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Observational cohort study of highly functioning community-dwelling older adults to assess their sarcopenic status, leisure physical activity, and quality of life over 12-months

A.G. Juby [a,*], C.M.J. Davis [b], S. Minimaana [c], D.R. Mager [d]

[a] Department of Medicine, Division of Geriatrics, Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta, Canada
[b] Faculty of Kinesiology, University of Alberta, Edmonton, Alberta, Canada
[c] Faculty of Science, University of Alberta, Edmonton, Alberta, Canada
[d] Faculty of Agriculture, Food and Nutrition Sciences, University of Alberta, Edmonton, Alberta, Canada

A B S T R A C T

Background: The prevalence of sarcopenia varies depending on the cohort evaluated, and the diagnostic criteria used. Older adults with sarcopenia report lower quality of life than their non-sarcopenic peers. Leisure physical activity is reported to have a variable effect on sarcopenic status. Most studies to date, have been done in "vulnerable" populations, with fewer done on independent community-dwelling older adults. None have been done in an Alberta, Canada population.

Objectives: To prospectively evaluate the sarcopenic status of independent community-dwelling older Albertan adults; whether this changed over 12-months; and any association with self-reported leisure activity or quality of life.

Methods: Independent community-dwelling older adults were invited to participate in a 12-month observational study. Assessments were done at baseline, 6 and 12-months for physical function (TUG, SPPB, gait speed, Tinetti, grip strength), muscle mass (DXA, arm and calf circumference), body fat (skinfold, DXA), reported daily exercise (aerobic, resistance), quality of life (EQ5D), and laboratory parameters. European Working Group on Sarcopenia in Older People (EWGSOP) definitions of sarcopenic status were used.

Results: All 50 participants (11 male), were independent of all basic activities of daily living at baseline, and most instrumental activities (some needed assistance with driving or finances). They had an average age of 75.8 (67–90) years, with average MMSE and MoCA cognitive scores of 28.1/30 (20–30) and 24.8/30 (14–30) respectively. Eight participants dropped out prior to their first DXA test. Of the remaining 42, 17 participants (5 male) fulfilled the EWGSOP revised criteria for probable, pre-sarcopenia, or sarcopenia, giving a rate of baseline total sarcopenia of 40.5% in this community-dwelling sample. The majority were pre-sarcopenic (28.6%), and sarcopenia was present only in 7.1%. The total sarcopenia group had a lower BMI (25.6 ± 5.1 versus 29 ± 5, $p = 0.01$), less body fat by skinfold measurement (36.4 ± 6.5 versus 39.3 ± 8.1, $p = 0.01$) and lower mid-calf (35.6 ± 3.2 versus 37.6 ± 3.4, $p = 0.04$) and mid-arm (29.1 ± 2.5 versus 31.9 ± 3.5, $p = 0.02$) circumferences when compared to their non-sarcopenic peers. After 12-months, 39 participants remained in the study. Of these, the sarcopenic status of 7 improved, 10 declined, with the remaining 56% not changing. There were no statistically significant differences in baseline laboratory parameters between the groups, including 25(OH)D status. But, of the status decliners, 40% had suboptimal 25(OH)D at baseline. Self-reported leisure activity (both total time and frequency) was not associated with sarcopenic status at 12-months. EuroQol -5D was not associated with sarcopenic status.

Conclusions: The rate of sarcopenia was 7.1%, but the total rate of pre, probable and sarcopenia in this highly functioning, community-dwelling older adult cohort was 40.5%. In the majority (75%), there was either no change, or an improvement, in their sarcopenic status over 12-months. There was no association identified with self-reported leisure activity or quality of life in this cohort.

* Corresponding author. Department of Medicine, University of AlbertaDivision of Geriatric Medicine 1-198 Clinical Sciences Building, University of Alberta 11350 - 83 Avenue, Edmonton, AB, Canada, T6G 2P4.
E-mail address: ajuby@ualberta.ca (A.G. Juby).

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1. Background

Sarcopenia impairs the ability to perform activities of daily living, and leads to mobility disorders and loss of independence, impairs quality of life (QoL), and increases the need for long-term care placement [1]. Like many other diseases, sarcopenia is asymptomatic in its initial stage [1]. The etiology of sarcopenia is multi factorial, including a sedentary lifestyle, hormone and cytokinin imbalances, decline in skeletal muscle protein synthesis and regeneration, changes in the skeletal muscle motor unit remodeling [2], smoking, malnutrition, and extreme (too long and too short) sleep duration [3]. Commonly used diagnostic criteria are the European Working Group on Sarcopenia in Older People (EWGSOP) criteria (now revised) [4], or the International Working Group on Sarcopenia (IWGS) criteria [5,6]. To add to the diagnostic challenges, the rising prevalence of obesity often masks underlying sarcopenia. This has been shown in a general Dutch population (aged 18–90) where although the overall prevalence of sarcopenic obesity was only 0.9–1.4%, over 80% with sarcopenic obesity were <70-years of age [7]. This highlights the sarcopenia awareness needed by both general physicians and geriatric specialists. Sarcopenic obesity is associated with even greater risks of increased morbidity and mortality [8].

The prevalence of sarcopenia reported in the literature varies according to the population being studied and the diagnostic criteria used, and ranges from 2.5% to 36.5% [3–6,9–12]. Using the EWGSOP revised criteria, recent data from the Canadian Longitudinal Study on Aging (CLSA) [13], reported a prevalence of sarcopenia of 0.2%, and severe sarcopenia of 1.2%. However, when using the IWGS criteria in this same population, the sarcopenia prevalence is reported as 6.7%. The IWGS criteria differ in that the gait speed cut-off for sarcopenia is higher (<1.0 m/s versus <0.8 m/s), as is the grip strength cut-off for both sexes, accounting for the higher prevalence with this tool [13].

Physical exercise, especially including resistance training, has been shown to be the most beneficial intervention in prevention of sarcopenia [14] as well as preventing its progression [15]. Ideally, exercise training should include both aerobic and resistance exercises to improve muscle mass and strength [16]. But studies have also shown that resistance training alone [17] and aerobic exercise alone, can improve muscle mass and strength, in addition to it's cardiorespiratory and metabolic benefit [18]. Exercise programs in clinical trials are usually supervised by trained exercise therapists and are intensive and personalised. In contrast, general leisure activity is felt to *not* be sufficient to prevent decline in muscle mass [19,20], but may benefit muscle strength. A study using an intervention with pilates [21] suggested supervised leisure activities may be the most important factor [22]. Community-dwelling individuals are usually more physically active and have a better dietary regimen [23,24] and therefore should have less sarcopenia. Nursing home residents report more sedentary activities, were less likely to report being currently physically active, and were also more likely to be malnourished, and reportedly have a higher prevalence of sarcopenia [25,26]. Community-dwelling individuals are more likely to be sarcopenic only in situations where they are less physically active and lack good nutritional status [27–31], or consume excess alcohol [32].

Adults with sarcopenia have been shown to have a decreased quality of life (QoL) on general measures of QoL (such as Short-form General Health Survey (SF-36) and the EuroQol-5D instruments (EQ-5D)) [33], including community dwelling individuals [34]. Therefore, assessment of QoL-related to sarcopenia constitutes an important aspect of sarcopenia assessment.

Despite health care providers being aware of the evidence of significant negative effects of sarcopenia on morbidity and mortality, the varied definitions have resulted in confusion among community practitioners not specialising in sarcopenia. A recent study described the current knowledge and practice regarding sarcopenia in a group of health-care professionals in Australia and New Zealand [35]. They reported that the lack of a clear diagnostic tool available in a clinical setting makes assessing sarcopenia, or even considering it, challenging [35]. This has led to a rather nihilistic approach to making the diagnosis of sarcopenia [4]. To simplify assessment, diagnostic tools have recently been updated to focus on muscle function over muscle mass and strength [4], such as use of the chair stand test for evaluation of both muscle strength and function [36].

Sarcopenic status and its relationship with quality of life and leisure activity has not been evaluated in a Canadian community-dwelling population. This study was undertaken to evaluate the rate of sarcopenia in a group of highly functioning (independent living) community-dwelling Albertan older adults using the EWGSOP sarcopenia criteria. Over the 12-months of the study, self-reported physical activity and quality of life were also evaluated. Sarcopenic status was re-evaluated at 12-months to assess for any change, and if so, if there were any potential contributing factors.

2. Hypotheses

1) The rate of sarcopenia in this cohort of highly functioning, community-dwelling older adults will approximate 2.5%, similar to the lowest rate reported in a comparable independent community-dwelling Taiwanese cohort also using EWGSOP diagnostic criteria [11].
2) Higher leisure-based physical activity will be associated with a reduced rate of sarcopenia, and increased muscle strength (but not muscle mass).
3) Quality of life will be associated with sarcopenic status.

2.1. Objectives

The primary objectives were to evaluate the sarcopenic status of a group of independently functioning community-dwelling older adults at baseline, and to evaluate whether their sarcopenic status changed over 12-months.

Secondary objectives were to evaluate: the amount of self-reported physical exercise over 12-months and its effect on sarcopenic

status, muscle mass and muscle strength; baseline laboratory parameter influence on sarcopenic status; the rate of obesity and sarcopenic obesity; and self-reported quality of life and sarcopenic status.

3. Methods

3.1. Study design and participants

This is a 12-month prospective, observational, single centre, cohort study, of highly functioning community-dwelling older adults (aged over 65-years) residing in the greater Edmonton area in Alberta, Canada. Participants were recruited by direct contact from a list of older adults expressing interest in participating in clinical trials, and by advertisements through older adult community organizations.

Using a population proportion of 2.5% sarcopenia, based on lowest level of comparable population data [11] with a confidence level of 95% and margin of error of 5%, a minimum sample size of 38 participants was needed. The CLSA data [13] was not published at the time of this study.

Inclusion criteria: age ≥65-years; English speaking; independent mobility (with or without walking aids); living independently (alone or with spouse); independent of basic activities of daily living (ADLs) and most instrumental ADLs; no formal support (homecare or nursing); and stable chronic medical conditions (e.g. diabetes, hypertension, hypothyroidism, depression).

Exclusion criteria: pacemaker or implanted device; chronic peripheral oedema; dependent for all instrumental ADLs; and unstable medical conditions.

Ethics approval was obtained through the University of Alberta Health Research Ethics Board (Pro00047132).

3.2. Study protocol

Participants had evaluations at baseline, six-months, and 12-months, at the same study site, by the same study evaluators (AGJ for geriatric assessment, cognitive testing, skinfold, waist circumference, and arm and calf measurements; CMJD and SM for all physical tests). Participants self-completed the QoL scale and physical activity reports. DXA body composition evaluations were done off-site at the same Medical Imaging Consultants (MIC) imaging location at baseline and 12-months, by qualified technicians independent of the study and blinded to the participant's performance results.

Each visit the following evaluations were done following standard testing protocols: Comprehensive Geriatric Assessment and cognitive evaluations *MMSE* [37] and *MoCA* [38] (The MMSE is an easier cognitive test, designed for general population screening, and in this independent cohort likely to have a ceiling effect. Thus, the MoCA was also included as this is a more challenging cognitive test, designed to screen for earlier cognitive deficits seen in mild cognitive impairment, so will be more discriminatory in this group of more highly functioning older adults); *grip strength* [39] (using an Almedic® dynamometer; *physical function* (Timed Up and Go (TUG) [40], Short Physical Performance Battery (SPPB) [41]), gait speed (10 m walk test) [42], Tinetti Gait and Balance scale [43]*; height measurement (cm)* (medical-grade Seca® stadiometer)*; waist and hip circumference (cm)* (to enable calculation of waist/hip ratio); *arm and calf circumference (cm)* by standard protocol following the published guidelines [44–46]; quality of life using *Euroqol-5D* validated questionnaire [47]; and laboratory parameters (see details in results section) which were analyzed in the laboratories of Alberta Health Services according to standard methodology.

Physical Activity record was completed by participants to report their average daily exercise routines. This included type, length of time, and frequency of exercise. Based on their reports it was classified as aerobic (eg. Walking, golf, pickle ball), resistance (eg. Weightlifting or resistance band exercises) or both (eg. Yoga). The few with short term memory issues were aided by their caregiver to complete this task.

At baseline and 12-month visits only: *Muscle mass* was assessed by DXA body composition (Hologic® Discovery DXA, Bedford MA/USA). Tests were performed by DXA-trained radiology technologists from Medical Imaging Consultants (MIC) Diagnostic Imaging, Edmonton, Canada.

Body fat (mm) by 3-site skinfold thickness (using Creative health products, Michigan, skinfold calipers) following standard protocols [38], and DXA body composition (only at baseline and 12-months).

3.3. Study cut-offs and definitions

For **DXA**, **low muscle mass** was defined as calculated appendicular lean muscle mass ÷ height^2 (ALM/ht^2) as ≤ 7.0 kg/m^2 in men and ≤5.5 kg/m^2 in women [4].

Obesity was defined as a ***body fat*** composition of >25% in men, and >35% in women [4] for DXA and total skinfold thickness. For ***BMI***, obesity was defined as a BMI >30. Skinfold thickness was measured at subscapular, supra-iliac and triceps, and the total thickness in mm combined. Using standardised charts (based on the Jackson Pollock equations), corrected for age and sex, percentage body fat was estimated [45].

Physical performance evaluation was using gait speed. Based on European Working Group on Sarcopenia in Older People (EWGSOP) defined low gait speed as a cut-off of ***gait speed*** <0.8 m/s [4].

Physical strength was assessed using ***grip strength*** with EWGSOP defined cut-offs of <16 kg *(women) and* <27 kg *(men)* for low grip strength [4].

"Sarcopenic group" included all participants classified by EWGSOP2 guidelines as *pre-sarcopenia (low muscle mass only), probable*

sarcopenia, sarcopenia, or *severe sarcopenia.* (See Table 1). Those with just low gait speed were classified as "slow", and as there is no classification for them under the EWGSOP2 criteria, and were included in the "non sarcopenic" group.

3.4. Statistical analysis

Data analysis was done by a member of the study team (DRM) who was not involved in any data collection and who had no knowledge of the individual participants, to prevent any bias during the analysis.

Data analysis was completed using SAS 9.0 statistical software (SAS, Version 9.4; SAS 124 Institute Inc., USA). Data was expressed as mean ± SD for variables showing normal distributions and/or median [interquartile range] for non-parametric variables The Shapiro-Wilk test was conducted to assess the normality of distribution. At baseline, t-tests (parametric) and/or Mann Whitney tests (non-parametric variables) were done to determine differences in anthropometric, demographic and laboratory variables between sarcopenic vs non-sarcopenic participants. Paired t-tests (parametric variables) and Wilcoxon tests (non-parametric) were performed to determine differences between baseline and 12-month time points for anthropometric, demographic, laboratory, functional measures, and body composition. In addition, univariate and multi-variate correlations were performed to determine associations between physical activity and outcomes of interest (body composition, functional tests). Analysis of co-variance for potential confounding variables (sex, age) was used where needed. Frequency and duration of self-reported physical activity were analyzed as both a continuous variable (exercise frequency and time) and as a categorical variable ($\geq$and $<$ median). A chi square test (or when necessary, Fisher Exact test) was used for categorical variables. For relationships as a continuous variable Spearman correlations were used. A difference with a p value < 0.05 was considered significant.

4. Results

4.1. Participants

Fifty-seven participants expressed interest in the study. Visits were scheduled for June/July, December/January, and the following June/July. Seven were unable to participate as they were "snowbirds" and would miss the six-month visit. Of 50 participants enrolled, 11 were male and 39 female. All were independent of basic activities of daily living at baseline, and most instrumental activities (some needed assistance with driving, finances). Table 2 shows their baseline information.

Eight dropped out (3 males): 6 no longer being interested after visit one; 1 due to caregiver responsibilities; and 1 due to declining physical health.

Of the remaining 42 participants, the average age was 75.8 (67–90) years, and BMI was 28 (18.8–39.2). Average MMSE cognitive scores were 28.4/30 (20–30) (normal adjusted score 22–26/30). For the MoCA, the average was 25.7/30 (14–30), normal score $\geq$26/30.

Forty-two completed the DXA body composition at baseline (8 males and 34 females).

4.2. Sarcopenic status at baseline

Participants were classified as *normal, slow* (defined by low physical performance only), *pre-sarcopenic, sarcopenic* or *severely sarcopenic* as per EWGSOP criteria and cut-offs (see Table 1).

Using DXA cut-offs (ALM/ht^2), 17 had low muscle mass at baseline. These participants (5 males and 12 females) were in the "total sarcopenia group", fulfilling the criteria for sarcopenia which included all the stages from pre-sarcopenic to sarcopenic. There were no severe sarcopenic participants at baseline, and 2 females classified as "slow". Twenty-three were classified as normal (54.8%), 3 men and 20 women.

As a cohort, and not a cross-sectional study, sarcopenia presence or absence is reported as rates and percentages, and not prevalence. The percentage of participants in the *"total sarcopenia group" (probable + pre + sarcopenic + severe sarcopenia*) was **40.5%** of whom **28.6%** had *pre-sarcopenia*. The number with *sarcopenia only* (sarcopenia + severe sarcopenia) was **7.1%.** See Fig. 1, Tables 3 and 4 show the baseline demographic features between the total sarcopenia and non-sarcopenia participants.

Sarcopenia group status was not associated with baseline cognitive function, MMSE ($p = 0.35$) and MoCA ($p = 0.44$), or IADLs ($p = 0.09$). The sarcopenia group had a *lower BMI* (25.6 ± 5.1 versus 29 ± 5, $p = 0.01$), *less body fat* by skinfold measurement (36.4 ± 6.5

Table 1
Definition of Sarcopenia categories (adapted from EWGSOP consensus [4] plus "slow classification).

	Low muscle strength	Low muscle mass (quantity) or quality	Low physical performance	Obesity
Pre-sarcopenia	0	✓	0	
Probable sarcopenia	✓	0	0	
Sarcopenia	✓	✓	0	0
Severe sarcopenia	✓	✓	✓	0
Sarcopenic obesity	✓	✓	✓or 0	✓
"Slow"	0	0	✓	

(√ denotes present, 0 denotes absent).

Table 2
Baseline demographic data by sex. Data are mean ± SD and/or median (interquartile range).

Variable Name	Male (n = 11)	Female (n = 39)	P-value
Age (years)	78.9 ± 5.1	74.9 ± 4.6	0.02*
MMSE**	27 ± 2.8	28 ± 2.4	0.10
MoCA##	22.3 ± 4.2	25.6 ± 4.4	0.04*
Weight (kg)	76.1 ± 12.2	72.7 ± 12.6	0.09
Height (cm)	173 ± 7.0	159 ± 5.4	<0.00*
BMI	28.9 ± 4.8	27.8 ± 5.4	0.53
Waist to hip ratio	1.00 ± 0.06	0.84 ± 0.08	0.001*
Fat (skinfold) (%)	28.9 ± 5.8	41.3 ± 5.9	<0.001*
Fat (DXA) (%)	30.8 ± 5.2	40.7 ± 6.8	0.004*
Gait speed (m/s)	1.5 ± 0.9	1.4 ± 0.3	0.53
Grip strength (kg)	31.4 ± 6.7	20.7 ± 5.2	<0.001*

(*denotes statistical significance) (** MMSE: normal range ≥22/30, ##MoCA: normal range ≥26/30).
Abbreviations: MMSE: Mini Mental Status Examination; MoCA: Montreal Cognitive Assessment.

versus 39.3 ± 8.1, p = 0.01), and *lower calf* (35.6 ± 3.2 versus 37.6 ± 3.4, p = 0.04) and *arm* (29.1 ± 2.5 versus 31.9 ± 3.5, p = 0.02) *circumferences* when compared to their non-sarcopenia peers. See Tables 3 and 4

There were no statistically significant differences in baseline laboratory parameters between the two groups, including 25(OH)D status. See Table 5.

4.3. Participant status/dropouts at 12-months

At baseline there were 42 participants enrolled in the study. During the study there were 3 dropouts, all females, who were unable to complete the final visit leaving *39 participants at* 12-months. Reasons for dropouts were poor health in 2, and generalised pain in 1. For the 3 dropouts 2 were normal, and one pre-sarcopenic at baseline.

4.4. Sarcopenic status at 12-months

At 12-months, 39 participants completed their second DXA BC test (8 males and 31 females). The sarcopenic status evaluated at 12-months in all participants is shown in Fig. 2, comparing baseline status in all, to 12-month evaluations. For 54% of participants, there was no change in their sarcopenic status. However, 29.7% did have a decline, and 6% improved.

For those whose sarcopenic status ***declined*** (4 male, and 7 female), 7 moved from normal to probable because of a decline in their grip strength, 2 moved from normal to pre-sarcopenia (due to a decline in muscle mass), 1 moved from pre-sarcopenia to sarcopenia (due to a decline in grip strength), and 1 moved from sarcopenia to severe sarcopenia due to decreased gait speed. The EQ5D VAS scale score did not reflect this decline in sarcopenic status. 82% of decliners had concomitant obesity (defined by DXA percentage body fat).

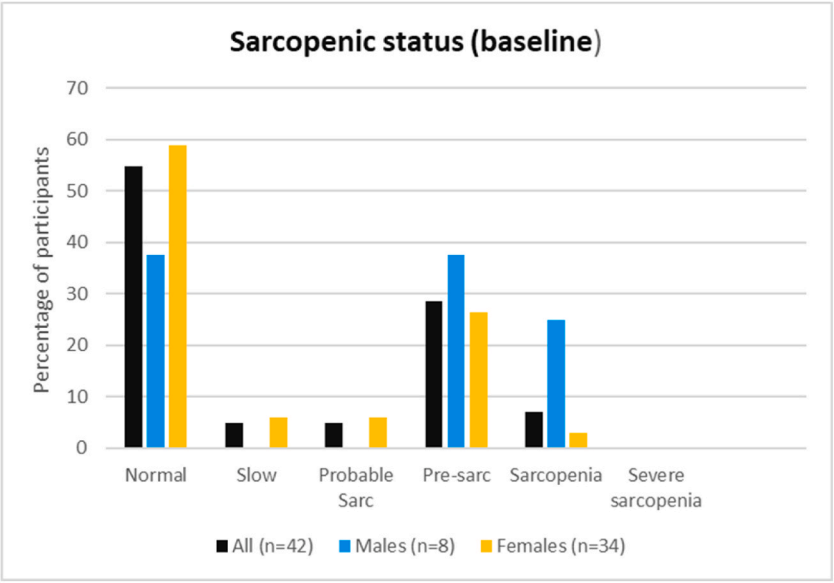

Fig. 1. Sarcopenic status at baseline.

Table 3
Anthropometric and Demographic data at baseline.

Variable Name	Total Sarcopenia group (includes probable, pre-, and sarcopenic) (n = 17)	Non-Sarcopenia group (includes "slow" and normal) (n = 25)	P-value
Sex (M/F)	5/12	3/22	0.82
Age (years)	76.6 ± 4.3	75 ± 5.2	0.13
Weight (kg)	64.8 ± 11.9	72.7 ± 12/6	0.02
Height (cm)	162 ± 7.3	163 ± 8.2	0.31
BMI	25.6 ± 5.1	29 ± 5	0.01*
Waist to hip ratio	0.85 ± 0.1	0.89 ± 0.1	0.45
Fat (skinfold) (%)	36.4 ± 6.5	39.3 ± 8.1	0.01*
Fat (DXA) (%)	38 ± 6.4	39.2 ± 8.4	0.29
Calf circumference (cm)	35.6 ± 3.2	37.6 ± 3.4	0.04*
Arm circumference (cm)	29.1 ± 2.5	31.9 ± 3.5	0.02*
Total skinfold (mm)	74.7 ± 26.2	95.7 ± 38.9	0.006*

(*denotes statistical significance).

Table 4
Baseline cognitive, functional, and quality of life status.

Variable	Total Sarcopenia group (includes probable, pre-, and sarcopenic) (n = 17)	Non-Sarcopenia group (includes "slow" and normal) (n = 25)	P-value
Cognition			
MMSE **	28.4 ± 1.9	28 ± 2.7	0.35
MOCA##	24.5 ± 2.9	24.9 ± 5.2	0.44
Function			
BADL	1.0	5.7 ± 5.8	0.57
IADL	8 ± 4.2	16.3 ± 11,8	0.09
SPPB (sec)	11.8 ± 4.6	12.9 ± 6.1	0.73
Total walk	3.4 ± 1	2.9 ± 0.9	0.29
SC Walk	3 ± 0.9	3.6 ± 0.7	0.01*
TUG (sec)	12 ± 5.8	10 ± 4.1	0.09
TEN (average) (sec)	5.6 ± 2.1	4.6 ± 1.4	0.02*
TIN-Balance	14.8 ± 2.3	15.3 ± 1.5	0.09
TIN-GAIT	10.7 ± 2.2	11.1 ± 1.4	0.62
TIN-Total	25.5 ± 4.3	26.3 ± 2.7	0.19
Hand grip 1 (kg)	20.7 ± 6.6	24.4 ± 7.2	0.07
Hand grip 2 (kg)	21.4 ± 8.7	22.4 ± 6.7	0.11
SQ1 (sec)	11.5 ± 4.1	11.1 ± 2.9	0.46
SQ2 (sec)	10.9 ± 3.6	10.4 ± 2.1	0.16
Quality of Life			
EQ 5D VAS	76.8 +/18.5	85.7 +/10.1	0.06
EQ 5D mobility	1.9 ± 1.0	1.8 ± 1.0	0.38
EQ5D self care	1.3 ± 0.6	1 ± 0	0.07
EQ5D usual activities	1.9 ± 1.1	1.3 ± 0.6	0.05
EQ5D pain	1.9 ± 0.7	2.1 ± 0.7	0.51
EQ5D anxiety/depression	1.6 ± 1.0	1.3 ± 0.5	0.18

(*denotes statistical significance, ** MMSE: normal range ≥22/30, ##MoCA: normal range ≥26/30).
Abbreviations: MMSE: Mini Mental Status Examination; MoCA: Montreal Cognitive Assessment; BADL: Basic Activities of Daily Living; IADL: Instrumental Activities of Daily Living; SPPB: Short Physical Performance Battery; SPPB walk score: gait ordinal score for 8 feetwalk; TUG: Timed Up and Go test; TEN: 10 Meter Walk test; TIN: Tinetti Gait and Balance scale; SQ: Square Step test; EQ-5D VAS: EuroQol 5D Visual Analogue Scale; EQ-5D mobility: EuroQol 5D mobility score; EQ-5D self care: EuroQol 5D self care score; EQ-5D usual activities: EuroQol 5D usual activities score; EQ-5D pain: EuroQol 5D pain score; EQ-5D anxiety/depression: EuroQol 5D anxiety/depression score.

For the 6 participants (1 male, 5 female), whose sarcopenic status ***improved***, 1 moved from probable to normal, 3 from pre-sarcopenic to normal, 1 from sarcopenia to pre-sarcopenia, and 1 from "slow" to normal. The EQ5D VAS scale score did not reflect this change in sarcopenic status. Only 3 participants showed increased EQ5D VAS, 2 remaining unchanged and 1 declining. 83% of those with improving sarcopenic status had concomitant obesity (defined by DXA percentage body fat).

This descriptive data does not seem to indicate any trend to predict change in sarcopenic status. The number of participants whose status changed is insufficient for statistical analysis.

4.5. Change over 12-months in cognitive function

There were no significant changes in MMSE and MoCA over the study period, and this was consistent when comparing those participants in the sarcopenia or non-sarcopenia groups at 12-months.

Table 5
Laboratory parameters in Sarcopenia versus Non sarcopenia groups.

Variable Name	Total Sarcopenia group (includes probable, pre-, and sarcopenic) (n = 17)	Non-Sarcopenia group (includes "slow" and normal) (n = 25)	P value
25(OH) vitamin D (nM)	101 ± 26	90 ± 29	0.27
Vitamin B12 (pmol/L)	454 ± 226	358 ± 203	0.19
Total protein (g/L)	67.8 ± 4.1	67 ± 4.4	0.81
Albumin (g/L)	42.2 ± 2.2	40.9 ± 2.7	0.10
CRP (mg/L)	3.1 ± 5.5	2.9 ± 3.3	0.99
GGT (U/L)	35.2 ± 53.9	32.8 ± 33.9	0.49
TSH (mU/L)	2.8 ± 0.8	2.2 ± 1.7	0.20
Cholesterol (total) (mmol/L)	5.6 ± 0.7	5 ± 1.1	0.38
Triglyceride (mmol/L)	1.3 ± 0.5	1.2 ± 0.6	0.58
HDL (mmol/L)	1.8 ± 0.4	1.7 ± 0.5	0.46
LDL (mmol/L)	3.1 ± 0.6	2.8 ± 0.90	0.58
Creatinine (umol/L)	72 ± 20	69 ± 18	0.22
GFR (ml/min/1.73m2)	74 ± 15	78 ± 11	0.19
Homocysteine (umol/L)	11.5 ± 3.2	11.4 ± 3.6	0.45
Fasting insulin (pmol/L)	52 ± 39	59 ± 25	0.32
Hemoglobin A1C (%)	5.7 ± 0.3	5.7 ± 0.5	0.81

(Normal reference ranges: 25(OH)D 80–200 nM; B12 > 150 pmol/L; total protein 64–84 g/L; albumin 35–50 g/L; CRP<8.0 mg/L; GGT <70U/L; TSH 0.2–4.0 mU/L; cholesterol <6.2 mmol/L; triglyceride <1.7 mmol/L; HDL >0.9 mmol/L; creatinine50-115μmol/L; GFR >59 ml/min; homocysteine <12.1 μmol/L; fasting insulin 35–140 pmol/L; Hemoglobin A1c 4.3–6.1%).

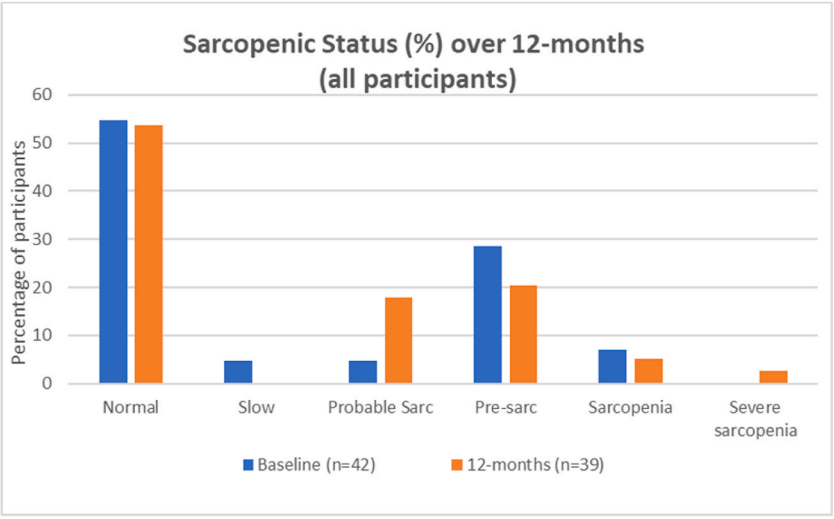

Fig. 2. Baseline versus 12-month sarcopenic status (percentage of all participants).

Table 6
Rate of obesity and sarcopenic obesity using BMI and DXA percentage fat.

	BMI >30	DXA % fat (>25% men, >35% women)
BASELINE	(n = 50)	(n = 42)
All participants	36%	80.9%
Sarcopenic obesity (pre + probable + sarcopenia)	7.5%	64.7%
12-MONTHS	**(n= 39)**	**(n = 39)**
All participants	26%	79.5%
Sarcopenic obesity (pre + probable + sarcopenia)	7.7%	72.2%

Abbreviations: n: number of participants; DXA: Dual energy X-ray absorptiometry; BMI: body mass index (kg/m^2).

4.6. Obesity status

Using ***BMI* >30 kg/m^2,** at baseline, **36%** of participants (n = 50) were obese. Of those who had a DXA (n = 42) with BMI cut-offs ***7.5%*** had concomitant pre, probable or severe sarcopenia, fulfilling the criteria for *sarcopenic obesity*. At 12-months, 26% of remaining participants (n = 39) had obesity, with ***7.7%*** having *sarcopenic obesity*.

However, using ***DXA body composition*** percentage fat criteria (>25% fat in men, and >35% fat in women), **80.9%** of participants (n = 42) had obesity. Using DXA percentage fat cut-offs, at baseline ***64.7%*** participants had concomitant obesity in the total sarcopenia group, and 17.6% in the sarcopenia only group. At 12-months ***72.2%*** in the total sarcopenia group, had concomitant obesity, with 11.1% having sarcopenic obesity or severe sarcopenic obesity. See Table 6.

4.7. Quality of life (QoL)

For quality-of-life parameters in the EuroQol 5-D (EQ5D) tool, questions with a higher score indicate worsening of symptoms, but for the visual analogue scale (VAS) scale question, a higher score indicates improved impression of health. There was an overall *increase in EQ5D self reported pain* score (p = 0.02) over the duration of the study, but there was no difference between total sarcopenic and non-sarcopenic individuals for this parameter (p = 0.21). In contrast, there was a *decrease in EQ5D Self Care scores* over the 12-months (suggesting better function) specifically in the total sarcopenia group participants. In addition, there was a trend towards an increase in EQ5D VAS scores (p = 0.09) in all participants, with the non-sarcopenia group participants having higher scores overall than the total sarcopenia group participants (p = 0.03).

4.8. Self-reported leisure activity level, 12-month evaluation

Evaluation of self-reported leisure activity was done at 12-months by categorizing the reported activity times based on total duration: <30 min; 30–60 min; and >60 min; and frequency ≥ and < a median of 5 times/week. The average reported leisure activity time was 60 min (ranging from 0 to 360), 4 times weekly.

When looking at categorical leisure physical activity time (0–30 min; 30–60 min and >60 min) there was *no difference* in percentage of participants in "total" sarcopenia group versus non-sarcopenic (0–30 min: 61.7% vs 62%; 30–60 min: 23.5% vs 25.8%; >60 min 14.7% vs 12%, p = 0.90). Similarly, there was *no association* found between frequency of leisure physical activity (<5 times/week versus ≥5 times/week) and "total" sarcopenic status (probable + pre + sarcopenic + severe sarcopenic) (p = 0.27), gait speed (p = 0.09) or DXA ALM/ht^2 (p = 0.78).

Looking at a continuous variable of total leisure physical activity time (minutes) there was again *no association* found between total time and sarcopenic status (p = 0.39), gait speed (p = 0.15), or DXA ALM/ht^2 (p = 0.72).

5. Discussion

In this cohort of highly functioning community-dwelling older adults, we hypothesised the rate of sarcopenia would be similar to that of a comparable population from Taiwan [11], but lower than that reported from the USA [10]. However, in this study of Albertans, the rate of sarcopenia was found to be 7.1%, more equivalent to the data from community dwelling populations in the UK reported by Patel and colleagues of 6.6% [9].

This study chose to report a "total" sarcopenia group (probable + pre + sarcopenic + severe sarcopenic) to allow comparison with published studies on similar community dwelling populations in other countries. The percentage of participants in the *total sarcopenia group (probable + pre + sarcopenic + severe* sarcopenic) was 40.5%, of whom 28.6% had *pre-sarcopenia.* The rate with *sarcopenia only* (sarcopenic + severe sarcopenic) was 7.1%. In a large community group (1890 participants) evaluated in Hertfordshire, UK, the overall sarcopenia prevalence reported by Patel and colleagues, was 6.6% (for all participants) and 4.6% in men, and 7.9% in women [9]. With their data grouped in the same way as in this study, the total sarcopenia group (probable + pre + sarcopenic + severe sarcopenic) is 31.6% in their cohort [9]. Similar to the 28.6% in this study, the majority of their participants were in the pre-sarcopenia stage (25%). They did not report on probable sarcopenia. Their cut-offs for grip strength were higher (women <20 kg versus <16 kg, and men <30 kg versus <27 kg), therefore identifying more participants with low grip strength than the present study, and the average age of their participants was10-years younger than this cohort (67 years versus 75 years). Kim and colleagues followed a group of 538 community dwelling Japanese women for 4-years, average age of 78 years [12]. Using bioimpedance assay (BIA) for muscle mass assessment, they found a prevalence of total sarcopenia of 39.6%. Like this study, they included pre-sarcopenia, and severe sarcopenia in this number, but did not assess probable sarcopenia (low muscle strength alone). In the present study, if this group is excluded from the total sarcopenia group, then the percentage becomes 35.7%, and is very comparable to the Japanese group. As in this study, the majority of their total sarcopenia group were pre-sarcopenic (23.8%) with only 11.2% having established sarcopenia.

After completion of the present study, data was published from the Canadian Longitudinal Study on Aging (CLSA) study of community-dwelling older adults from across Canada. Using the EWGSOP criteria Purcell and colleagues [13] reported a prevalence for low muscle mass (pre-sarcopenia) of 5.8% in males and 8.2% in females, but sarcopenia in 0.2% and severe sarcopenia in 1.2%. This is much lower than that reported in the present study, and in that reported by other authors [9–12,48]. However, when using a different sarcopenia diagnostic criteria (IWGS), the CLSA reported rates of sarcopenia are similar to this study, with 5.2% in males and 7.2% in females. The reason for the low reported pre-sarcopenia and sarcopenia in the CLSA study is likely related specifically to their cohort: 93% were Caucasians, 89% never smokers, 84% married, and 51% with Bachelors degree or higher. As a longitudinal study

those in the older age group (70 to >80 years) may have been self-selected by their survival, and being enrolled in a longitudinal study on healthy aging may encourage better general health and physical activity. As a result, this population may not necessarily be reflective of the average Canadian community-dwelling cohort. Nonetheless, their prevalence of obesity (defined by BMI) was 18.6–32.2% [13], similar to the present study of 36%.

In contrast, Brown and colleagues, evaluated a large community-based cohort (4425 older adults 43.5% men and 56.5% women) in the USA, and reported a very high prevalence of 36.5% in their sarcopenia only group [10]. But their definition of sarcopenia was low gait speed + low muscle mass, as opposed to the EWGSOP criteria of low strength (eg. grip) + low muscle mass. They also used BIA and not DXA to assess muscle mass. It is generally accepted that when using cut-off definitions with both BIA and DXA measures, BIA results in higher prevalence estimates than DXA [48]. They also did not assess grip strength, so could not identify any of their participants as probable or severe sarcopenia [10]. Instead, they used gait speed as a measure of muscle strength because of its correlation with lower limb muscle strength [49]. 24.4% had low muscle mass alone (pre-sarcopenia by EWGSOP), which was similar to the present study, but of these, only 14% had normal gait and muscle mass, as opposed to the present study where 54% are in this category. Obesity as defined by BMI was 23.7%, and waist circumference was 57.9% in their cohort [10]. The sarcopenia prevalence reported in their study is also higher than is reported in most other community-based studies [50].

The present study and the ones discussed show the challenge of identify sarcopenia. One systematic review of 15 prevalence studies found the prevalence in community-dwelling populations ranged from 1% to 29% [6]. Whereas another reported prevalence's from 9.9% to 40.4% [48]. Even studies on the same population using different definitions, have found that sarcopenia estimates vary up to 40% by definition used [50]. Cruz-Jentoft stated that "this heterogeneity in published estimates of sarcopenia prevalence may be influenced by multiple factors such as the age and sex distribution of the population, and the methods and cut-points used to measure muscle mass and muscle function to define sarcopenia" [6]. Mayhew summarised the current challenges well, stating that the best definition of sarcopenia will be "the one with the strongest association with the health outcomes relevant to sarcopenia" [51]. Once the definition is firmly established, more precision will be needed at choosing study populations and outcomes [52].

Regarding obesity, this study identified a considerable difference between the diagnosis of obesity when using the BMI cut off ($\geq$30 kg/m^2) versus DXA body composition cut-offs (>25% men, >35% women). DXA was able to detect 2.25 times more participants with obesity. This study confirmed what has been shown in other studies, including by Shah [53] who reported an obesity rate of 26% with BMI, but 2.4 times higher with DXA at 64%, very similar to this study. Based on BMI, the percentage of total sarcopenic obesity in the study was only 7.5% at baseline and 7.7% at 12-months. However, using DXA criteria for obesity, the percentage of total sarcopenic obesity was considerably higher at 65% and 72.2% respectively. This highlights the potential under-recognition of sarcopenic obesity when only BMI criteria are used. In their review on sarcopenic obesity, Zamboni and colleagues emphasise the importance of a clear and decisive definition for sarcopenic obesity [8]. Given the added comorbidities of these two conditions it is important that the obesity component is not overlooked. This could be the case if only BMI criteria is used. To this point, Brown and colleagues reported no particular association of obesity with sarcopenia in their US study, but this may have been a reflection of their definition of obesity [10].

In the present study, those reporting more leisure-based physical activity over the 12-months, somewhat unexpectedly had no measurable difference in sarcopenic status. In addition, self-reported physical activity did not appear to be associated with muscle strength or muscle mass in this cohort in this study. This is unlike our hypothesis, as well as the current published studies. One 3-year study found that although leisure-time physical activity did not seem to prevent decline in muscle mass or fat accumulation, it was associated with higher muscle mass overall [19]. Ko and colleagues recently found a significant protective effect of physical activity on sarcopenia in all older adults in a Taiwanese cohort, even after adjusting for potential confounders [54]. And a recent metanalysis showed an overall benefit and reduction in the odds-ratio of developing sarcopenia in those participating in leisure physical activity [55], with the effect appearing to be greater for females than males.

The reason for the lack of association with sarcopenia in this study may reflect the small cohort, sub-optimal physical activity levels, or a lack of documentation of sedentary time in addition to active time [56]. The average leisure activity time (aerobic and resistance) reported was 60 min, 4 days/week. The American Heart Association (AHA) and the American College of Sports Medicine (ASCM) recommendations, however, are $\geq$30 min per day on $\geq$5 days per week for a total of $\geq$150 min per week for moderate-intensity aerobic exercise, and $\geq$20 min per day on $\geq$3 day per week ($\geq$75 min per week) for vigorous-intensity activity [57]. In addition, to counteract muscle loss and increase strength, resistance exercises are strongly recommended for 2–3 days per week for the major muscle groups, and to include balance, agility, and coordination exercises [57]. Physical activity time and sedentary time have both been shown to influence sarcopenia development. Sedentary time was not captured in the present study. In a male cohort, gait speed and grip strength were positively associated with moderate-to-vigorous physical activity and inversely associated with total sedentary time [56]. In addition, each extra 30-min of sedentary time was associated with an increased risk of severe sarcopenia [56].

We also did not show any association between the quality of life of participants and their sarcopenic status. This may be because a generic QoL tool was used. Generic QoL instruments (such as the EQ5D) have an advantage in that they allow QoL to be compared between a range of populations. However, disease specific instruments often possess better construct validity and are more sensitive to changes in QoL over time [58]. So generic QoL tools may not detect the subtle effects of sarcopenia (or pre-sarcopenia) on quality of life. A disease specific QoL tool, the SarQoL® [59] was able to identify sarcopenic versus non-sarcopenic subjects regardless of the definition used for sarcopenia diagnosis, as long as it included an assessment of both muscle mass and muscle function [60]. Poorer QoL therefore seems more related to muscle function than to muscle mass. For sarcopenia, the SarQoL® has been shown to be more discriminatory for QoL changes than generic tools [60].

6. Limitations

This is a cohort study so is open to potential limitations/biases associated with the design. Attempts were made to minimise selection bias by general advertising, but all participants were Caucasians. The self-referred enrollment suggested they were motivated to maintain their health, and those remaining in the study may be the most motivated and/or the healthiest ("selective survivor bias") [61]. These factors may affect the applicability of the results to other populations. The study group was also predominantly female. Because of the small number of males, there was insufficient power to detect sex differences, however sex specific cut-offs were used in the assessment of sarcopenic status parameters.

It is also a very small cohort compared to others published, and after dropouts in those completing the DXA BC, was underpowered. However, the rates of sarcopenia identified are very comparable to Kim and colleagues (all female study) [12] and Patel and colleagues (male and female participants) [9]. The number of participants improving or declining in their sarcopenic status were too small to be able to assess any particular risk factors for this change.

The apparent lack of association of leisure activity with sarcopenic status may reflect the challenge of a cohort design in conditions such as sarcopenia with long latency, suggesting no effect; or that the study duration was too short; the physical activity levels were less than recommended; and/or the participant numbers were too small. Leisure activity is self-reported and has the associated limitations inherent in self reporting. Self-reported exercise tends to over-report physical activity and have lower accuracy due to recall limitations [56]. In addition, we did not use a standardised questionnaire with structured items, such as the IPAQ-S [62] which would also have provided important data on sedentary time.

Finally, use of a disease specific QoL instrument, such as the SarQoL®, may have improved the discriminatory ability between those with and without sarcopenia.

7. Conclusions

The rate of sarcopenia in this small highly functioning community-dwelling cohort was higher than that reported in the larger CLSA cohort, but similar to rates described in cohorts from the UK and Japan. The obesity rate was high, especially when using DXA percentage fat cut-offs, highlighting the need for using DXA obesity diagnostic criteria in addition to BMI. Within the context of limitations already highlighted, leisure-related physical activity and a general QoL tool did not seem to be related to sarcopenic status in this study. This study serves to reinforce the need for further studies to identify sarcopenia and pre-sarcopenia in a clinical setting, especially in the context of concomitant obesity; the need for using a standardised way to capture leisure and sedentary activity time; and consideration of a disease specific tool for QoL to avoid under-estimating the impact of sarcopenia and pre-sarcopenia. More studies may provide information on a window of opportunity to perhaps prevent progression to sarcopenia and/or sarcopenic obesity in community-dwelling older adults.

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Author contribution statement

Conceived and designed the experiments: Angela G Juby.
Performed the experiments: Angela G Juby, Christopher MJ Davis, Suglo Minimaana
Analyzed and interpreted the data: Diana R Mager, Angela G Juby
Contributed reagents, materials, analysis tools or data: Angela G Juby, Christopher MJ Davis, Suglo Minimaana
Wrote the paper: Angela G Juby, Diana R Mager

Data availability statement

The authors do not have permission to share data.

Additional information

No additional information is available for this paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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