4-21-2021

# Sarcopenia: A Functional Chronic Disease

Mike Haines, MD
*Thomas Jefferson University*

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# Disclosures

- Conflicts of Interests: None
- Bias: Reformed Meathead
  - When in doubt:
    - Move more weight
    - Eat more protein

# Objectives

- Define sarcopenia as a clinical diagnosis as described by the European Working Group on Sarcopenia in Older Persons (EWGSOP2)
- Recognize, identify, and describe sarcopenia as a distinct disease process
- Review impact on health outcomes and healthcare costs
- Explain tools used to aid in diagnosis in clinical practice
- Explore the nuances of therapeutic interventions
- Discuss role of the primary care physician

# What we will cover

- Definition of sarcopenia as laid out by the European Working Group on Sarcopenia in Older People 2018 (EWGSOP2)
- Related adverse health outcomes and healthcare costs
- Ways to diagnose sarcopenia in clinical practice
- Current paradigms of treatment of sarcopenia with focus mainly on primary sarcopenia

# What we will NOT cover

- In-depth discussion of various forms of sarcopenia (secondary sarcopenia, sarcopenic obesity, etc.)
- Comprehensive review of cachexia and frailty
- In-depth analysis of biochemical basis of sarcopenia
- Complex diagnostic tests or possible future tests or therapeutic targets

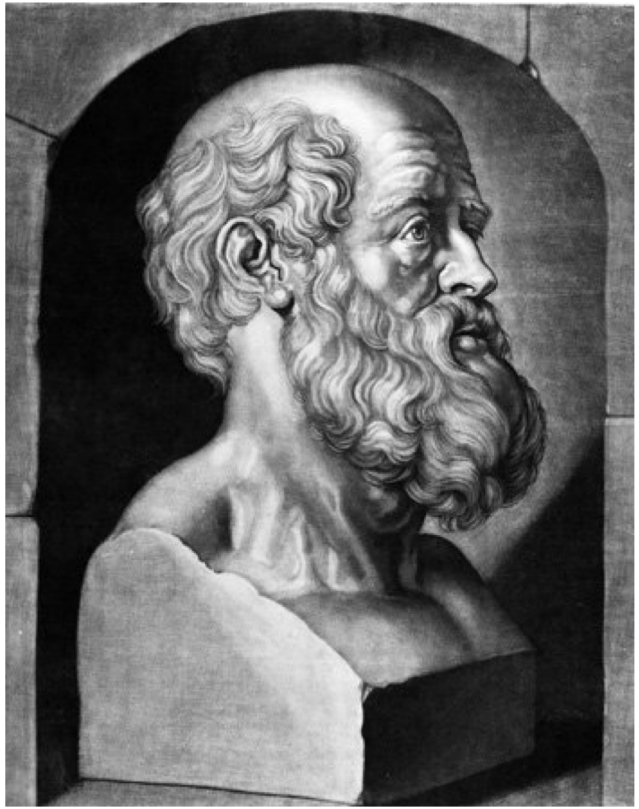
# Outline

- What is sarcopenia?
  - Definition provided by EWGSOP2
  - Brief overview of pathophysiology
- Why is it important?
  - Epidemiology
  - Impact on health outcomes
  - Healthcare costs
- Diagnosis
  - Review EWGSOP2 framework for clinical practice
  - Questionnaires
  - Office based testing
  - Imaging
- Treatment and Prevention
  - Dietary interventions
  - Exercise Interventions
  - Role of PCP

# What is sarcopenia?

# What is sarcopenia? Definitions

- Greek etymology
- “Poverty of flesh”
- “Sarco” = “flesh”
- “Penia” = deficiency or poverty



# What is sarcopenia? Definitions

- Muscle disease rooted in adverse muscle changes that accrue across a lifetime defined by low levels of:
  - Muscle strength
  - Muscle quantity/quality
  - Physical performance as an indicator of severity
- “Muscle failure"

GUIDELINES

## Sarcopenia: revised European consensus on definition and diagnosis

Alfonso J. Cruz-Jentoft[1], Gülistan Bahat[2], Jürgen Bauer[3], Yves Boirie[4], Olivier Bruyère[5], Tommy Cederholm[6], Cyrus Cooper[7], Francesco Landi[8], Yves Rolland[9], Avan Aihie Sayer[10], Stéphane M. Schneider[11], Cornel C. Sieber[12], Eva Topinkova[13], Maurits Vandewoude[14], Marjolein Visser[15], Mauro Zamboni[16], Writing Group for the European Working Group on Sarcopenia in Older People 2 (EWGSOP2), and the Extended Group for EWGSOP2

# European Working Group on Sarcopenia in Older Persons (EWGSOP)

- Organized by European Geriatric Medicine Society (EuGMS)
- First meeting (EWGSOP1) - 2010
- Second meeting (EWGSOP2) - 2018
- Final content and recommendations reviewed and endorsed by many organizations
  - EuGMS
  - European Society for Clinical and Economic Aspects of Osteoporosis, Osteoarthritis and Musculoskeletal Diseases (ESCEO)
  - European Society for Clinical Nutrition and Metabolism (ESPEN)
  - International Osteoporosis Foundation (IOF)
  - Among others

# European Working Group on Sarcopenia in Older Persons - 2010

- Paradigm shift
  - Muscle function = key element
- Former definitions
  - Based only on low muscle mass

**Table 1.** Criteria for the diagnosis of sarcopenia

| Diagnosis is based on documentation of criterion 1 plus (criterion 2 or criterion 3) |
| --- |
| 1. Low muscle mass |
| 2. Low muscle strength |
| 3. Low physical performance |

# European Working Group on Sarcopenia in Older Persons - 2018

- Strength comes to the forefront
  - Better predictor of adverse outcomes
  - Difficult to measure muscle quantity & quality in practice
- Quality as important as quantity
- Physical performance
  - Part of core definition vs outcome measure
  - Use to grade severity

**Table 1.** 2018 operational definition of sarcopenia

| |
|---|
| **Probable sarcopenia is identified by Criterion 1.**<br>**Diagnosis is confirmed by additional documentation of Criterion 2.**<br>**If Criteria 1, 2 and 3 are all met, sarcopenia is considered severe.** |
| (1) Low muscle strength |
| (2) Low muscle quantity or quality |
| (3) Low physical performance |

# What is sarcopenia? Pathophysiology - Strength

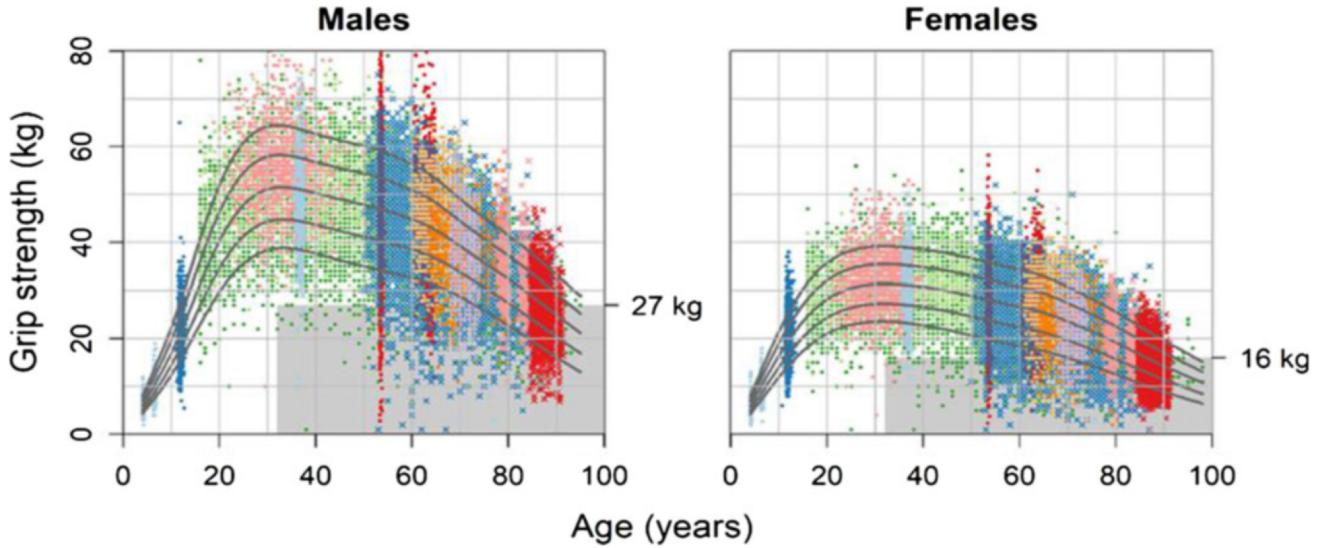
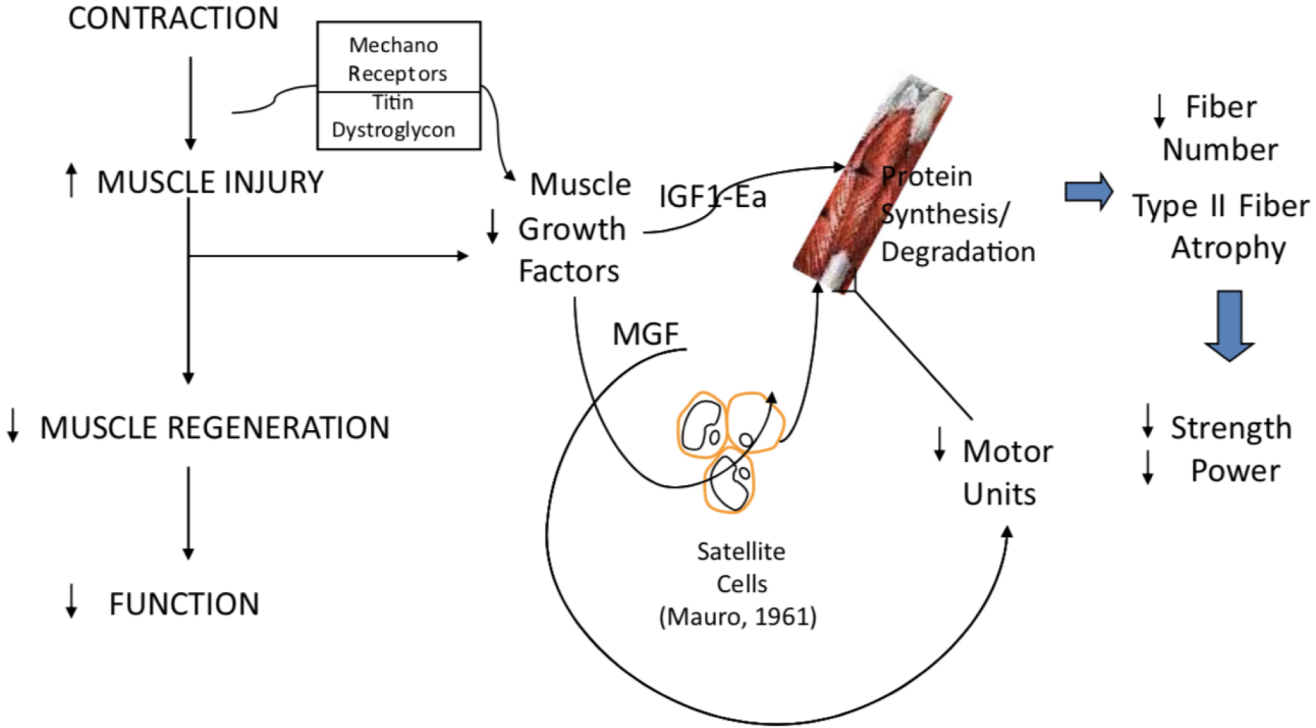



**Figure 2.** Normative data for grip strength across the life course in men and women in the UK (Dodds RM, *et al.* PLoS One. 2014;9:e113637). Centiles shown are 10th, 25th, 50th, 75th and 90th. Cut-off points based on *T*-score of ≤ -2.5 are shown for males and females (≤27 kg and 16 kg, respectively). Color-coding represents different birth cohorts used for the study (Figure adapted with permission from R Dodds and PLOS One).

# What is sarcopenia? Pathophysiology - Strength

- Development of strength accelerates during adolescence
- Males
  - Peaks between age 29-39
  - Mean peak in grip strength 51kg
- Females
  - Peaks between age 26-42
  - Mean peak in grip strength is 31kg
- Decline after age 50
  - 1.5-5% decline in strength per year
  - 1-2% decline in muscle mass per year

# What is sarcopenia? Pathophysiology - Biochemistry



# What is sarcopenia? Pathophysiology - Biochemistry

# What is sarcopenia? Sarcopenia vs Cachexia

- Cachexia
  - Complex metabolic syndrome associated with underlying illness
  - Loss of muscle mass with or without loss of fat mass
  - Associated with inflammation, insulin resistance, and anorexia
  - Most cachectic individuals are sarcopenic
- Sarcopenia
  - Skeletal muscle disorder characterized by loss of strenght and muscle mass
  - Most sarcopenic patients are not cachectic
    - Ex: Sarcopenic obesity

# What is sarcopenia? Sarcopenia vs Frailty

- Frailty
  - Multidimensional geriatric syndrome
  - Physical and social dimensions
- Sarcopenia
  - Distinct disease process
  - Contributor to physical frailty

# Why is it important?

If the body be feeble, the mind will not be strong. The sovereign invigorator of the body is exercise...Not less than two hours a day should be devoted to exercise.

-Thomas Jefferson to Thomas Mann Randolph, *August 1786*

# Why is it important? Epidemiology

- UK Study
  - Prevalence
    - 4.6% in men
    - 7.9% in women
  - Average age 67
- US study
  - Prevalence = 36.5%
  - Average age 70.1

# Why is it important? Health outcomes

- Own distinct disease process
- Interconnected to other diseases and various other forms of morbidity and mortality
- Associated with:
  - Falls and fractures
  - Impairment of activities of daily living
  - Cardiac disease
  - Respiratory disease
  - Cognitive impairment
  - Loss of independence
  - All cause mortality

# Cognitive Impairment

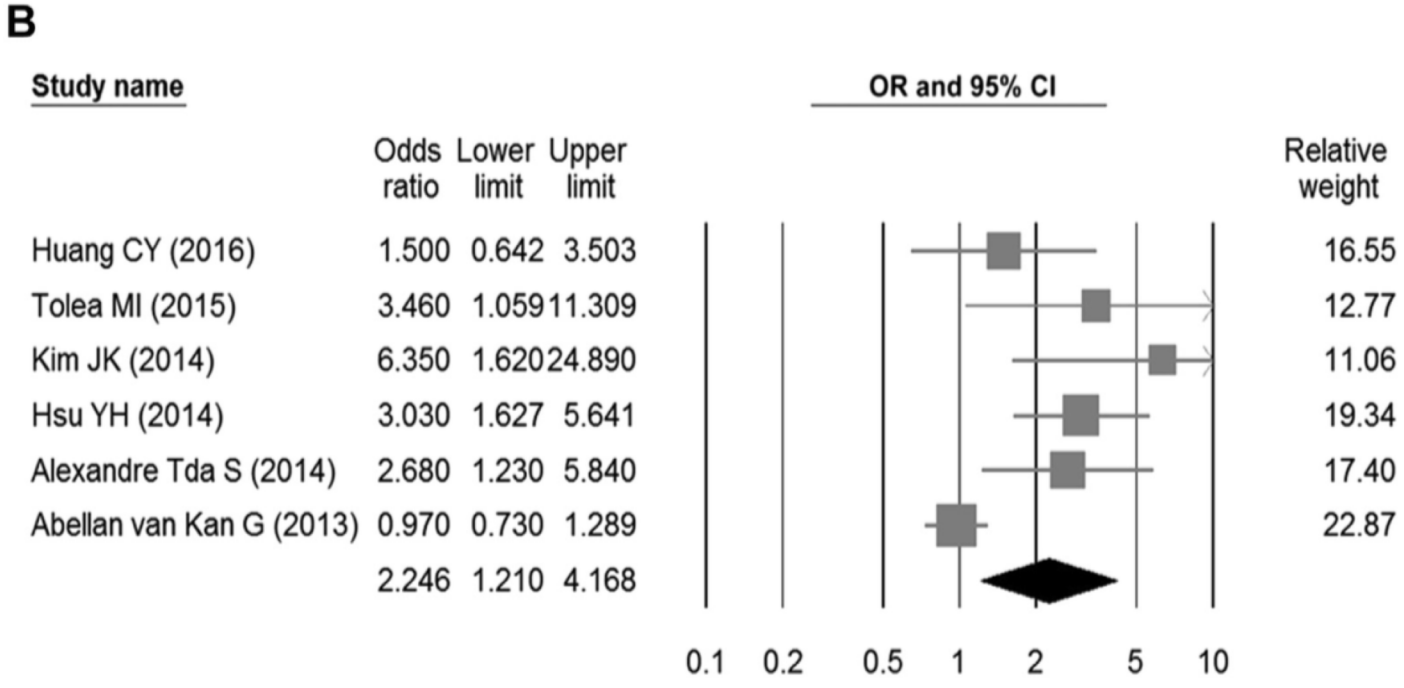



**Fig. 2.** Forest plot of the (A) crude and (B) adjusted associations between sarcopenia and cognitive impairment.

# Independence

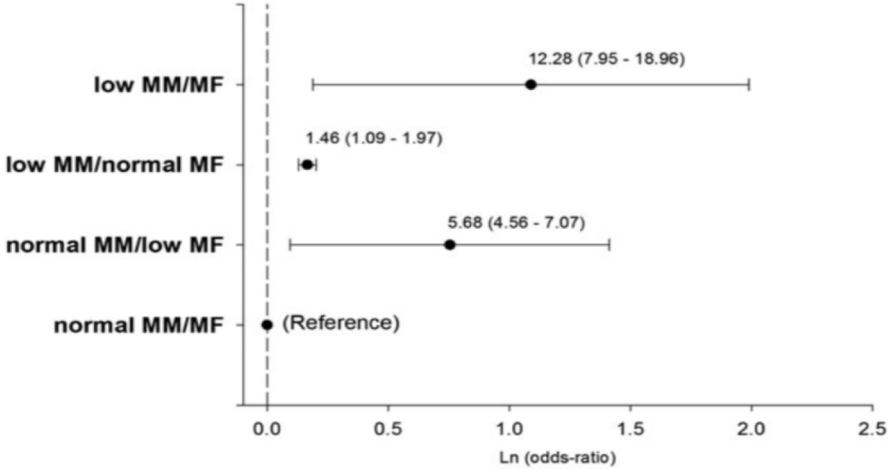
**Table 2** Odds-ratio for being at risk for losing physical independence

| | N | n (%) at risk | Odds-ratio (95% CI) |
|---|---|---|---|
| Muscle mass | | | |
| normal (reference) | 2795 | 789 (28.2) | 1.00 |
| low | 698 | 265 (38.0) | 1.65 (1.27–2.31) |
| Muscle function | | | |
| normal (reference) | 2795 | 633 (22.6) | 1.00 |
| low | 698 | 421 (60.3) | 6.19 (5.08–7.53) |

Model adjusted for sex, age, education, medical history for chronic disease, hypertension, elevated cholesterol or glycemia, current medication status and body mass index.

# Independence continued

**Figure 1** Joint association of muscle mass (MM)/muscle function (MF) categories [normal MM and MF; normal MM low MF; low MM normal MF; low MM and MF] with the risk for losing physical independence in older adults ($n = 3493$). *Results are presented as odds-ratio (95% confident intervals) Model adjusted for sex, age, education, medical history for chronic disease, hypertension, elevated cholesterol or glycemia, current medication status and body mass index.



# Falls

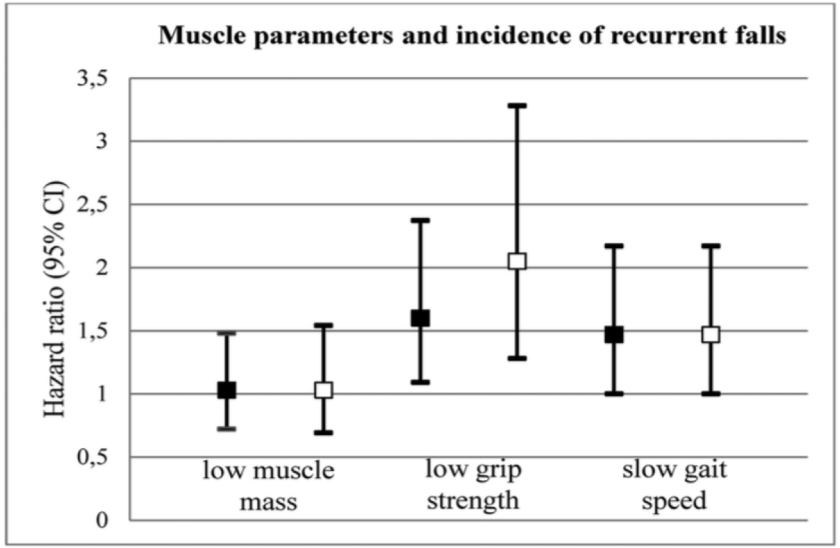



**Figure 1.** Adjusted hazard ratios for the association between single sarcopenia components and 3-year incidence of recurrent falls among 489 older adults. *Note:* Black squares: hazard ratios of sarcopenia components based on cut-off scores of the European Working Group on Sarcopenia in Older People; white squares: hazard ratios of sarcopenia components based on cut-off scores of the Foundation of the National Institutes of Health sarcopenia project.

# Mortality

| | Incidence | Adjusted model | Country-income interaction p value* |
|---|---|---|---|
| All-cause mortality | 3379 (2·4%) | 1·16 (1·13–1·20); p<0·0001 | 0·7607 |
| Cardiovascular mortality | 1184 (0·9%) | 1·17 (1·11–1·24); p<0·0001 | 0·9731 |
| Non-cardiovascular mortality | 2195 (1·6%) | 1·17 (1·12–1·21); p<0·0001 | 0·7674 |
| Myocardial infarction | 1539 (1·1%) | 1·07 (1·02–1·11); p=0·0024 | 0·9345 |
| Stroke | 1212 (0·9%) | 1·09 (1·05–1·15); p<0·0001 | 0·9255 |
| Diabetes | 2939 (2·1%) | 1·03 (0·996–1·06); p=0·0836 | 0·7710 |
| Cancer | 2042 (1·5%) | 0·950 (0·919–0·982); p=0·0024† | 0·0264 |
| Pneumonia | 1047 (0·7%) | 0·991 (0·947–1·04); p=0·715 | 0·7465 |
| Hospital admission for pneumonia or COPD | 505 (0·4%) | 1·04 (0·974–1·12); p=0·2278 | 0·3407 |
| Hospital admission with respiratory illness | 1111 (0·8%) | 1·03 (0·981–1·08); p=0·241‡ | 0·0146 |
| Injury from fall | 2894 (2·0%) | 0·968 (0·939–0·998); p=0·0348 | 0·1873 |
| Fracture | 1981 (1·4%) | 0·966 (0·931–1·00); p=0·0689 | 0·3094 |

Numbers are HR (95% CI) or number (%). COPD=chronic obstructive pulmonary disease. HR=hazard ratio. HR are adjusted for age; sex; education level; employment status; physical activity level; tobacco and alcohol use; daily dietary energy intake; proportion of caloric intake from protein; self-reported hypertension, diabetes, heart failure, coronary artery disease, and chronic obstructive pulmonary disease; and self-reported prior stroke or cancer; body-mass index and waist-to-hip ratio. *p values refer to the interaction between grip strength by tertile and country income. Other p values refer to main effects estimates. †For cancer, subdistribution HRs stratified by country income were 0·916 (0·880–0·953; p<0·0001) for high-income countries, 1·01 (0·950–1·08; p=0·7) for middle-income countries, and 1·12 (0·934–1·34; p=0·2) for low-income countries. ‡For hospital admission for any respiratory illness, subdistribution HRs stratified by country income were 1·00 (0·946–1·06; p=0·9) for high-income countries, 1·08 (0·968–1·20; p=0·2) for middle-income countries, and 1·16 (1·00–1·34; p=0·045) for low-income countries.

***Table 2:*** **Incidence and HR for all-cause mortality and subdistribution HR for outcomes per 5 kg reduction in grip strength**

# Mortality continued

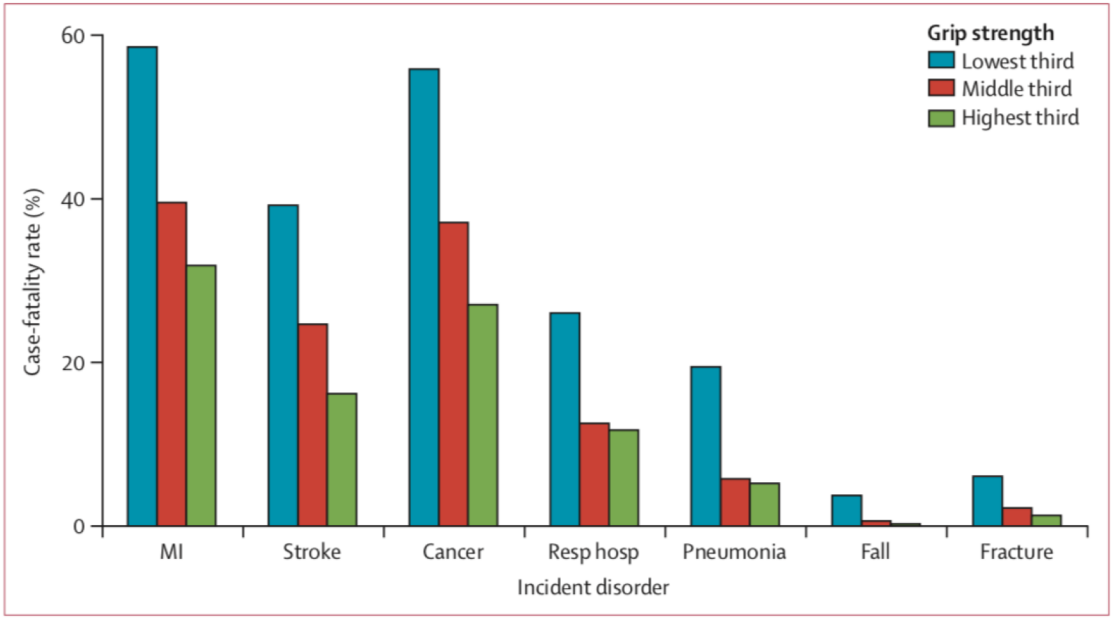



***Figure 3*: Case-fatality rates for incident cases of myocardial infarction, stroke, cancer, hospital admission for pneumonia or COPD, pneumonia, injury from a fall, and fracture, stratified by grip strength tertile**
COPD=chronic obstructive pulmonary disease. MI=myocardial infarction. Resp hosp=hospital admission for pneumonia or COPD.

# Why is it important? Healthcare costs

- Sarcopenia associated with:
  - Increased risk of hospitalization
  - Increased cost of hospitalization
  - Increased total cost of healthcare
  - Decreased quality of life

# Why is it important? Healthcare costs

**Table 2**

Spearman correlations (r) between muscle, health and economic outcomes (n = 227)

| | ADL function | | Quality of life | | Health care costs | |
|---|---|---|---|---|---|---|
| | r | P Value | r | P Value | r | P Value |
| SMI, kg/m$^2$ | | | | | | |
| Men | -0.07 | .43 | 0.05 | .57 | -0.08 | .39 |
| Women | -0.03 | .78 | -0.06 | .57 | -0.01 | .93 |
| Grip strength, kg | | | | | | |
| Men | -0.41 | <.01 | 0.37 | <.01 | -0.39 | <.01 |
| Women | -0.54 | <.01 | 0.35 | <.01 | -0.42 | <.01 |
| Gait speed, m/s | -0.64 | <.01 | 0.48 | <.01 | -0.49 | <.01 |
| Chair stand, seconds | 0.51 | <.01 | -0.35 | <.01 | 0.30 | <.01 |
| SPPB score, 0-12 | -0.66 | <.01 | 0.47 | <.01 | -0.47 | <.01 |

ADL, activities of daily living (based on GARS score); SMI, skeletal muscle index; SPPB, short physical performance battery.

# Why is it important? Healthcare costs

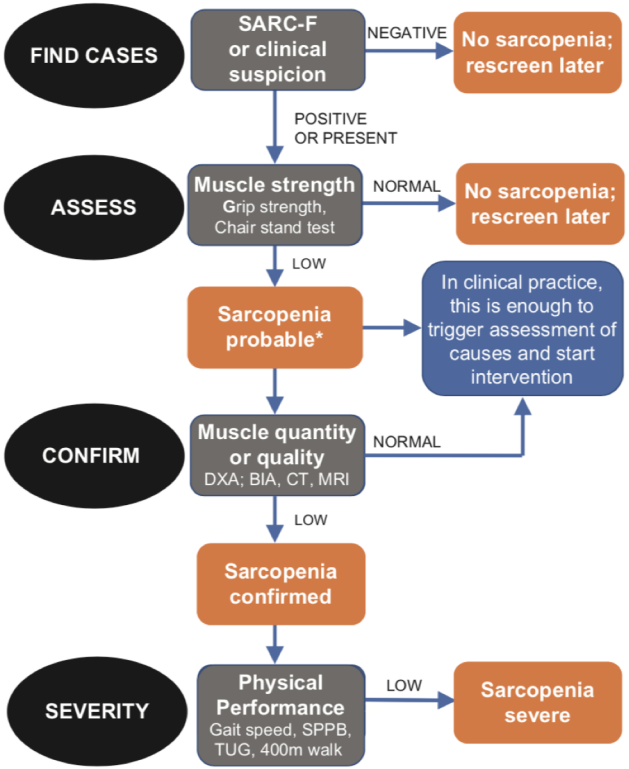
**Table 3** Logistic regression models for the association of sarcopenia and muscle strength with hospital costs

| | *OR* | *95% CI* | P* |
|---|---|---|---|
| Model 1 | | | |
| Sarcopenia (yes *vs* no) | 5.70 | 1.57–20.71 | 0.008 |
| Age (years) | 1.03 | 0.99–1.08 | 0.157 |
| Gender (male *vs* female) | 0.47 | 0.26–0.86 | 0.015 |
| Model 2 | | | |
| Muscle strength (low *vs* high) | 2.40 | 1.12–5.15 | 0.025 |
| Age (years) | 0.99 | 0.95–1.04 | 0.782 |

*$P < 0.05$ was considered statistically significant.

# Diagnosis

# Diagnosis: Overview



# Diagnosis: Questionnaires

- SARC-F
  - 5-item self-reported questionnaire; easily used in practice
  - Valid, consistent at identifying patients at risk for sarcopenia-related adverse outcomes
- SarQoL
  - Predicts sarcopenia complications that impact quality of life
  - Assesses patient’s perception of disease
  - Not as well validated
  - May serve as proxy to measure treatment efficacy

# Diagnosis: SARC-F

| Component | Question | Scoring | Score |
|---|---|---|---|
| **Strength** | How much difficulty do you have in lifting and carrying 10 pounds? | None = 0<br>Some = 1<br>A lot or unable = 2 | |
| **Assistance in walking** | How much difficulty do you have walking across a room? | None = 0<br>Some = 1<br>A lot, use aids, or unable = 2 | |
| **Rise from a chair** | How much difficulty do you have transferring from a chair or bed? | None =0<br>Some =1<br>A lot or unable without help = 2 | |
| **Climb stairs** | How much difficulty do you have climbing a flight of 10 stairs? | None = 0<br>Some =1<br>A lot or unable = 2 | |
| **Falls** | How many times have you fallen in the past year? | None =0<br>Some = 1<br>A lot or unable= 2 | |
| | | **TOTAL SCORE** | |

# Diagnosis: SARC-F

**Table 4 Construct validity: longitudinal comparisons for health outcomes among participants with high (≥4) vs. low (<4) SARC-F scores***

| African American Health | SARC-F scores ≥ 4 | |
|---|---|---|
| | Odds ratio (95% CI) | *P*-value* |
| Hospitalized overnight in the past year | 2.43 (1.46–4.05) | <0.001 |
| Gait speed < 0.8 m/s | 2.46 (1.13–5.34) | 0.023 |
| Mortality | 1.87 (1.17–2.98) | 0.009 |
| | Unstandardized coefficients B (SE) | *P*-value* |
| Instrumental Activities of Daily Living (IADLs; 0–8) | 0.78 (0.27) | 0.004 |
| Chair stands (s) | 3.14 (1.1) | 0.004 |
| Grip strength (kg) | −1.07 (1.0) | 0.288 |
| Short physical performance battery (0–12) | −0.29 (0.08) | <0.001 |
| **Baltimore Longitudinal Study of Aging** | **SARC-F scores ≥ 4** | |
| | Unstandardized coefficients B (SE) | *P*-value* |
| IADLs (0–7) | 1.24 (0.22) | <0.001 |
| Grip strength, right hand (kg) | −2.44 (1.19) | 0.041 |
| Grip strength, left hand (kg) | −2.96 (1.26) | 0.019 |
| | Odds ratio (95% CI) | *P*-value* |
| Mortality | 3.00 (1.57–5.73) | <0.001 |

CI, confidence interval; SE, standard error.

*Linear regression for continuous outcomes and logistic regression for dichotomous outcomes. Mortality analyses adjusted for age and gender. All other analyses adjusted for age, gender, and baseline value of the outcome variable being examined.

# Diagnosis: Strength Testing

- Grip strength
  - Simple and inexpensive
  - Requires calibrated dynamometer under defined test conditions with appropriate reference population
- Isometric torque methods
  - Measures lower extremity strength in patients with hand arthritis or deficits from stroke
- Chair sit to stand
  - Proxy for leg strength
  - Easy to perform in clinical setting

# Diagnosis: Grip Strength

REVIEW

## A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach

Helen C. Roberts[1,2], Hayley J. Denison[2], Helen J. Martin[2], Harnish P. Patel[1,2], Holly Syddall[2], Cyrus Cooper[2], Avan Aihie Sayer[1,2]

# Diagnosis: Grip Strength

**Figure 1.** Southampton protocol for adult grip strength measurement.

# Diagnosis: Grip Strength

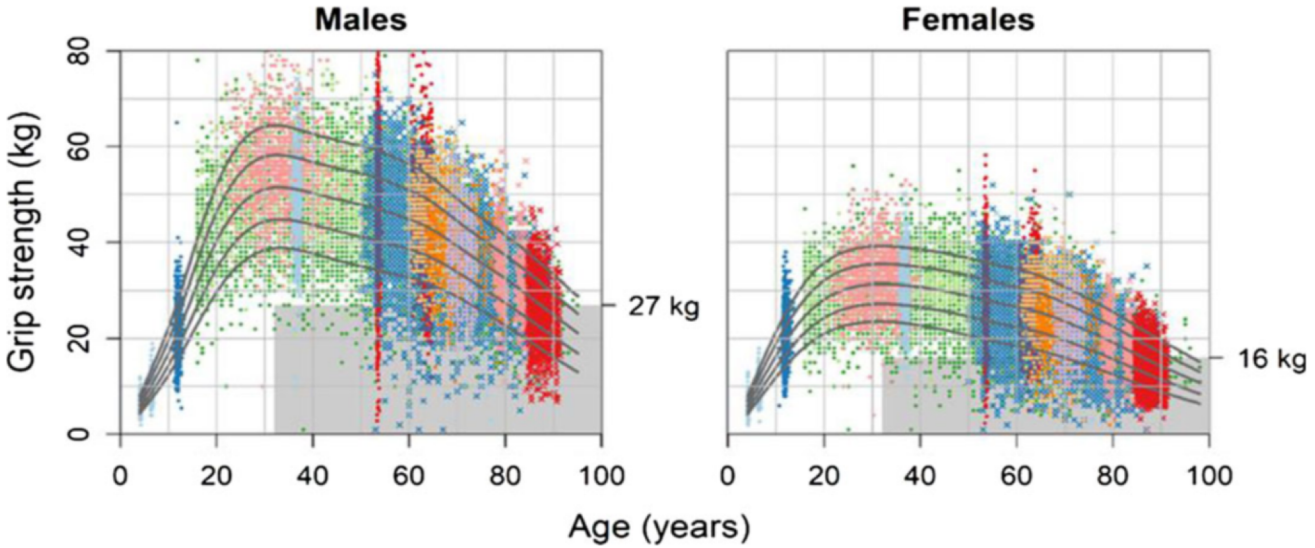



**Figure 2.** Normative data for grip strength across the life course in men and women in the UK (Dodds RM, *et al.* PLoS One. 2014;9:e113637). Centiles shown are 10th, 25th, 50th, 75th and 90th. Cut-off points based on *T*-score of ≤ -2.5 are shown for males and females (≤27 kg and 16 kg, respectively). Color-coding represents different birth cohorts used for the study (Figure adapted with permission from R Dodds and PLOS One).

# Diagnosis: Sit to Stand

## The sit-to-stand muscle power test: An easy, inexpensive and portable procedure to assess muscle power in older people

Julian Alcazar[a,b], Jose Losa-Reyna[a,b,c], Carlos Rodriguez-Lopez[a,b], Ana Alfaro-Acha[b,c], Leocadio Rodriguez-Mañas[b,d], Ignacio Ara[a,b], Francisco J. García-García[b,c,*], Luis M. Alegre[a,b,**]

[a] *GENUD Toledo Research Group, Universidad de Castilla-La Mancha, Toledo, Spain*
[b] *CIBER of Frailty and Healthy Aging (CIBERFES), Madrid, Spain*
[c] *Department of Geriatrics, Hospital Virgen del Valle, Complejo Hospitalario de Toledo, Toledo, Spain*
[d] *Department of Geriatrics, Hospital Universitario de Getafe, Madrid, Spain*

# Diagnosis: Muscle Mass

- Current area of study
- Difficult to incorporate into practice currently
- Dual-energy X-ray Absoptiometry (DXA)
  - Reproducible measure of appendicular skeletal mass
  - Not portable and influenced by hydration
- Bioelectrical impedance analysis
  - Estimates muscle mass based on whole-body conductivity
  - Math used needs validation
- Calf circumference
  - Used by WHO
  - Shown to predict survival and physical performance in older adults

# Diagnosis: Muscle Mass

**Table 2**
Unadjusted means (standard errors) of frailty index, physical performance and physical function measures (dependent variables) according to calf circumference.

| | Unadjusted mean (standard error) calf circumference | | |
|---|---|---|---|
| | <31 cm ($n = 108$) | ≥31 cm ($n = 158$) | $p$ |
| **Frailty measure** | | | |
| Frailty index score | 2.46 (0.14) | 1.48 (0.09) | <0.001 |
| **Physical performance measures** | | | |
| Short Physical Performance Battery | 5.23 (0.40) | 7.88 (0.26) | <0.001 |
| 4-m walking speed (m/s) | 0.39 (0.03) | 0.56 (0.02) | <0.001 |
| **Muscle strength measure** | | | |
| Hand grip strength (kg) | 24.44 (1.42) | 35.17 (1.14) | <0.001 |
| **Functional status measures** | | | |
| ADL scale score | 2.42 (0.27) | 0.86 (0.15) | <0.001 |
| IADL scale score | 3.90 (0.26) | 2.37 (0.18) | <0.001 |

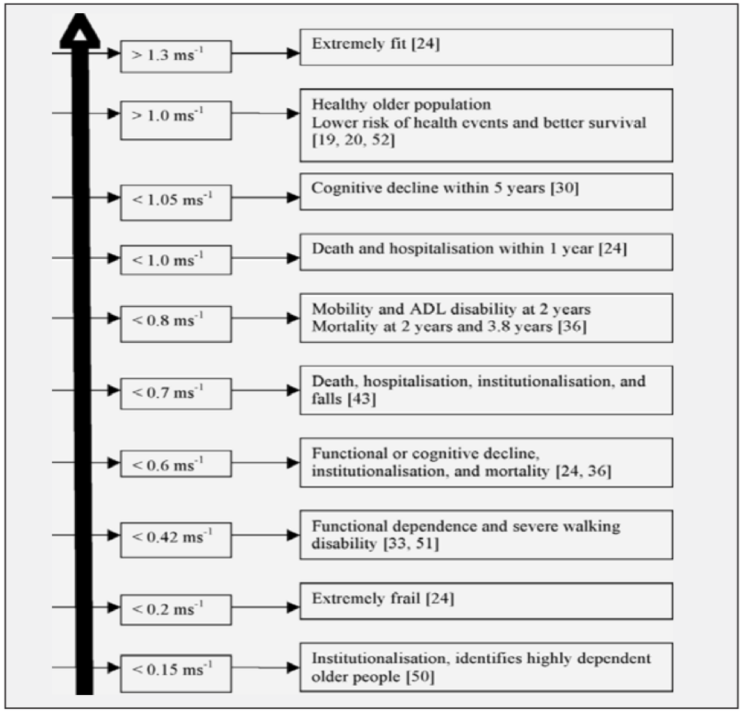
Frailty index score ranges from 0 (low grade) to 5 (high grade).
The Short Physical Performance Battery score (composed by usual gait speed, balance, and chair stand tests) ranges from 0 (worse performance) to 12 (best performance). ADL: Activities of Daily Living (range 0–7, a higher number indicates higher impairment). IADL: Instrumental Activities of Daily Living (range 0–7, a higher number indicates higher impairment).

# Diagnosis: Physical Performance

- Gait speed
  - Recommended by EWGSOP2 due to feasibility and ability to predict sarcopenia related outcomes
- Short Physical Performance Battery
  - Composite that includes gait speed, balance test, chair stand
  - Used mainly in research - takes at least 10 min to administer
- Timed Up and Go (TUG)
- 400m walk test

# Diagnosis: Gait Speed

**Figure 2**
Cut-points of gait speed at usual pace and risk of adverse outcomes found in literature



# Diagnosis: Summary

**Table 3.** EWGSOP2 sarcopenia cut-off points

| Test | Cut-off points for men | Cut-off points for women | References |
|---|---|---|---|
| EWGSOP2 sarcopenia cut-off points for low strength by chair stand and grip strength | | | |
| Grip strength | **<27 kg** | **<16 kg** | Dodds (2014) [26] |
| Chair stand | **>15 s for five rises** | | Cesari (2009) [67] |
| EWGSOP2 sarcopenia cut-off points for low muscle quantity | | | |
| ASM | **<20 kg** | **<15 kg** | Studenski (2014) [3] |
| ASM/height$^2$ | **<7.0 kg/m$^2$** | **<5.5 kg/m$^2$** | Gould (2014) [125] |
| EWGSOP2 sarcopenia cut-off points for low performance | | | |
| Gait speed | **≤0.8 m/s** | | Cruz-Jentoft (2010) [1]<br>Studenski (2011) [84] |
| SPPB | **≤8 point score** | | Pavasini (2016) [90]<br>Guralnik (1995) [126] |
| TUG | **≥20 s** | | Bischoff (2003) [127] |
| 400 m walk test | **Non-completion or ≥6 min for completion** | | Newman (2006) [128] |

# Prevention and Treatment

# Prevention and Treatment: Diet

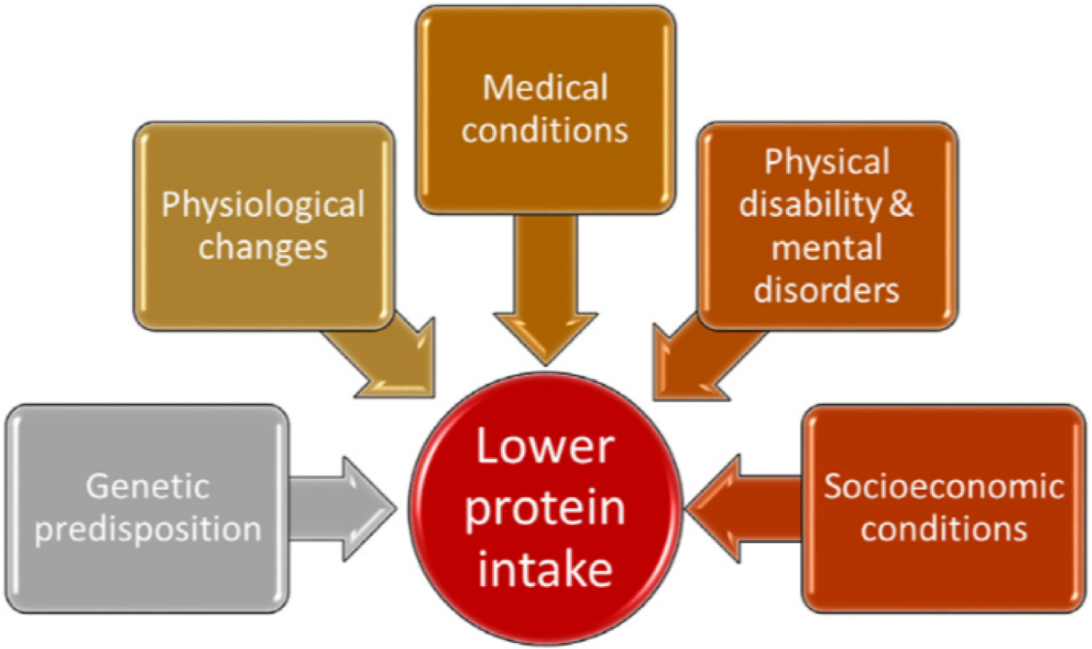



**Fig. 1.** Protein status: factors leading to lower protein intake in older persons.

# Prevention and Treatment: Diet

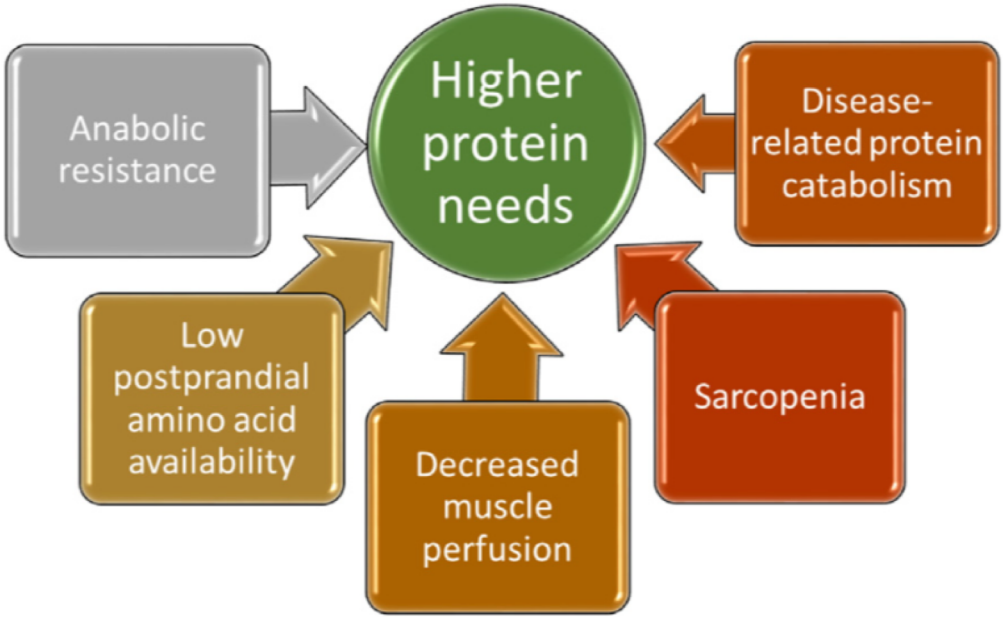



**Fig. 2.** Protein status: factors leading to higher protein needs in older persons.

# Prevention and Treatment: Diet

**Table 1**
Practical guidance for optimal dietary protein intake and exercise for older adults above 65 years.

| Recommendations |
| --- |
| For healthy older adults, we recommend a diet that includes at least 1.0–1.2 g protein/kg body weight/day. |
| For certain older adults who have acute or chronic illnesses, 1.2–1.5 g protein/kg body weight/day may be indicated, with even higher intake for individuals with severe illness or injury. |
| We recommend daily physical activity for all older adults, as long as activity is possible. We also suggest resistance training, when possible, as part of an overall fitness regimen. |

# Prevention and Treatment: Diet

## Biomarker-Calibrated Protein Intake and Physical Function in the Women's Health Initiative

*Jeannette M. Beasley, PhD,* Betsy C. Wertheim, MS,† Andrea Z. LaCroix, PhD,‡ Ross L. Prentice, PhD,‡ Marian L. Neuhouser, PhD,‡ Lesley F. Tinker, PhD,‡ Stephen Kritchevsky, PhD,§ James M. Shikany, DrPH,‖ Charles Eaton, MD,# Zhao Chen, PhD,** and Cynthia A. Thomson, PhD†***

# Prevention and Treatment: Diet

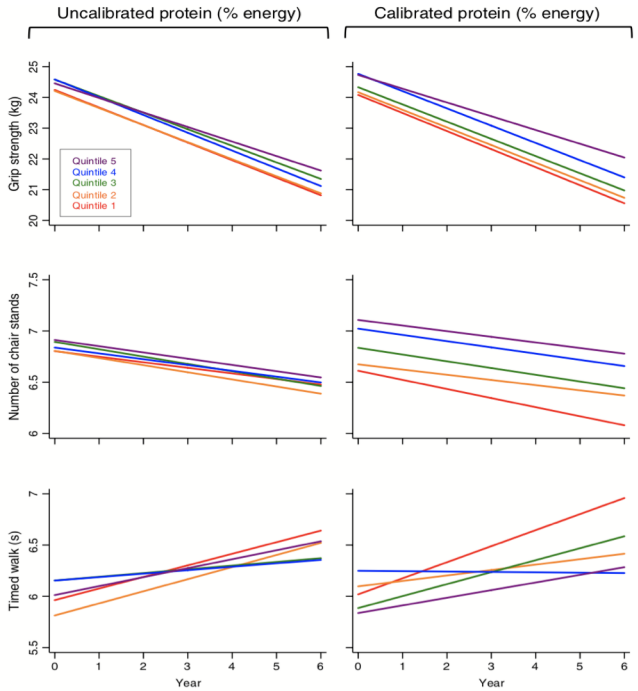
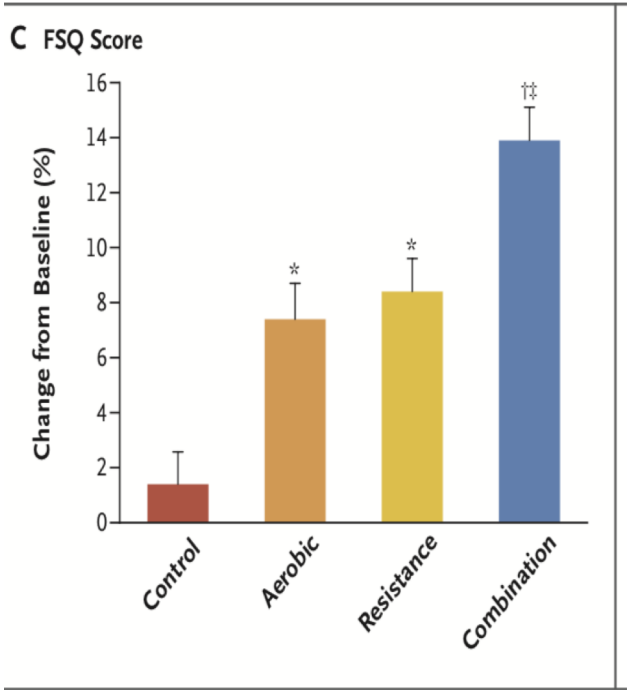
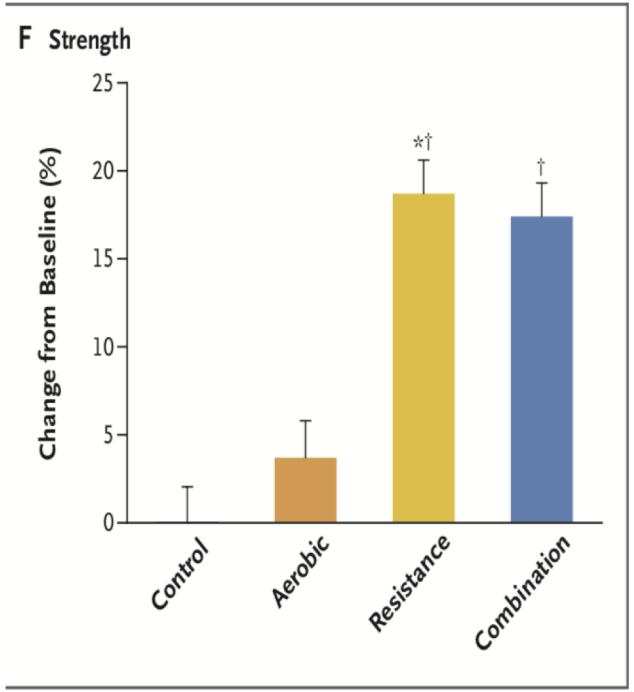


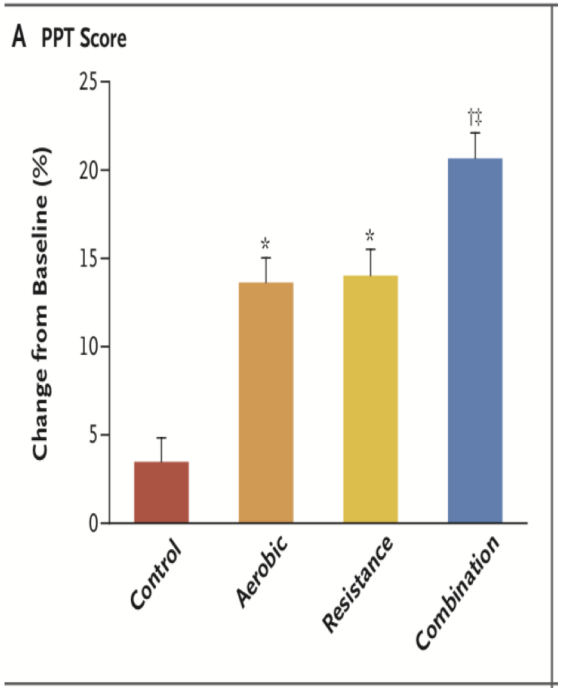

**Figure 2.** Physical performance measures over time, according to quintile of protein intake, calculated using generalized estimat ing equations. Models were adjusted for age, income, education, race and ethnicity, body mass index, smoking status, alcoho consumption, physical activity, hormone therapy use, whether the participant lived alone, having a healthcare provider, numbe of falls, disability, depression, self-reported history of medical conditions (emphysema, diabetes mellitus, hypertension, arthritis and cancer), calibrated total energy intake, and clinical trial arm.

# Treatment and Prevention: Exercise

# Exercise: Type Matters



# Exercise: Frequency Matters

**Table 2.** Association of physical activity with the sarcopenia incidence proportion over a 5-year period

| | Sarcopenia incidence (%) | Unadjusted model OR (95% CI) | Model 1 OR (95% CI) | Model 2 OR (95% CI) |
|---|---|---|---|---|
| Amount of MVPA at baseline | | | | |
| Never ($n$ = 799) | 14.8 | Ref | Ref | Ref |
| Rarely–occasionally ($n$ = 527) | 10.4 | 0.67 (0.48–0.95) | 0.78 (0.54–1.12) | 0.79 (0.54–1.14) |
| Moderate–high ($n$ = 814) | 9.0 | 0.58 (0.42–0.79) | 0.68 (0.49–0.94) | 0.64 (0.45–0.91) |

Ref, reference group. Model 1 is adjusted for age, sex, education and marital status. Model 2 further included BMI, smoking status, total number of comorbidities, depressive symptoms, weight loss and cognitive function.

# Exercise: Intensity Matters

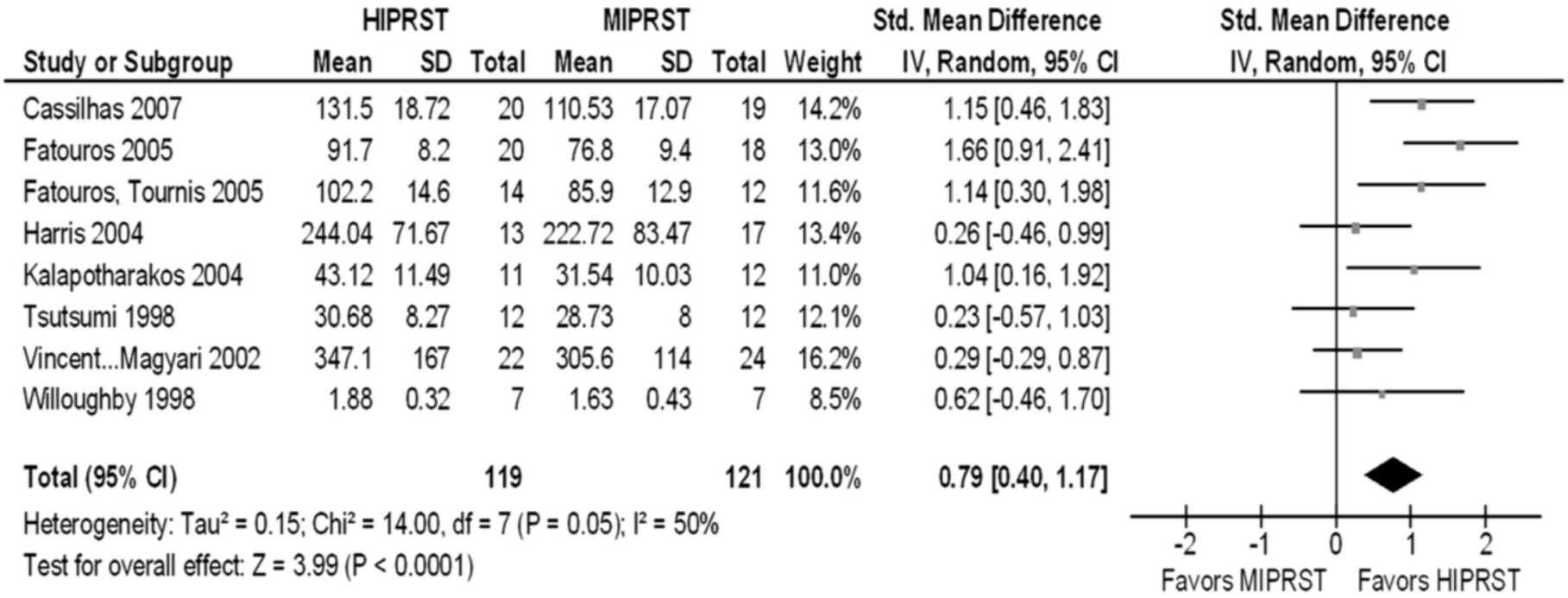
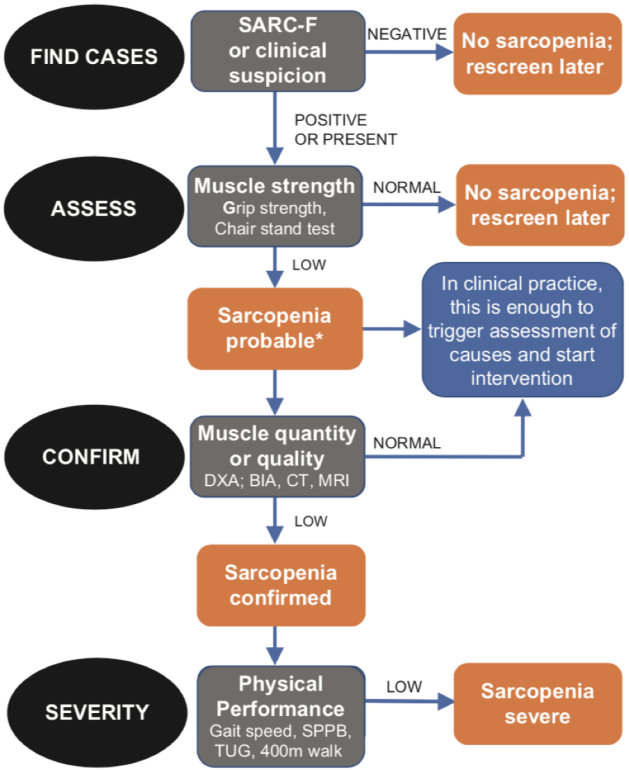



**Fig 3** HIPRST versus MIPRST for lower-limb strength. Abbreviations: IV, inverse variance; Std., standard.

# Role of the Primary Care Physician

# Role of the Primary Care Physician

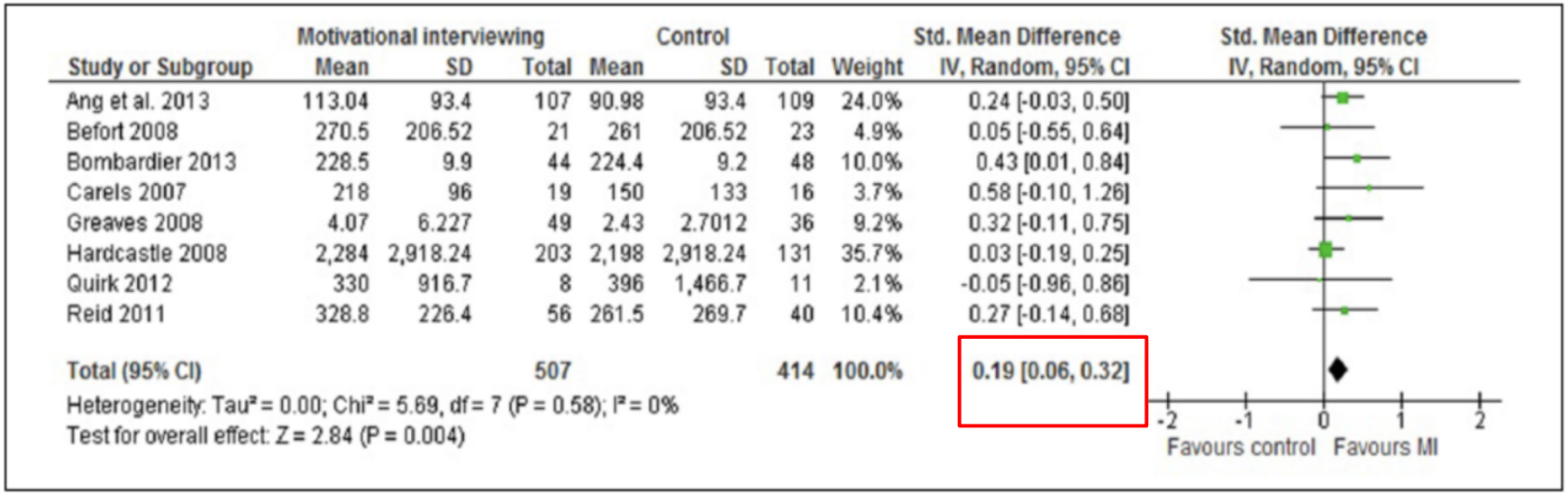


# Role of the Primary Care Physician

## Motivational interviewing to increase physical activity in people with chronic health conditions: a systematic review and meta-analysis

Paul D O'Halloran[1], Felicity Blackstock[1], Nora Shields[1,2], Anne Holland[1,3], Ross Iles[4], Mike Kingsley[1], Julie Bernhardt[1,5], Natasha Lannin[1,6], Meg E Morris[1] and Nicholas F Taylor[1,7]

# Role of the Primary Care Physician



| Study or Subgroup | Motivational interviewing Mean | SD | Total | Control Mean | SD | Total | Weight | Std. Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Ang et al. 2013 | 113.04 | 93.4 | 107 | 90.98 | 93.4 | 109 | 24.0% | 0.24 [-0.03, 0.50] |
| Befort 2008 | 270.5 | 206.52 | 21 | 261 | 206.52 | 23 | 4.9% | 0.05 [-0.55, 0.64] |
| Bombardier 2013 | 228.5 | 9.9 | 44 | 224.4 | 9.2 | 48 | 10.0% | 0.43 [0.01, 0.84] |
| Carels 2007 | 218 | 96 | 19 | 150 | 133 | 16 | 3.7% | 0.58 [-0.10, 1.26] |
| Greaves 2008 | 4.07 | 6.227 | 49 | 2.43 | 2.7012 | 36 | 9.2% | 0.32 [-0.11, 0.75] |
| Hardcastle 2008 | 2,284 | 2,918.24 | 203 | 2,198 | 2,918.24 | 131 | 35.7% | 0.03 [-0.19, 0.25] |
| Quirk 2012 | 330 | 916.7 | 8 | 396 | 1,466.7 | 11 | 2.1% | -0.05 [-0.96, 0.86] |
| Reid 2011 | 328.8 | 226.4 | 56 | 261.5 | 269.7 | 40 | 10.4% | 0.27 [-0.14, 0.68] |
| **Total (95% CI)** | | | **507** | | | **414** | **100.0%** | **0.19 [0.06, 0.32]** |

Heterogeneity: Tau² = 0.00; Chi² = 5.69, df = 7 (P = 0.58); I² = 0%
Test for overall effect: Z = 2.84 (P = 0.004)



**Figure 2.** Forest plot of comparison physical activity all conditions.

# Social Determinants

RESEARCH ARTICLE Open Access

## Inequalities in participation and time spent in moderate-to-vigorous physical activity: a pooled analysis of the cross-sectional health surveys for England 2008, 2012, and 2016

Shaun Scholes* and Jennifer S. Mindell

# Social Determinants

**Table 1** Total and domain-specific MVPA outcomes by income tertile among men, Health Survey for England 2008, 2012 and 2016

| | | Income | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | All | Lowest | Middle | Highest | Middle versus lowest | | Highest versus lowest | |
| | | | | | Difference (95% CI) | *P*-value[a] | Difference (95% CI) | *P*-value[a] |
| N | 11,199 | 3197 | 3729 | 4273 | | | | |
| **Total MVPA:** | | | | | | | | |
| Any: % (95% CI) | 85 (84, 85) | 75 (73, 77) | 86 (85, 87) | 90 (89, 91) | 11 (9, 13) | < 0.001 | 15 (13, 17) | < 0.001 |
| Sufficient: % (95% CI)[b] | 66 (65, 67) | 54 (52, 56) | 68 (66, 69) | 74 (72, 75) | 13 (11, 16) | < 0.001 | 19 (17, 22) | < 0.001 |
| MVPA hours/week:mean (SE)[c] | 9.7 (0.12) | 8.1 (0.23) | 10.3 (0.21) | 10.4 (0.18) | 2.2 (1.6, 2.8) | < 0.001 | 2.2 (1.7, 2.8) | < 0.001 |
| MVPA-active hours/week:mean (SE)[d] | 11.5 (0.13) | 10.4 (0.27) | 11.7 (0.23) | 11.4 (0.19) | 1.3 (0.6, 1.9) | < 0.001 | 0.9 (0.3, 1.6) | 0.004 |

# Social Determinants

**Table 2** Total and domain-specific MVPA by income tertile among women, Health Survey for England 2008, 2012 and 2016

| | All | Lowest | Middle | Highest | Middle versus lowest | | Highest versus lowest | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Difference (95% CI) | *P*-value[a] | Difference (95% CI) | *P*-value[a] |
| N | 13,683 | 4605 | 4627 | 4451 | | | | |
| **Total MVPA:** | | | | | | | | |
| Any: % (95% CI) | 81 (80, 82) | 74 (73, 76) | 81 (80, 82) | 86 (85, 88) | 7 (5, 8) | < 0.001 | 12 (10, 14) | < 0.001 |
| Sufficient: % (95% CI)[b] | 56 (55, 57) | 49 (47, 50) | 56 (54, 57) | 63 (62, 65) | 7 (5, 9) | < 0.001 | 14 (12, 16) | < 0.001 |
| MVPA hours/week:mean (SE)[c] | 6.8 (0.09) | 5.8 (0.15) | 6.9 (0.14) | 7.6 (0.16) | 1.1 (0.7, 1.5) | < 0.001 | 1.8 (1.3, 2.2) | < 0.001 |
| MVPA-active hours/week:mean (SE)[d] | 8.4 (0.10) | 7.6 (0.17) | 8.3 (0.16) | 8.6 (0.17) | 0.7 (0.3, 1.2) | 0.001 | 1.0 (0.6, 1.5) | < 0.001 |

# Summary

- Sarcopenia is a disease characterized by adverse muscle changes that cause
  - Decreased strength
  - Decreased muscle quantity and/or quality
  - Poor physical performance in severe cases
- Sarcopenia is associated with adverse health outcomes and increased costs
- EWGSOP2 provides framework for clinical diagnosis and evaluation
- Treatment mainstays are exercise and dietary protein intake
- Role of the primary care doctor includes recognition, motivational interviewing, and awareness of social determinants

1. Abellan Van Kan G, Rolland Y, Andrieu S, et al. Gait speed at usual pace as a predictor of adverse outcomes in community-dwelling older people an International Academy on Nutrition and Aging (IANA) Task Force. *J Nutr Health Aging*. 2009;13(10):881-889. doi:10.1007/s12603-009-0246-z

2. Alcazar J, Losa-Reyna J, Rodriguez-Lopez C, et al. The sit-to-stand muscle power test: An easy, inexpensive and portable procedure to assess muscle power in older people. *Experimental Gerontology*. 2018;112:38-43. doi:10.1016/j.exger.2018.08.006

3. Antunes AC, Araújo DA, Veríssimo MT, Amaral TF. Sarcopenia and hospitalisation costs in older adults: a cross-sectional study. *Nutrition & Dietetics*. 2017;74(1):46-50. doi:https://doi.org/10.1111/1747-0080.12287

4. Bahat G, İlhan B. Sarcopenia and the cardiometabolic syndrome: A narrative review. *European Geriatric Medicine*. 2016;7(3):220-223. doi:10.1016/j.eurger.2015.12.012

5. Bahat G, Yilmaz O, Kiliç C, Oren MM, Karan MA. Performance of SARC-F in Regard to Sarcopenia Definitions, Muscle Mass and Functional Measures. *J Nutr Health Aging*. 2018;22(8):898-903. doi:10.1007/s12603-018-1067-8

6. Barha CK, Falck RS, Skou ST, Liu-Ambrose T. Personalising exercise recommendations for healthy cognition and mobility in ageing: time to consider one's pre-existing function and genotype (Part 2). *Br J Sports Med*. 2021;55(6):301-303. doi:10.1136/bjsports-2020-102865

7. Barha CK, Falck RS, Skou ST, Liu-Ambrose T. Personalising exercise recommendations for healthy cognition and mobility in aging: time to address sex and gender (Part 1). *Br J Sports Med*. 2021;55(6):300-301. doi:10.1136/bjsports-2020-102864

8. Barker KL, Reid M, Lowe CJM. What does the language we use about arthritis mean to people who have osteoarthritis? A qualitative study. *Disability and Rehabilitation*. 2014;36(5):367-372. doi:10.3109/09638288.2013.793409

9. Beasley JM, Wertheim BC, LaCroix AZ, et al. Biomarker-Calibrated Protein Intake and Physical Function in the Women's Health Initiative. *Journal of the American Geriatrics Society*. 2013;61(11):1863-1871. doi:https://doi.org/10.1111/jgs.12503

10. Beaudart C, Biver E, Reginster J-Y, et al. Validation of the SarQoL®, a specific health-related quality of life questionnaire for Sarcopenia. *Journal of Cachexia, Sarcopenia and Muscle*. 2017;8(2):238-244. doi:https://doi.org/10.1002/jcsm.12149

11. Beaudart C, McCloskey E, Bruyère O, et al. Sarcopenia in daily practice: assessment and management. *BMC Geriatr*. 2016;16(1):170. doi:10.1186/s12877-016-0349-4

12. Bone AE, Hepgul N, Kon S, Maddocks M. Sarcopenia and frailty in chronic respiratory disease. *Chron Respir Dis*. 2017;14(1):85-99. doi:10.1177/1479972316679664

13. Brown JC, Harhay MO, Harhay MN. Sarcopenia and mortality among a population-based sample of community-dwelling older adults. *J Cachexia Sarcopenia Muscle*. 2016;7(3):290-298. doi:10.1002/jcsm.12073

14. Cesari M, Kritchevsky SB, Newman AB, et al. Added Value of Physical Performance Measures in Predicting Adverse Health-Related Events: Results from the Health, Aging and Body Composition Study. *Journal of the American Geriatrics Society*. 2009;57(2):251-259. doi:https://doi.org/10.1111/j.1532-5415.2008.02126.x

15. Chang K-V, Hsu T-H, Wu W-T, Huang K-C, Han D-S. Association Between Sarcopenia and Cognitive Impairment: A Systematic Review and Meta-Analysis. *Journal of the American Medical Directors Association*. 2016;17(12):1164.e7-1164.e15. doi:10.1016/j.jamda.2016.09.013

16. Cruz-Jentoft AJ, Bahat G, Bauer J, et al. Sarcopenia: revised European consensus on definition and diagnosis. *Age and Ageing*. 2019;48(1):16-31. doi:10.1093/ageing/afy169

17. Cruz-Jentoft AJ, Sayer AA. Sarcopenia. *The Lancet*. 2019;393(10191):2636-2646. doi:10.1016/S0140-6736(19)31138-9

18. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. *Age and Ageing*. 2010;39(4):412-423. doi:10.1093/ageing/afq034

19. Curcio F, Ferro G, Basile C, et al. Biomarkers in sarcopenia: A multifactorial approach. *Experimental Gerontology*. 2016;85:1-8. doi:10.1016/j.exger.2016.09.007

20. Damanti S, Azzolino D, Roncaglione C, Arosio B, Rossi P, Cesari M. Efficacy of Nutritional Interventions as Stand-Alone or Synergistic Treatments with Exercise for the Management of Sarcopenia. *Nutrients*. 2019;11(9):1991. doi:10.3390/nu11091991

21. De Buyser SL, Petrovic M, Taes YE, et al. Validation of the FNIH sarcopenia criteria and SOF frailty index as predictors of long-term mortality in ambulatory older men. *Age and Ageing*. 2016;45(5):602-608. doi:10.1093/ageing/afw071

23. Deutz NEP, Bauer JM, Barazzoni R, et al. Protein intake and exercise for optimal muscle function with aging: Recommendations from the ESPEN Expert Group. *Clinical Nutrition*. 2014;33(6):929-936. doi:10.1016/j.clnu.2014.04.007

24. Deyle GD, Allen CS, Allison SC, et al. Physical Therapy versus Glucocorticoid Injection for Osteoarthritis of the Knee. *New England Journal of Medicine*. 2020;382(15):1420-1429. doi:10.1056/NEJMoa1905877

25. Dhillon RJS, Hasni S. Pathogenesis and Management of Sarcopenia. *Clinics in Geriatric Medicine*. 2017;33(1):17-26. doi:10.1016/j.cger.2016.08.002

26. Dodds R, Denison HJ, Ntani G, et al. Birth weight and muscle strength: A systematic review and meta-analysis. *J Nutr Health Aging*. 2012;16(7):609-615. doi:10.1007/s12603-012-0053-9

27. Dodds RM, Syddall HE, Cooper R, et al. Grip Strength across the Life Course: Normative Data from Twelve British Studies. *PLOS ONE*. 2014;9(12):e113637. doi:10.1371/journal.pone.0113637

28. Emami A, Saitoh M, Valentova M, et al. Comparison of sarcopenia and cachexia in men with chronic heart failure: results from the Studies Investigating Co-morbidities Aggravating Heart Failure (SICA-HF). *European Journal of Heart Failure*. 2018;20(11):1580-1587. doi:https://doi.org/10.1002/ejhf.1304

29. Fried LP, Tangen CM, Walston J, et al. Frailty in Older Adults: Evidence for a Phenotype. *The Journals of Gerontology: Series A*. 2001;56(3):M146-M157. doi:10.1093/gerona/56.3.M146

30. Han A, Bokshan SL, Marcaccio SE, DePasse JM, Daniels AH. Diagnostic Criteria and Clinical Outcomes in Sarcopenia Research: A Literature Review. *Journal of Clinical Medicine*. 2018;7(4):70. doi:10.3390/jcm7040070

31. Hendry M, Williams NH, Markland D, Wilkinson C, Maddison P. Why should we exercise when our knees hurt? A qualitative study of primary care patients with osteoarthritis of the knee. *Fam Pract*. 2006;23(5):558-567. doi:10.1093/fampra/cml022

32. Hsu K-J, Liao C-D, Tsai M-W, Chen C-N. Effects of Exercise and Nutritional Intervention on Body Composition, Metabolic Health, and Physical Performance in Adults with Sarcopenic Obesity: A Meta-Analysis. *Nutrients*. 2019;11(9):2163. doi:10.3390/nu11092163

33. Hull H, He Q, Thornton J, et al. iDXA, Prodigy, and DPXL dual-energy X-ray absorptiometry whole-body scans: a cross-calibration study. *J Clin Densitom*. 2009;12(1):95-102. doi:10.1016/j.jocd.2008.09.004

34. Ibrahim K, May C, Patel HP, Baxter M, Sayer AA, Roberts H. A feasibility study of implementing grip strength measurement into routine hospital practice (GRImP): study protocol. *Pilot Feasibility Stud*. 2016;2(1):27. doi:10.1186/s40814-016-0067-x

35. Ishii S, Tanaka T, Shibasaki K, et al. Development of a simple screening test for sarcopenia in older adults. *Geriatrics & Gerontology International*. 2014;14(S1):93-101. doi:https://doi.org/10.1111/ggi.12197

36. Jones CJ, Rikli RE, Beam WC. A 30-s Chair-Stand Test as a Measure of Lower Body Strength in Community-Residing Older Adults. *null*. 1999;70(2):113-119. doi:10.1080/02701367.1999.10608028

37. Jones SE, Kon SSC, Canavan JL, et al. The five-repetition sit-to-stand test as a functional outcome measure in COPD. *Thorax*. 2013;68(11):1015-1020. doi:10.1136/thoraxjnl-2013-203576

38. Keller K, Engelhardt M. Strength and muscle mass loss with aging process. Age and strength loss. *Muscles Ligaments Tendons J*. 2014;3(4):346-350.

39. Landi F, Onder G, Russo A, et al. Calf circumference, frailty and physical performance among older adults living in the community. *Clinical Nutrition*. 2014;33(3):539-544. doi:10.1016/j.clnu.2013.07.013

40. Leong DP, Teo KK, Rangarajan S, et al. Prognostic value of grip strength: findings from the Prospective Urban Rural Epidemiology (PURE) study. *The Lancet*. 2015;386(9990):266-273. doi:10.1016/S0140-6736(14)62000-6

41. Malmstrom TK, Miller DK, Simonsick EM, Ferrucci L, Morley JE. SARC-F: a symptom score to predict persons with sarcopenia at risk for poor functional outcomes. *Journal of Cachexia, Sarcopenia and Muscle*. 2016;7(1):28-36. doi:https://doi.org/10.1002/jcsm.12048

42. Martínez-Velilla N, Casas-Herrero A, Zambom-Ferraresi F, et al. Effect of Exercise Intervention on Functional Decline in Very Elderly Patients During Acute Hospitalization: A Randomized Clinical Trial. *JAMA Intern Med*. 2019;179(1):28-36. doi:10.1001/jamainternmed.2018.4869

McKee A, Morley JE, Matsumoto AM, Vinik A. Sarcopenia: An Endocrine Disorder? *Endocrine Practice*. 2017;23(9):1143-1152. doi:10.4158/EP171795.RA

44. Mijnarends DM, Luiking YC, Halfens RJG, et al. Muscle, Health and Costs: A Glance at their Relationship. *J Nutr Health Aging*. 2018;22(7):766-773. doi:10.1007/s12603-018-1058-9

45. Mijnarends DM, Koster A, Schols JMGA, et al. Physical activity and incidence of sarcopenia: the population-based AGES—Reykjavik Study. *Age and Ageing*. 2016;45(5):614-620. doi:10.1093/ageing/afw090

46. Mijnarends DM, Meijers JMM, Halfens RJG, et al. Validity and Reliability of Tools to Measure Muscle Mass, Strength, and Physical Performance in Community-Dwelling Older People: A Systematic Review. *Journal of the American Medical Directors Association*. 2013;14(3):170-178. doi:10.1016/j.jamda.2012.10.009

47. Moore SA, Hrisos N, Errington L, et al. Exercise as a treatment for sarcopenia: an umbrella review of systematic review evidence. *Physiotherapy*. 2020;107:189-201. doi:10.1016/j.physio.2019.08.005

48. Morley JE. Pharmacologic Options for the Treatment of Sarcopenia. *Calcif Tissue Int*. 2016;98(4):319-333. doi:10.1007/s00223-015-0022-5

49. Morley JE. Treatment of sarcopenia: the road to the future. *Journal of Cachexia, Sarcopenia and Muscle*. 2018;9(7):1196-1199. doi:https://doi.org/10.1002/jcsm.12386

50. Naseeb MA, Volpe SL. Protein and exercise in the prevention of sarcopenia and aging. *Nutrition Research*. 2017;40:1-20. doi:10.1016/j.nutres.2017.01.001

51. Nicola F, Catherine S. Dose–response relationship of resistance training in older adults: a meta-analysis. *British Journal of Sports Medicine*. 2011;45(3):233-234. doi:10.1136/bjsm.2010.083246

52. Nijholt W, Scafoglieri A, Jager-Wittenaar H, Hobbelen JSM, Schans CP van der. The reliability and validity of ultrasound to quantify muscles in older adults: a systematic review. *Journal of Cachexia, Sarcopenia and Muscle*. 2017;8(5):702-712. doi:https://doi.org/10.1002/jcsm.12210

53. O'Halloran PD, Blackstock F, Shields N, et al. Motivational interviewing to increase physical activity in people with chronic health conditions: a systematic review and meta-analysis. *Clin Rehabil*. 2014;28(12):1159-1171. doi:10.1177/0269215514536210

54. Patel HP, Syddall HE, Jameson K, et al. Prevalence of sarcopenia in community-dwelling older people in the UK using the European Working Group on Sarcopenia in Older People (EWGSOP) definition: findings from the Hertfordshire Cohort Study (HCS). *Age and Ageing*. 2013;42(3):378-384. doi:10.1093/ageing/afs197

55. Pavasini R, Guralnik J, Brown JC, et al. Short Physical Performance Battery and all-cause mortality: systematic review and meta-analysis. *BMC Med*. 2016;14(1):215. doi:10.1186/s12916-016-0763-7

56. Prado CMM, Wells JCK, Smith SR, Stephan BCM, Siervo M. Sarcopenic obesity: A Critical appraisal of the current evidence. *Clinical Nutrition*. 2012;31(5):583-601. doi:10.1016/j.clnu.2012.06.010

57. Raymond MJ, Bramley-Tzerefos RE, Jeffs KJ, Winter A, Holland AE. Systematic Review of High-Intensity Progressive Resistance Strength Training of the Lower Limb Compared With Other Intensities of Strength Training in Older Adults. *Archives of Physical Medicine and Rehabilitation*. 2013;94(8):1458-1472. doi:10.1016/j.apmr.2013.02.022

58. Roberts HC, Denison HJ, Martin HJ, et al. A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. *Age and Ageing*. 2011;40(4):423-429. doi:10.1093/ageing/afr051

59. Santos L dos, Cyrino ES, Antunes M, Santos DA, Sardinha LB. Sarcopenia and physical independence in older adults: the independent and synergic role of muscle mass and muscle function. *Journal of Cachexia, Sarcopenia and Muscle*. 2017;8(2):245-250. doi:https://doi.org/10.1002/jcsm.12160

60. Sayer AA, Syddall H, Martin H, Patel H, Baylis D, Cooper C. The developmental origins of sarcopenia. *J Nutr Health Aging*. 2008;12(7):427. doi:10.1007/BF02982703

61. Sayer AA, Syddall HE, Gilbody HJ, Dennison EM, Cooper C. Does Sarcopenia Originate in Early Life? Findings From the Hertfordshire Cohort Study. *The Journals of Gerontology: Series A*. 2004;59(9):M930-M934. doi:10.1093/gerona/59.9.M930

62. Schaap LA, van Schoor NM, Lips P, Visser M. Associations of Sarcopenia Definitions, and Their Components, With the Incidence of Recurrent Falling and Fractures: The Longitudinal Aging Study Amsterdam. *The Journals of Gerontology: Series A*. 2018;73(9):1199-1204. doi:10.1093/gerona/glx245

63. Schaap LA, Koster A, Visser M. Adiposity, Muscle Mass, and Muscle Strength in Relation to Functional Decline in Older Persons. *Epidemiologic Reviews*. 2013;35(1):51-65. doi:10.1093/epirev/mxs006

64. Scholes S, Mindell JS. Inequalities in participation and time spent in moderate-to-vigorous physical activity: a pooled analysis of the cross-sectional health surveys for England 2008, 2012, and 2016. *BMC Public Health*. 2020;20(1):361. doi:10.1186/s12889-020-08479-x

65. Shad BJ, Thompson JL, Breen L. Does the muscle protein synthetic response to exercise and amino acid-based nutrition diminish with advancing age? A systematic review. *American Journal of Physiology-Endocrinology and Metabolism*. 2016;311(5):E803-E817. doi:10.1152/ajpendo.00213.2016

66. Silva NL, Oliveira RB, Fleck SJ, Leon ACMP, Farinatti P. Influence of strength training variables on strength gains in adults over 55 years-old: A meta-analysis of dose–response relationships. *Journal of Science and Medicine in Sport*. 2014;17(3):337-344. doi:10.1016/j.jsams.2013.05.009

67. Sousa AS, Guerra RS, Fonseca I, Pichel F, Ferreira S, Amaral TF. Financial impact of sarcopenia on hospitalization costs. *European Journal of Clinical Nutrition*. 2016;70(9):1046-1051. doi:10.1038/ejcn.2016.73

68. Sousa-Santos AR, Amaral TF. Differences in handgrip strength protocols to identify sarcopenia and frailty - a systematic review. *BMC Geriatr*. 2017;17(1):238. doi:10.1186/s12877-017-0625-y

69. Steffl M, Bohannon RW, Sontakova L, Tufano JJ, Shiells K, Holmerova I. Relationship between sarcopenia and physical activity in older people: a systematic review and meta-analysis. *Clin Interv Aging*. 2017;12:835-845. doi:10.2147/CIA.S132940

70. Steiber N. Strong or Weak Handgrip? Normative Reference Values for the German Population across the Life Course Stratified by Sex, Age, and Body Height. *PLOS ONE*. 2016;11(10):e0163917. doi:10.1371/journal.pone.0163917

71. Studenski S, Perera S, Patel K, et al. Gait Speed and Survival in Older Adults. *JAMA*. 2011;305(1):50-58. doi:10.1001/jama.2010.1923

72. Villareal DT, Aguirre L, Gurney AB, et al. Aerobic or Resistance Exercise, or Both, in Dieting Obese Older Adults. *N Engl J Med*. 2017;376(20):1943-1955. doi:10.1056/NEJMoa1616338

73. Yang Y, Breen L, Burd NA, et al. Resistance exercise enhances myofibrillar protein synthesis with graded intakes of whey protein in older men. *British Journal of Nutrition*. 2012;108(10):1780-1788. doi:10.1017/S0007114511007422

74. APTA - Under-dosed strength training programs | Choosing Wisely. Published September 15, 2014. Accessed April 14, 2021. https://www.choosingwisely.org/clinician-lists/american-physical-therapy-association-under-dosed-strength-training-for-older-adults/

75. Physical Activity Guidelines for Americans, 2nd edition. :118.

Questions?