ± 15	329	235, 520	320	42	29	1000	6	ND
Non-users: Food only	18	381 ± 48		314	239, 497		44			11	
Users: Food only	13	376 ± 49		365	231, 549		38			0	
Users: Food + Supplements	13	788 ± 52		797	635, 959		0			15	
Vitamin C (mg/d)											
All participants: Food only	31	126 ± 12	120 ± 5	118	79, 157	75	26	27	2000	0	0
Non-users: Food only	19	129 ± 14		136	79, 157		21				
Users: Food only	12	124 ± 21		113	68, 176		25				
Users: Food + Supplements	12	383 ± 80**		225	158, 676		0			0	
Vitamin D (μ /d)[e]											
All participants: Food only	31	4 ± 1	6 ± 0.4	4	1, 6	10	90	~90 [f]	100	0	<3
Non-users: Food only	19	4 ± 1		4	1, 6		89				
Users: Food only	12	4 ± 2		4	2, 7		92				
Users: Food + Supplements	12	18 ± 2		15	12, 24		0			0	
Vitamin E (mg/d)											
All participants: Food only	31	6 ± 1	ND	5	3, 9	12	90	ND	1000	0	ND
Non-users: Food only	20	6 ± 1		4	3, 9		90				
Users: Food only	11	7 ± 1		7	5, 9		91				
Users: Food + Supplements	11	37 ± 1		37	34, 39		0			0	
Calcium (mg/d)											
All participants: Food only	31	934 ± 73	692 ± 21	845	638, 1089	1000	61	80	2000	0	0
Non-users: Food only	19	916 ± 110		780	612, 1076		63				
Users: Food only	13	958 ± 83		968	740, 1213		54				
Users: Food + Supplements	13	1194 ± 80		1198	928, 1457		0			0	
Magnesium (mg/d)											
All participants: Food only	31	350 ± 26	305 ± 7	324	258, 434	350	61	73	350	39	ND
Non-users: Food only	21	360 ± 35		324	275, 434		62			38	
Users: Food only	10	330 ± 36		312	240, 417		60			40	
Users: Food + Supplements	10	424 ± 38		412	336, 455		0			62	

Zinc (mg/d)											
All participants: Food only	31	8.7 ± 0.6	10.2 ± 0.3	8.4	6.4, 10.1	9.4	58	41	40	0	0
Non-users: Food only	22	9.0 ± 0.9		8.5	6.5, 10.9		55				
Users: Food only	9	8.1 ± 0.6		8.0	6.3, 9.8		67				
Users: Food + Supplements	9	23.1 ± 0.6		23.0	21.3, 24.8		0			0	
Total Energy Intake (kcal/d)											
All participants	31	2174 ± 113	1774 ± 36	2094	1657, 2650	N/A	ND	ND	ND		
Non-users	22	2097 ± 140		2052	1570, 2588						
Users	9	2361 ± 179		2195	1916, 2720						
Protein (g/kg/d)											
All participants	31	1.10 ± 0.08	ND	0.92	0.78, 1.31	0.66	10	ND	ND		
Non-users	22	1.11 ± 0.11		0.92	0.74, 1.30		14				
Users	9	1.06 ± 0.08		1.04	0.82, 1.33		0				
Carbohydrate (digestible) (g/d)											
All participants	31	290 ± 19	230 ± 5	266	195, 395	100	0	<3	ND		
Non-users	22	279 ± 24		261	185, 370						
Users	9	319 ± 30		285	260, 404						

Data are means with standard errors and selected percentiles. [a] SE= Standard error; [b] RAE= retinol activity equivalents; [c] DFE =dietary folate equivalents; [d] Cannot be determined because the sum of the case weights is ≤ 1.0; [e] Vitamin D intake cannot stand alone and consideration for serum 25 OHD levels must be given; [f] Estimates provided only; ND = not determined. * Significant difference between users and non-users for food alone ($p<0.05$); ** Significant difference between users and non-users for food and supplement intake ($p<0.05$). CHSS cohort [6,7]

Table 4: Female nutrient intake and percent below the estimated average requirement (EAR) and above the tolerable upper limit (UL) for the current cohort and the CCHS cohort (n = 1345).

Nutrient Status	*n*	*M ± SE*[a]	CHMS, *M ± SE*[a]	Median	25th, 75th Quartiles	EAR	% < EAR	CCHS , % < EAR	UL	% > UL	CCHS , %> UL
Vitamin A RAE[b] (μ /d)											
All participants: Food only	31	641 ± 56	611 ± 30	595	402, 797	500	42	40	3000	0	ND
Non-users: Food only	20	610 ± 68		546	394, 743		50				
Users: Food only	10	696 ± 58		742	429, 970		30				
Users: Food + Supplements	10	1499 ± 116**		1409	1252, 1479		0			0	
Thiamine (B$_1$) (mg/d)											
All participants: Food only	31	1.4 ± 0.1	1.4 ± 0.03	1.5	1.0, 1.7	0.9	23	ND	ND		
Non-users: Food only	18	1.4 ±0.1		1.3	0.8, 1.8		28				
Users: Food only	13	1.5 ± 0.2		1.5	1.2, 1.7		15				
Users: Food + Supplements	13	3.6 ± 0.5 **		3.1	2.7, 3.9		0				
Riboflavin (B$_2$) (mg/d)											
All participants: Food only	31	1.7 ± 0.1	1.5 ± 0.03	1.7	1.1, 2.2	0.9	10	ND	ND		
Non-users: Food only	18	1.6 ± 0.2		1.5	1.1, 2.1		6[d]				
Users: Food only	13	1.9 ± 0.2		2.1	1.1, 2.3		15				
Users: Food + Supplements	13	3.6 ± 0.2**		3.6	3.0, 3.8		0				
Niacin (B$_3$) (mg/d)											
All participants: Food only	31	19 ± 1	29 ± 0.7	19	15, 24	11	16	<3	35	3[d]	ND
Non-users: Food only	18	19 ± 1		20	15, 24		11			0	
Users: Food only	13	19 ± 2		19	14, 25		23			8[d]	
Users: Food + Supplements	13	43 ± 3**		41	35, 48		0			85	
Vitamin B$_6$ (mg/d)											
All participants: Food only	31	1.9 ± 0.1	1.5 ± 0.03	1.9	1.4, 2.5	1.3	19	36	100	0	0
Non-users: Food only	18	1.9 ± 0.2		1.9	1.3, 2.6		22				
Users: Food only	13	1.9 ± 0.2		2.0	1.4, 2.4		15				
Users: Food + Supplements	13	4.9 ± 0.2**		5.0	4.4, 5.4		0			0	
Vitamin B$_{12}$ (μ /d)											
All participants: Food only	31	3.4 ± 0.4	3.3 ± 0.3	2.9	1.3, 5.1	2.0	39	30	ND		
Non-users: Food only	18	3.1 ± 0.6		2.4	1.3, 4.9		50				
Users: Food only	13	3.7 ± 0.6		3.6	1.8, 5.2		23				
Users: Food + Supplements	13	29.4 ± 0.9**		29.1	27.0, 30.7		0				
Folate DFE[c] (μ /d)											
All participants: Food only	31	440 ± 40	353 ± 8	410	249, 636	320	35	44	1000	0	ND
Non-users: Food only	18	487 ± 57		515	251, 671		33				
Users: Food only	13	380 ± 52		354	240, 510		38				
Users: Food + Supplements	13	751± 60**		728	609, 910		0			15	
Vitamin C (mg/d)											
All participants: Food only	31	129 ± 11	116 ± 4	122	88, 180	60	19	16	2000	0	0
Non-users: Food only	16	122 ± 16		128	60, 173		13				
Users: Food only	15	138 ± 15		120	91, 202		27				
Users: Food + Supplements	15	328 ± 59**		227	149, 613		0			0	

Vitamin D (μ /d)[e]											
All participants: Food only	31	5 ± 1	5 ± 0.2	4	2, 9	10	84	~90 [f g]	100	0	0
Non-users: Food only	17	5 ± 1		3	1, 8		80				
Users: Food only	15	6 ± 1		4	1, 9		88				
Users: Food + Supplements	15	22 ± 3**		20	13, 28		0			0	
Vitamin E (mg/d)											
All participants: Food only	31	8 ± 1	ND	7	4, 11	12	84	ND	1000	0	ND
Non-users: Food only	19	8 ± 1		7	3, 12		74				
Users: Food only	12	7 ± 1		7	4, 10		100				
Users: Food + Supplements	12	37 ± 1**		37	34, 40		0			0	
Calcium (mg/d)											
All participants: Food only	31	847 ± 56	678 ± 18	795	587, 1028	1000	71	87 [f]		0	<3
Non-users: Food only	17	749 ± 66 *		689	546, 953		88				
Users: Food only	14	965 ± 86		1005	690, 1148		50				
Users: Food + Supplements	14	1366 ± 165**		1255	914, 1538		0			8 [d]	
Magnesium (mg/d)											
All participants: Food only	31	310 ± 21	275 ± 6	311	218, 377	265	42	52	350	29	ND
Non-users: Food only	18	329 ± 27		314	226, 396		33			33	
Users: Food only	13	282 ± 33		260	214, 355		54			23	
Users: Food + Supplements	13	374 ± 35**		360	289, 455		0			54	
Zinc (mg/d)											
All participants: Food only	31	8.2 ± 0.6	8.5 ± 0.2	8.0	4.8, 10.4	6.8	35	32	40	0	0
Non-users: Food only	21	7.8 ± 0.7		7.9	4.8, 10.3		43				
Users: Food only	10	8.9 ± 1.2		8.1	6.3, 11.4		20				
Users: Food + Supplements	10	23.9 ± 1.2**		23.1	21.3, 26.4		0			8 [d]	
Total Energy Intake (kcals/d)											
All participants	31	2002 ± 111	1521 ± 24	1923	1568, 2248	ND			ND		
Non-users	21	1914 ± 124		1712	1547, 2141						
Users	10	2030 ± 175		2041	1506, 2340						
Protein (g/kg/d)											
All participants	31	1.33 ± 0.07	ND	1.34	1.10, 1.52	0.66	3 [d]	ND	ND		
Non-users	21	1.28 ± 0.08		1.34	1.04, 1.52		5 [d]				
Users	10	1.44 ± 0.12		1.34	1.21, 1.87		0				
Carbohydrate (digestible) (g/d)											
All participants	31	251 ± 17	199 ± 3	223	187, 275	100	0	<3	ND		
Non-users	21	242 ± 21		209	186, 267						
Users	10	268 ± 29		252	211, 314						

Data are means with standard errors and selected percentiles. [a] SE= Standard error; [b] RAE= retinol activity equivalents; [c] DFE =dietary folate equivalents; [d] Cannot be determined because the sum of the case weights is ≤ 1.0; [e] Vitamin D intake cannot stand alone and consideration for serum 25 OHD levels must be given; [f] Estimates provided only; ND = not determined. *Significant difference between users and non-users for food alone ($p<0.05$); ** Significant difference between users and non-users for food and supplement intake ($p<0.05$). CCHS cohort [6,7]

Table 5: Pearson product-moment correlations between nutrient intake and lean mass (LM; kg), fat free mass index (FFMI), and combined handgrip strength (CGS; kg) for male and female participants. For LM and CGS, Body mass index (BMI; kg/m^2) was controlled.

	Males						**Females**					
	LM		**FFMI**		**CGS**		**LM**		**FFMI**		**CGS**	
Nutrient	***r***	***p***	***r***	***p***	***r***	***p***	***r***	***p***	***r***	***p***	***r***	***p***
Total Energy intake (kcals)	-0.143	0.221	-0.228	0.108	-0.118	0.137	**0.388**	**0.016***	**0.306**	**0.044***	0.005	0.489
Protein (g)	0.024	0.449	-0.179	0.167	-0.211	0.132	**0.377**	**0.018***	**0.341**	**0.028***	0.007	0.485
Protein (g/kg)	0.125	0.256	-0.441	**0.006***	0.154	0.208	0.209	0.130	0.144	0.216	0.018	0.461
Vitamin D (mcg)	0.263	0.080	0.170	0.180	0.017	0.465	**0.383**	**0.017***	**0.366**	**0.020***	0.010	0.479
Calcium (mg)	-0.044	0.818	-0.251	0.175	0.040	0.419	0.113	0.272	0.012	0.475	-0.168	0.365

*p (1-tailed) < 0.05

Correlation of FFMI and strength to dietary Intake

Correlations of dietary intake and LM (kg), FFMI, and CGS (kg) were analyzed on the total cohort separated by sex (Table 6). Since significant relationships existed between BMI and LM and CGS for both males and females, BMI was controlled for. Dietary intakes of protein (g/kg) (r = -0.441) were correlated with FFMI for males. For females, FFMI and LM were both correlated with total energy intake (r = 0.306, r = 0.388), protein (g) (r = 0.341, r = 0.377), and vit D (r = 0.366, r = 0.383); respectively (Table 5). No nutrients were correlated with CGS for males and females.

Predictive capacity of dietary intake and FFMI and LM

Regression models were attempted using the nutrients that were significantly correlated with LM and FFMI (Table 5) while

Table 6a: Multivariate regression model combining age (yrs), sex (male = 1, female = 2), and vitamin D (mg), intake from food and supplements to predict fat free mass index (FFMI) (*n* = 62).

Predictor Variables	*DF*	Parameter Estimate	SE	*β* value	Pr > |*t*|	VIF	*Adj. R²*
Intercept	1	33.999	3.571	0	<0.0001	0	
Age	1	-0.139	0.043	-0.241	<0.0001	1.072	
Sex	1	-4.726	0.415	-0.880	0.0020	1.128	
Vitamin D	1	0.045	0.019	-0.178	0.0210	1.063	0.672

DF = degrees of freedom; SE = standard error of the estimate; VIF = variance inflation factor; *Adj.* R^2 = adjusted R^2; Pr > /*t*/= 2-tailed

Table 6b: Multivariate regression model combining age (years), sex (male = 1, female = 2), body mass index (BMI; kg/m²), and vitamin D (mg) intake from food and supplements to predict lean mass (LM; kg) (*n* = 62).

Predictor Variables	*DF*	Parameter Estimate	SE	*β* value	Pr > |*t*|	VIF	Adj. *R²*
Intercept	1	88.542	13.957	0	<0.0001	0	
Age	1	-0326	0.144	-0.129	0.0281	1.154	
Sex	1	-21.451	1.358	-0.912	<0.0001	1.177	
BMI	1	0.582	0.182	0.178	0.0021	1.098	
Vitamin D	1	0.145	0.060	0.132	0.0190	1.063	0.825

DF = degrees of freedom; SE = standard error of the estimate; VIF = variance inflation factor; *Adj.* R^2 = adjusted R^2; Pr > /*t*/= 2-tailed

adjusting for sex (1 = male, 2 = female), age, and BMI (LM only). Vitamin D was the only nutrient that increased the predictive capacity of the models. For the first model (Table 6a), age (β = -0.247) and sex (β = -0.839) explained 65% of the variance in FFMI (Adj. R^2 = 0.646). When vitamin D was added to the model, age (β = -0.241), sex (β = -0.880), and vit. D (β = 0.178) explained 67% of the variance (Adj. R^2 = 0.672) in FFMI (Table 6a). For the second regression model, age (β = -0.133), sex (β = -0.880), and BMI (β = -0.181) explained 81% of the variance in LM (Adj. R^2 = 0.810). When vit. D was added to the model, age (β = -0.129), sex (β = -0.912), BMI (β = 0.179), and vit. D (β = 0.132) predicted 83% of the variance in LM (Adj. R^2 = 0.825) (Table 6b). Therefore, the incorporation of vit. D increased the predictive capacity of the models by 2%.

DISCUSSION

The purpose of this study was to examine, in a cohort of community-dwelling adults 70 years of age and older with high SES, the dietary intake and risk of inadequate intake of nutrients from food alone. We also determined the prevalence of dietary supplement use and whether those that supplemented their diet consumed a healthier diet than those who were non-users. Finally, the relationships between nutrient intake and LM, FFMI, and CGS were investigated, since research has previously reported a decrease in lean muscle mass and strength with age [12], and research is accumulating to support the role of diet in lean mass and strength.

Nutrient intake and comparison to other research

The majority of males in the present cohort were at risk for inadequate intake (< EAR) from food alone of vit A (53%), D (90%), E (90%), and calcium (61%), magnesium (61%), and zinc (58%); and the majority of females for vit D (84%) and E (84%) and calcium (71%). Previous research has indicated that individuals with a higher SES tend to select healthier food choices [9]. However, the percentage at risk in this cohort was similar to nationally representative studies in Canada (CCHS) [6,7] for many of the nutrients examined. The present male cohort had a higher risk of inadequate intake of vit B-3 (16% vs. <3%), B-6 (35% vs. 21%), folate (42% vs. 29%), and zinc (58% vs. 41%), and a lower risk of inadequate intake of calcium (61% vs. 90%) and magnesium (61% vs. 73%) than the CCHS population. For females, the present cohort had a lower risk of inadequate intake of vit B-6 (19% vs. 36%) and calcium (71% vs. 91%) than the CCHS data [6,7]. Similar risks of inadequate intake for vit D were observed for both cohorts. Caution must be taken when interpreting inadequate intakes of vitamin D, since it can also be synthesized by the body from UV radiation. Although there appears to be a high prevalence of inadequate intake of vit D, widespread deficiency has not been shown to be present in the population [30,31]. Finally, we were unable to compare our cohort values of vit E intake with those from the CCHS, since it was not analyzed for risk of inadequate intake. In general, we were surprised to find that this cohort with a high SES was at a similar nutrition risk as those from lower socioecomonic profiles.

Dietary supplement use

The prevalence of dietary supplement use in our cohort was 56%, with the most frequently reported supplement being a MVMM (31%). A greater percentage of females (61%) reported supplementing their diet than males (52%). Research collected from CCHS reported similar values, with 51% of adults >50 years of age taking supplements, and a greater percentage of females supplementing their diet than males [32]. When the cohort was separated into supplement users and non-users, both groups of males were found to consume similar diets, since there were no significant differences in mean intake values or risk of inadequate intakes. For females, supplement users consumed similar intakes of micronutrients from food, with the exception of calcium where a greater mean intake from food alone was consumed by supplement users than non-users. This is in contrast to numerous studies documenting that more nutritious diets are consumed by supplement users than non-users [33-35]. The high educational level of the current cohort may be a potential reason for this discrepancy [36,37], since nutrition experts have focused on educating Canadians to consume a diet rich in micronutrient-dense foods rather than relying on supplement intake for daily nutrition, with the exception of vitamin D and B-12 [38]. Even in higher SES backgrounds, it appears to still be a challenge to achieve the EAR values for many nutrients in the oldest age category of the DRIs. This may be due to the decrease in caloric needs with age, or merely selecting foods with lower micronutrient profiles.

With the increased use of dietary supplements over the past decade, there is concern that supplement users may exceed the tolerable upper limit (UL) of nutrients. In the current study, the use of supplements led to intakes above the UL for niacin (46% males and 85% females), folate (15% males and females), and magnesium (62% males and 54% females). Previous studies have reported similar percentages, with the addition of intakes above the UL for vitamin A and iron [4,39]. However, it has been recommended that caution must be taken when interpreting risk above the tolerable UL since these levels are based on limited research [1,25,40]. Sodium consumption was also very high in this population, with 55% of males and 29% of females consuming amounts above the UL (2300 mg/d). CCHS data has reported higher intakes, with 77% of males and 45% of females >70 years of age consuming amounts above the UL [41]. Excessive intake of sodium above the UL has been implemented in hypertension, a major risk factor for cardiovascular disease, stroke, and renal disease [42].

Nutrient intake and LM, FFMI, and CGS

When evaluating the relationships between nutrient status and LM and FFMI, higher total energy, protein, and vit D intake were correlated with greater LM and FFMI for females. For males, protein was the only nutrient correlated with FFMI, and none of the nutrients were correlated with LM. We did not find any significant relationships between nutrient intake and CGS for both males and females. Two regression equations were produced to predict LM and FFMI using dietary intake of vit D while accounting for age, sex, and BMI (LM only). The strongest model predicted LM and explained 83% of the variation within the cohort. Previous research has reported significant correlations between intake of protein and lean muscle mass, which is not surprising, given the necessity of amino acids for protein synthesis [43]. Inadequate intake of vit D is common in older adults, since this age group typically consumes lower amounts of vit D from dietary sources (reduced intake of milk with age), and few dietary sources of vit D exist. In addition, older adults experience a reduced cutaneous synthesis of vit D when exposed to ultraviolet B radiation, and have a decreased number of nuclear 1, 25 vit D receptors (VDR) in the muscle [44]. Skeletal muscle VDR may bind 1, 23-dihydroxyvitamin D (1, 25OHD3), the active form of vit D and promote protein synthesis [44]. Research has demonstrated that VDR polymorphisms are associated with lower lean mass and strength [45-47]. Further, we found that vitamin D intake along with age and sex can predict FFMI in the current cohort. However, we found no association between vitamin D status and CGS. In addition to protein and vitamin D, magnesium, selenium, and zinc intake were also positive predictors of FFMI for females (data not shown). Mechanisms by which these nutrients are associated with muscle mass have been suggested to be multifactorial, in that these nutrients mediate age-related hormonal or immunological changes that are involved in skeletal muscle anabolism [43].

Since vitamin D is obtained in very small amounts in food and very few foods contain vitamin D, it is difficult to attain the RDA requirements from food alone without supplementation. In our cohort, the majority of males and females did not attain the EAR requirements through diet. Since we have found that low vitamin D intakes are related to low FFMI, it is important that older adults consume at least 10 mcg/day to meet the EAR, or more optimally, 20 mcg/day to meet the RDA [25].

FUTURE STUDIES

The influence of nutrition on physical parameters in older adults is best explored through intervention designs. Future studies could attempt to provide additional research into whether vitamin D supplementation in older adults with low vit. D serum levels results in an increase in muscle fibre area and overall muscle mass over a period of time. Limitations to the current study include the cross-sectional design, small sample size, and the use of self-reported dietary intake.

CONCLUSION

In general, many older adults face the challenge of consuming fewer calories from food while the need for micronutrients remains the same or increases. For these reasons, consumption of micronutrient dense foods is essential, and if this cannot be achieved, the use of dietary supplements may be needed. In the current cohort, the majority of male participants consumed inadequate dietary intakes from food of vit A, D, E, and calcium, magnesium, and zinc. For females, these micronutrients included vit D and E, and calcium. When we examined the influence of supplement use on nutrient intake, supplement users did not consume more healthy diets than supplement non-users, with the exception of calcium for females. Further, we were unable to conclude that our cohort with higher socioeconomic status has an overall less risk of inadequate intake from food in comparison to data collected by the CHMS [6,7]. However, it appears that higher socioeconomic status may be associated with less risk for inadequate intake of calcium and magnesium for males and calcium for females, but an increased risk of inadequate intake for vit B-3, B-6, folate, and zinc for males. Finally, a participant's age, sex, BMI, and vit D intake from food and supplements was used to successfully predict FFMI. Understanding these relationships is essential for the management of the ongoing health of Canadian seniors.

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