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SCREENING FOR SARCOPENIA IN A SMALL COHORT OF ELDERLY CARE HOME RESIDENTS USING HANDGRIP STRENGTH DYNAMOMETRY; AND BIOELECTRICAL IMPEDANCE ASSESSMENT OF SKELETAL MUSCLE MASS AND FAT FREE MASS

A. Slee

Abstract: *Objective:* The loss of skeletal muscle strength and mass termed sarcopenia is linked to disability, frailty, nutritional risk and poor outcomes in the elderly. This study aimed to perform screening for sarcopenia in a group of elderly care home residents using handgrip strength (HGS) dynamometry and bioelectrical impedance assessment (BIA). *Design:* An observational study performed over a 2 month period with BIA screening performed at week 0 and HGS at 0, 4 and 8. *Setting:* A residential care home in Lincolnshire, United Kingdom. *Participants:* 14 elderly Caucasian participants were recruited (8 females and 6 males), mean age 85.6 ±6.2 (77-96). *Measurements:* Anthropometric measurements (height, weight, mid-upper arm (MUAC) and calf circumferences (CC)), calculation of body mass index (BMI), HGS, and BIA (Bodystat ®1500 MDD) were performed. Skeletal muscle mass index (SMI), kg/m^2 was calculated using an equation by Janssen et al, 2000 and fat free mass index (FFMI), kg/m^2 using both the Bodystat manufacturers equation and from Kyle et al, 2000. Cut-off points and criteria from the European Working Group on Sarcopenia in Older People (EWGSOP) for HGS and SMI were utilised to determine the presence of sarcopenia and values for FFMI compared and correlated with variables including SMI, BMI, MUAC, CC and age of participants. *Results:* HGS indicated that functional strength was low compared to reference values and cut-off points. SMI values indicated that all males (6/6) had some degree of sarcopenia and 3/8 females moderate sarcopenia (1 other borderline). FFMI analysis indicated good correlation with SMI and BMI ($r = > 0.82$; $P < 0.0001$) and moderately with MUAC and CC ($r = 0.59$-0.78; $P < 0.05$-0.0001), regardless of BIA equation used. Distinct regions of potential nutritional risk were identified on FFMI/SMI and /BMI graph-plots, whereby low FFMI and SMI coexisted in normal and even overweight BMI ranges. *Conclusion:* These results indicate that the utilisation of a combination of tools and methods may provide useful and practical information in the assessment of sarcopenia.

Key words: Sarcopenia, handgrip strength, bioelectrical impedance assessment.

Introduction

During ageing there is a characteristic reduction in fat free mass (FFM), skeletal muscle mass (SMM) and simultaneous increase in fat mass (FM) (1-3). The loss of SMM and physical strength in ageing has been termed sarcopenia, is a component of frailty and increases disability, morbidity and mortality (1, 4-9). Further, sarcopenia may coexist with other states such as malnutrition and cachexia and is difficult to clinically diagnose (9-11).

The 'European Working Group on Sarcopenia in Older People' (EWGSOP) (9) has recently produced a current working definition and clinical diagnosis for sarcopenia using an algorithm of practical testing methods of physical function such as gait speed and hand grip strength and utilising bioelectrical impedance assessment (BIA) for SMM using a prediction equation derived by Janssen et al, 2000 and specific cut-off points (7, 12).

Screening for sarcopenia may be useful in the community care setting for the elderly and provide useful information for both carers and clinicians on muscle function, frailty and nutritional risk. Therefore, non-invasive diagnostic tools, criteria and specific cut-off points are required. In particular, the use of BIA is attractive due to its portable and inexpensive nature compared to other tools such as DEXA; but there are concerns about the accuracy and validity of BIA prediction equations in the comorbid elderly population; and other models such as BIA vector analysis have been described and utilised (13-17).

This study set out to investigate the potential screening for sarcopenia in a small cohort of elderly care home

Corresponding Author: Adrian Slee, Senior Lecturer in Human Nutrition, School of Life Sciences, University of Lincoln, Lincoln,Lincolnshire, LN6 7TS, Email: aslee@lincoln.ac.uk

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residents in the United Kingdom, UK, measuring functional handgrip strength (HGS); and SMM (and index, SMI) and FFM (and index, FFMI) by BIA at 50 kHz. In addition, a comparison of FFM BIA predictive equations was made between the manufacturers (Bodystat Ltd. ®1500MDD) and the FFM equation derived by Kyle et al (18).

Methods

Participants and study design

Participants were recruited from an elderly care home (LACE Housing Association, Lincoln) in Lincolnshire, United Kingdom in September 2011. Participants were elderly Caucasian residents, 14 in total (8 females and 6 males), with a mean age of 85.6 ±6.2 standard deviation (SD) (age range: 77-96). Participants were comorbid with medical history which included; CVD/ stroke (11/14), musculoskeletal/falls/ arthritis (8/14), neuropsychological/ mental health/dementia (11/14), respiratory disorders/ chronic obstructive pulmonary disorder (COPD) (2/14), malignancy (2/14), urinary/renal (6/14), diabetes/metabolic/endocrine (6/14) and other diagnoses. All participants were taking prescription medications averaging 12 different medications for females and 9 for males.

Study protocol was submitted to the School of Life Sciences, University of Lincoln Ethics committee in June 2011. Full written consent from LACE Housing Association and written informed consent from individual participants was gained before study commencement. Exclusion criteria included the inability to provide written informed consent and co-morbidity which may significantly impair ability to perform measurements. Participants were un-identified and designated codes female, 'F' 1-8 and male, 'M' 1-6.

A full nutritional assessment was performed at three time points over a 2 month period, at week - '0'-initial screening/assessment, and at second and third time points, week '4' and '8' weeks. All measurements were taken in the presence of and with assistance from local known carers and nursing staff.

Anthropometric measurements

Measurements of height in m and weight in kg were completed by local site carers. In some cases these had to be estimated, e.g. height from demi-span. Body mass index, BMI was then calculated in kg/m^2. In addition, mid-upper arm, MUAC and calf circumferences, CC in cm were taken.

Handgrip functional strength

Handgrip strength (HGS) in kg was measured using a Grip-D handheld dynamometer, (Takei Scientific Instruments Ltd, Japan). Measurements were taken on both the dominant and non-dominant hands (if possible) in a seated position with the arm by the side and bent at the elbow at 90° with dynamometer in front. Measurements were taken in order 'left-, right-, left-, and right-hand and recorded. Residents with disability or severe arthritis in hands/arms were excluded.

Bioelectrical impedance measurements

Bioelectrical impedance assessment (BIA) measurements were taken using a dual-frequency (5 kHz & 50 kHz) Bodystat ®1500MDD bioelectrical impedance analyzer (Bodystat Ltd., Isle of Man). Measurements were taken using a hand-to-foot tetra-polar technique with participants in the supine position, in accordance with the manufacturer's guidelines. All measures were recorded including %FFM, FFM in kg, and the FFM index (FFMI) in kg/m^2 derived from the manufacturers programmed predictive equations. Raw impedance measurements of resistance (R) and reactance (capacitance, xC) in ohms at 50 kHz frequency were also recorded and used to calculate FFM using the equation by Kyle et al, 2001 (18).

FFM = -4.104 + (0.518 X H^2/R) + (0.231 X W) + (0.130 X xC) + (4.229 X gender).

Where H is height in cm; R is BIA resistance in ohms at 50 kHz; W is weight in kg; xC is reactance in ohms; for gender, men = 1 and women = 0.

Skeletal muscle mass (SMM), in kg and index (SMI), in kg/m^2 was calculated for each participant using the BIA equation from Janssen et al, 2000 (12).

SMM mass (kg) = [(H^2/R X 0.401) + (gender X 3.825) + (age X -0.071)] + 5.102. Where H is height in centimetres, cm; R is BIA resistance in ohms at 50 kHz; for gender, men = 1 and women = 0; and age is in years.

Estimation of sarcopenia prevalence

Sarcopenia was determined using the algorthym developed by EUWGOS (9) using physical function, HGS and SMI by BIA. HGS cut off points were as follows: < 30 kg men, < 20 kg women. Other suggested cut-off points (9) according to BMI were also applied and data compared against percentiles from a recent review article by Norman et al. (19).

The cut-off points designated to signify presence of sarcopenia using SMI include: 8.87 kg/m^2 for men and 6.42 kg/m^2 for women (9). This paper also suggested using cut-off points developed by Janssen et al 2004 (7) where 'severe sarcopenia' in men is ≤ 8.50 kg/m^2 and in women ≤ 5.75 kg/m^2; 'moderate sarcopenia' in men is 8.51-10.75 kg/m^2 and in women 5.76-6.75 kg/m^2; and 'normal muscle' is ≥ 10.76 kg/m^2 for men and women ≥ 6.76 kg/m^2.

Further, correlations were made between FFM and FFMI for the Bodystat and Kyle et al equations and

variables including SMI, BMI, MUAC, CC and with age.

Data analysis

Data is presented as mean average measurements ± SD with a range (minimum-maximum). Data has been grouped into whole participant group, females and males, and where relevant at all time points weeks 0, 4 and 8. Statistical analysis has been performed using IBM SPSS Statistics, version 19, New York, USA and PAST, version 1.97, Hammer and Harper, 2010. Data sets were tested for normal distribution using the Shapiro-Wilk Statistic test. Although sample size was low, data sets were compared for female versus males across all variables at week 0. T-tests were used for normally distributed data and Mann-Whitney-U test for nonparametric data. Correlations between variables were performed with r and P values presented. A P value of < 0.05 was considered statistically significant.

Results

Of the 14 participants, 1 female resident (F4) and 1 male resident (M5) were unable to complete the HGS measurements due to co-morbidity however all other measurements were taken at week 0. Participant characteristics at week 0 can be seen in Table1.

Physical function and hand grip strength

All participants had a characteristically low level of physical functional ability and mobility. According to the ratings tests for physical function described by Cruz-Jentoft et al, 2010 (9) (e.g. short physical performance battery, SPPB and gait speed tests) participants would score in lower percentiles and this was not tested for safety reasons.

HGS was measured in 12/14 of participants and some of those one-handed only (excluded due to arthritis, disability or previous CVA). As in Table 1 the group mean score for week 0 was 14.8±5.0 (6.4-21.5), males 19.3±3.2 (13.9-21.5) and females 11.5±3.2 (6.4-15.6). The difference between males and females was highly significant ($P < 0.001$).

The individual grip strength scores were recorded at weeks 0, 4 and 8 for all residents and shown in Figure 1.

Using cut-off points suggested in (9) and percentiles from a recent Review (19) results indicate that both male and female participants fall within lower percentiles for handgrip strength for their ages and BMI classifications indicating potential sarcopenia-although it should be noted individually for example that M6 (94 years of age) maintained a hand grip strength ~20 kg at a low body weight (57.2 kg) and BMI (20.3 kg/m^2).

Skeletal muscle mass and fat free mass

Skeletal muscle mass, SMM and index, SMI are shown in Table 1 for group, females and males. Fat free mass, FFM and index, FFMI using both Bodystat and Kyle et al equations are also found within Table 1 also. For the purpose of individual participant 'screening' these are displayed for each person in Figure 2 below.

Table 1

Participant characteristics at week 0, mean values presented ± SD and range in brackets (minimum-maximum) for the group, females and males

	Group	Females	Males
Number of participants, n	14	8	6
Age, years	85.6±6.2 (77-96)	83.8±7.2 (77-96)	88±4.1 (82-94) *
Height, m	1.61±0.05 (1.52-1.68)	1.59±0.04 (1.52-1.66)	1.64±0.04 (1.56-1.68)
Weight, kg	68.8±17 (44.5-90.6)	67.9±20 (44.5-90.6)	70±13.6 (57.2-84.9)
Body mass index, kg/m^2	26.4±6.5 (18.3-35.9)	26.8±7.8 (18.3-35.9)	25.9±4.8 (19.5-31.2)
BIA Resistance at 50 kHz, ohms	549.4±110.1 (373-733)	563.5±118.6 (373-733)	530.7±105.2 (421-698)
BIA Reactance at 50 kHz, ohms	38.0±11.3 (27.1-73.5)	42.6±13.1 (32.5-73.5)	31.8±3.5 (27.1-36.5) *
†Skeletal muscle mass, kg	21.0±5.0 (14.2-28.6)	19±4.3 (14.2-26.5)	23.7±4.8 (16.2-28.6) *
†Skeletal muscle mass index, kg/m^2	8.0±1.7 (5.7-10.6)	7.5±1.7 (5.7-10.6)	8.8±1.5 (6.7-10.6)
BODYSTAT			
‡Fat free mass, %	60.1±6.0 (50.2-62.6)	56.4±4.3 (50.2-62.6)	65.1±4.0 (59.1-70.5) **
‡Fat free mass, kg	41.1±9.9 (26.0-56.1)	37.7±9.3 (26.0-51.0)	45.6±9.6 (31.7-56.1)
‡Fat free mass index, kg/m^2	15.8±3.5 (10.7-20.8)	14.9±3.6 (10.7-20.4)	17.0±3.3 (12.1-20.8)
KYLE et al			
Fat free mass, %	65.9±9.2 (53.4-83.0)	63.6±9.1 (53.4-80.6)	69.0±9.3 (55.2-83.0)
Fat free mass, kg	44.4±8.8 (32.8-57.3)	41.9±8.8 (32.8-57.0)	47.8±8.2 (38.1-57.3)
Fat free mass index, kg/m^2	17.1±3.1 (12.7-22.8)	16.6±3.5 (12.7-22.8)	17.7±2.5 (14.6-21.2)
Handgrip strength, kg	14.8±5.0 (6.4-21.5)	11.5±3.2 (6.4-15.6)	19.3±3.2 (13.9-21.5) ***
Mid-upper arm circumference, cm	29.5±5.8 (21.0-40.0)	29.9±6.6 (22-40)	28.9±4.9 (21-35)
Calf circumference, cm	31.1±4.9 (22.5-41.0)	30.8±4.4 (23.5-36.5)	31.5±6.0 (22.5-41.0)

† estimate derived using prediction equation by Janssen et al, 2000 and raw BIA impedance values at 50 kHz. ‡ estimates derived from BIA prediction equations used by Bodystat manufacturers. *significantly different compared to female group ($P < 0.05$); **significantly different compared to female group ($P < 0.01$); ***significantly different compared to female group ($P < 0.001$).

Figure 1

Graph to show hand grip strength (HGS) in kg for all participants at weeks 0, 4 and 8. Note that measurements for F4, M5 and M3 (week 8 only) were not taken due to comorbidity

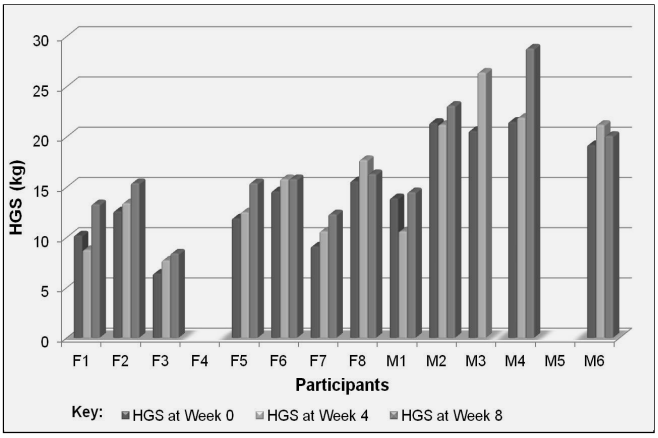
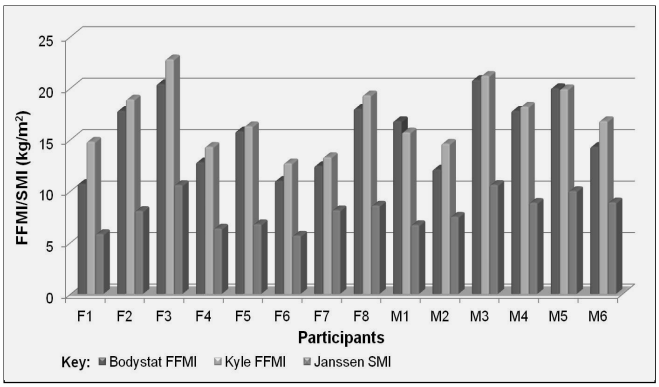


Figure 2

Graph to show the fat-free mass index, FFMI and skeletal muscle mass index, SMI in kg/m^2 for all participants at week 0. Note the comparison between the two FFMI equations, Bodystat and Kyle et al



With respects to screening for sarcopenia on the basis of low SMI according to the cut-off criteria described (7, 9), 63% (5/8) females were classified as having 'normal muscle', and 38% (3/8-F1, 4 and 6) 'moderate sarcopenia'. One of these was 'borderline sarcopenic' (F5) with an SMI of 6.78 kg/m^2 (cut-off: 6.76). Of the males 33% (2/6) were classified as having 'severe sarcopenia', and 67% (4/6) as 'moderate sarcopenia'.

Screening for FFM and correlations between FFM and other variables, SMI, BMI, MUAC, CC and age of participants was completed for both the Bodystat and Kyle et al equations (see Table 2 and Figure 3 below).

Utilising the FFMI percentiles for older age groups (> 75) determined by Schultz et al, (3), regardless of FFM equation used 4 females (F1, 4, 6 and 7) participants fell within the ~25/<25th percentile region. Of the males, 2 participants came within <5, 1 within 5-10 and 1 in the 25-50 percentile region.

Additionally, SMI moderately correlated with BMI (r = 0.57, P < 0.05).

Table 2

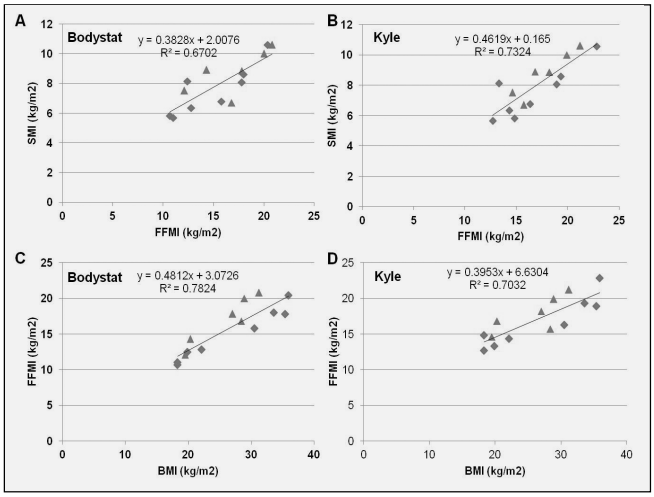
Table to show group correlations between fat free mass (kg) and fat free mass index (kg/m^2), FFM and FFMI, respectively against variables using the bioelectrical impedance Bodystat manufacturers and Kyle et al, prediction equations. Correlation r and significance P values are presented

Bodystat 1500 MDD	r	P	Kyle	r	P
FFM vs SMI	0.86	7.15x10-5	FFM vs SMI	0.91	7.86x10-6
FFMI vs SMI	0.82	0.00034	FFMI vs SMI	0.86	9.44x10-5
FFM vs BMI	0.79	0.0008	FFM vs BMI	0.73	0.0029
FFMI vs BMI	0.88	2.66x10-5	FFMI vs BMI	0.84	0.00018
FFM vs MUAC	0.60	0.024	FFM vs MUAC	0.52	0.057
FFMI vs MUAC	0.67	0.0094	FFMI vs MUAC	0.59	0.026
FFM vs CC	0.77	0.0014	FFM vs CC	0.70	0.005
FFMI vs CC	0.78	0.00095	FFMI vs CC	0.71	0.0048
%FFM vs Age	0.63	0.0157	%FFM vs Age	0.78	0.00095
FFM vs Age	-0.417	0.137	FFM vs Age	-0.33	0.25
FFMI vs Age	-0.57	0.035	FFMI vs Age	-0.51	0.065

Key: SMI, skeletal muscle mass index (kg/m^2); BMI, body mass index (kg/m^2); MUAC, mid-upper arm circumference (cm) and CC, calf circumference (cm).

Figure 3

Graphs A-D to show study participants (♦: females, ▲: males) fat free mass index, FFMI (kg/m^2) against skeletal muscle mass index, SMI (kg/m^2) (graphs A, B) and FFMI against BMI (kg/m^2) (graphs C, D) for both Bodystat and Kyle et al equations



Discussion

HGS measurements (at week 0; group: 14.8±5.0 kg (6.4-21.5); females: 11.5±3.2 (6.4-15.6) and males: 19.3±3.2 (13.9-21.5)) indicated that physical function was within lower reference values for an elderly population, and were associated with general poor physical mobility. Males retained greater strength compared to females (P < 0.001) despite the male group being significantly older (P < 0.05). Results for all participants are displayed in Figure

1 for weeks 0, 4 and 8 to show the variation in strength and to avoid any errors in the interpretation of strength data at one single time point. This is important for screening and monitoring as strength may alter for a variety of reasons including illness and/or the test may be completely uncommon to the participant-hence results may be lower than is normally maximally physically attainable and lead to false estimations. The variability in HGS screening is an important aspect to control for in the elderly population and has been recently reviewed by Roberts et al (20).

Sarcopenia prevalence was estimated using BIA determination of SMI as previously described (7, 9, 12). Prevalence was high in males, (100%-4 moderate and 2 severely sarcopenic) and moderately high in females (50%-3 moderate, 1 borderline and 4 normal). These results indicate a higher prevalence when comparing to a residential nursing home study performed in Italy (n = 122) which found males to have high prevalence of sarcopenia (68%) and females lower (21%) (21). The SMI values were then compared to the FFMI derived using both the Bodystat and Kyle et al (18) equations and are shown in Figure 2. Using the FFMI percentiles for older age groups (> 75) determined by Schultz et al (3), 4 female participants were within the ~25/< 25th percentile region and 3 of these classified as moderately sarcopenic. The 2 male participants who came within < 5 percentile were both severely sarcopenic, and the other 2 who were within the 5-10 and 25-50 percentile range, moderately sarcopenic. The correlation relationships were then investigated as these variables may be viewed as potential components for the screening of frailty and nutritional risk in old age. Strong correlations between FFMI with SMI and BMI using either the Bodystat or Kyle formulae were found and moderate correlations with age (see Table 2 and Figure 3). Importantly, it should be noted that specific regions in the FFMI/BMI graph may indicate high nutritional risk at a BMI of ~22-23 kg/m^2 as participants within this region have both low FFMI and SMI. Additionally, at a higher BMI region ~27-28 kg/m^2 (overweight classification according to the WHO) there are 2 male residents which had low/lower FFMI and SMI. This indicates from an assessment of nutritional risk and frailty perspective that BMI may not be an adequate indicator of status in the comorbid elderly. This is of concern as the BMI score (as a component also of the 'malnutrition universal screening tool', MUST, (22)) is well utilised within the nutritional assessment of comorbid elderly people on a regular daily/monthly basis within the UK. Note that screening of this same study group using the MUST (data not shown here –see (17)) categorised the participant group on average within a 'normal'/'low risk' of malnutrition. The data shown here on HGS and BIA indicate that most likely the participants should be classified on average within a 'medium'/'at risk' classification, which was also in line with previous screening using the 'mini-nutritional assessment' MNA tool (23, 24) in this same study group (17). Further, the comparison of the individual participants using Figure 1 and 2 is most useful for personalised assessment and monitoring of status in residents.

As described HGS was low in this elderly group, was linked with poor mobility and did not correlate with BMI or any of the BIA measurements. This is an important finding as physical capability, and HGS in particular has been consistently shown to be predictive of disability, malnutrition, morbidity and mortality (9, 19, 25-28). It is likely that the group size was too small and/or that there was an 'uncoupling' between strength and SMM/SMI due to a range of potential factors such as comorbidity. Many drugs commonly used in elderly medicine (and taken habitually by the participants within this study) may exacerbate losses in muscle function such as sedatives and cardiovascular medicines (29-31). Further, this 'uncoupling' or divergence between strength and SMM/SMI has been reported and discussed in the literature and termed as 'dynapenia' by Mannini and Clark as "the age-related loss of strength and power" (28). Further studies will be necessary to confirm or refute the debate between sarcopenia and dynapenia and the relationship between strength and SMM/SMI in the elderly. Understanding the relationship between sarcopenia in illness, particularly after stroke (32), with cachexia, malnutrition and newer definitions such as dynapenia (28), the new term of 'myopenia' by Fearon et al (33), in the context of the practical assessment and care of the elderly nutritional and physical status will be a challenge and is clearly necessary in coming years.

Sources of error and improvements to this study include: this was a small exploratory study with a low sample size-although, there was a valid group mix of male and female participants of different ages, body sizes, and characteristics. The BIA method is assumed to be reasonably accurate in healthy elderly people (2, 3, 7, 9, 12) however; this group was comorbid and at least 2-3 participants during the study period were either recovering from illness or became ill. This may have had a significant impact upon cellular hydration and unknown factors affecting BIA resistance and reactance measures and hence produce significant errors in FFM and SMI calculation, and should be considered and is been discussed by other authors (13-16).

In summary, screening for sarcopenia using HGS dynamometry and BIA was completed in a small group of comorbid elderly care home residents in the UK. This study provided useful information regarding the prevalence of low HGS/physical function, SMI and FFMI in this group and additional information on possible nutritional risk and a comparison of BIA methodology. Future studies will be required to assess the importance and significance of these tools in the assessment and

monitoring of comorbid elderly for sarcopenia, frailty and nutritional risk.

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Contributions: Dr A.Slee designed and carried out the study. A. Slee analysed the data and wrote the manuscript.

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