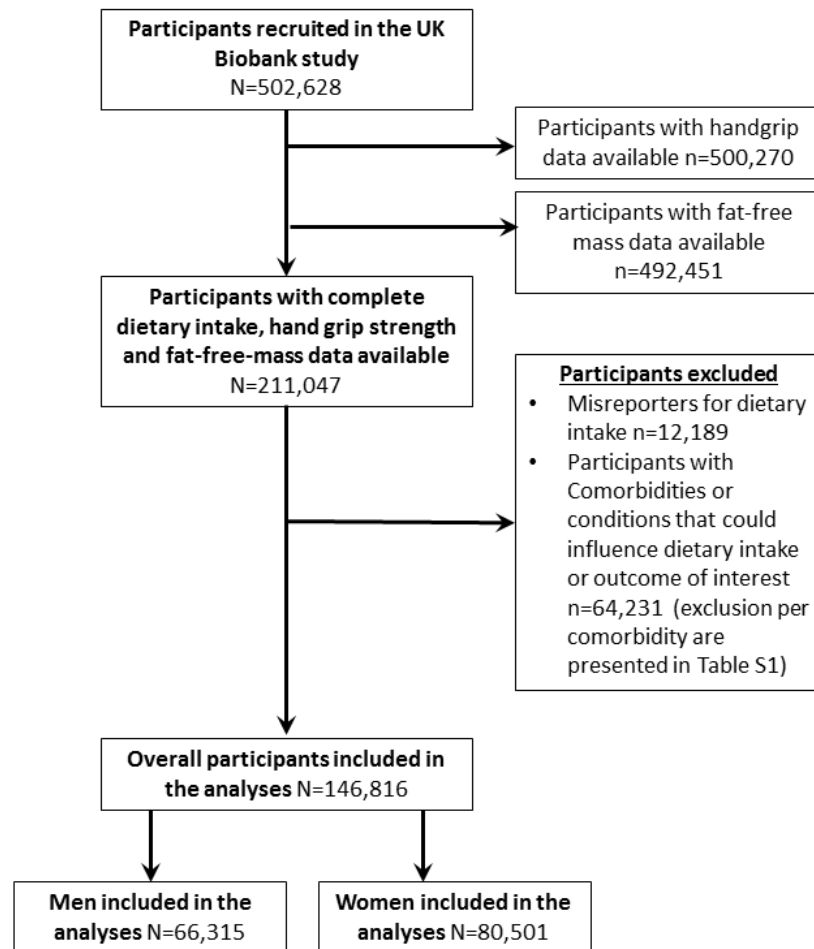


## ONLINE-SUPPLEMENTARY MATERIAL

**Supplementary Table S1. Participants with protein intake data who were excluded from analysis due to comorbidities or conditions that could influence protein intake, body composition or handgrip strength.**

| Comorbidity,              | Number of participants excluded |
|---------------------------|---------------------------------|
| Epilepsy                  | 1,369                           |
| Dementia                  | 28                              |
| Parkinson                 | 290                             |
| Schizophrenia             | 651                             |
| Depression                | 28,478                          |
| Hepatitis                 | 579                             |
| Eating disorders          | 172                             |
| Chronic liver disease     | 349                             |
| Inflammatory diseases     | 4,204                           |
| Chronic pain              | 32,226                          |
| Substance abuse           | 22                              |
| Osteoarthritis            | 13,838                          |
| Rheumatoid arthritis      | 1,888                           |
| Alcohol intake problems   | 220                             |
| Cancer diagnosed          | 15,929                          |
| Misreports dietary intake | 12,189                          |

Out of 211,047 participants with available data for protein intake, 64,231 participants were excluded based on the condition listed above; therefore, 146,816 participants were included in the analysis. Participants could have one or more of these conditions listed.



Supplementary Figure 1. Flowchart of UK Biobank participants included and excluded of the current study

**Supplementary Table S2. Baseline characteristics of women from the UK Biobank who were included or excluded from the analyses.**

|                                | <b>Participants<br/>included</b> | <b>Participants<br/>excluded</b> |
|--------------------------------|----------------------------------|----------------------------------|
| <b>Socio-demographics</b>      |                                  |                                  |
| Total n                        | 80,501                           | 157,453                          |
| Age (years), mean (SD)         | 54.8 (7.83)                      | 56.9 (8.08)                      |
| Age categories                 |                                  |                                  |
| <45 years                      | 10,167 (12.6)                    | 15,042 (9.6)                     |
| 45-50 years                    | 12,974 (16.1)                    | 20,136 (12.7)                    |
| 51-55 years                    | 14,693 (18.3)                    | 23,416 (14.8)                    |
| 56-60 years                    | 15,607 (19.4)                    | 27,996 (17.8)                    |
| 61-65 years                    | 17,619 (21.9)                    | 38,512 (24.5)                    |
| >65 years                      | 9,441 (11.7)                     | 32,351 (20.6)                    |
| Deprivation index, mean (SD)   | -1.61 (2.82)                     | -1.17 (3.17)                     |
| Deprivation                    |                                  |                                  |
| 1 (Least Deprived)             | 21,415 (26.6)                    | 37,853 (24.0)                    |
| 2                              | 21,079 (26.2)                    | 38,761 (24.7)                    |
| 3                              | 21,017 (26.1)                    | 38,934 (24.8)                    |
| 4 (Most Deprived)              | 16,990 (21.1)                    | 41,663 (26.5)                    |
| Ethnicity, n (%)               |                                  |                                  |
| White                          | 76,822 (95.6)                    | 146,865 (93.8)                   |
| Mixed background               | 576 (0.7)                        | 1,054 (0.7)                      |
| South Asian                    | 963 (1.2)                        | 3,199 (2.0)                      |
| Black                          | 1,030 (1.3)                      | 3,107 (2.0)                      |
| Chinese                        | 292 (0.4)                        | 605 (0.4)                        |
| Other                          | 638 (0.8)                        | 1,676 (1.1)                      |
| Smoking status, n (%)          |                                  |                                  |
| Never                          | 49,801 (61.9)                    | 91,838 (58.8)                    |
| Previous                       | 25,431 (31.6)                    | 47,786 (30.6)                    |
| Current                        | 5,269 (6.5)                      | 16,605 (10.6)                    |
| <b>Obesity-related markers</b> |                                  |                                  |
| Height (meters), mean (SD)     | 1.63 (0.06)                      | 1.62 (0.06)                      |
| Body weight (kg), mean (SD)    | 69.9 (13.1)                      | 72.0 (14.3)                      |
| BMI, mean (SD)                 | 26.2 (4.76)                      | 27.5 (5.28)                      |

|  |                                       |  |
|--|---------------------------------------|--|
| BMI Categories, n (%)  |                                       |  |
| Under weight (<18.5 kg.m <sup>-2</sup> )                       | 644 (0.8)                             | 1,131 (0.7)                            |
| Normal weight (18.5-24.9 kg.m <sup>-2</sup> )                  | 37,493 (46.6)                         | 54,903 (35.2)                          |
| Overweight (25.0 to 29.9 kg.m <sup>-2</sup> )                  | 28,011 (34.8)                         | 59,159 (37.9)                          |
| Obese (≥30.0 kg.m <sup>-2</sup> )                              | 14,353 (17.8)                         | 40,831 (26.2)                          |
| Waist Circumference (cm)                                       | 82.5 (11.7)                           | 85.7 (12.7)                            |
| Central Obesity, n (%)   | 23,413 (29.1)                         | 62,108 (39.7)                          |
| % Body fat, mean (SD)  | 35.4 (6.79)                           | 37.1 (6.85)                            |
| Body fat-free mass (%), mean (SD)                              | 64.6 (6.79)                           | 62.9 (6.85)                            |
| Body fat-free mass (kg), mean (SD)                             | 44.5 (4.78)                           | 44.5 (5.10)                            |
| <b>Fitness and Physical activity</b>                           |                                       |  |
| Total PA (MET.h <sup>-1</sup> .week <sup>-1</sup> ), mean (SD) | 42.5 (48.4)                           | 46.1 (58.4)                            |
| Physically active individuals n,(%)                            | 45,144 (56.1)                         | 77,441 (49.2)                          |
| Grip Strength (kg), mean (SD)                                  | 24.4 (5.87)                           | 22.9 (7.22)                            |
| Grip strength (kg.kg body mass <sup>-1</sup> ), mean (SD)      | 0.36 (0.10)                           | 0.33 (0.10)                            |
| TV viewing (h.day <sup>-1</sup> ), mean (SD)                   | 2.41 (1.44)                           | 2.97 (1.69)                            |
| Total Sedentary behaviour (h.day <sup>-1</sup> ) , mean (SD)   | <del>24.4 (5.87)</del> 4.61<br>(2.00) | 4.61 (2.14)                            |
| <b>Dietary intakes</b>   |                                       |  |
| Total energy intake (kcal.day <sup>-1</sup> ), mean (SD)       | 1,994 (479)                           | 1,841 (559)                            |
| Carbohydrate intake (% of TE), mean (SD)                       | 47.5 (7.89)                           | 48.0 (8.65)                            |
| Fat intake (% of TE), mean (SD)                                | 32.4 (6.64)                           | 32.3 (7.22)                            |
| Protein intake (% of TE), mean (SD)                            | 15.8 (3.55)                           | <del>16.2 (4.79)</del> 3.51<br>(5.26)  |
| Alcohol intake (% of TE), mean (SD)                            | 4.31 (5.56)                           | <del>3.51 (5.26)</del> 104.8<br>(42.3) |
| Alcohol frequency (times.week <sup>-1</sup> ), mean (SD)       | 3.06 (1.48)                           | 2.67 (1.57)                            |
| Fruit and vegetable intake (g.day <sup>-1</sup> ), mean (SD)   | 354.2 (182.3)                         | 346.8 (197.7)                          |
| Processed meat intake (portion.week <sup>-1</sup> ), mean (SD) | 1.56 (1.00)                           | 1.62 (1.00)                            |
| Red meat (portion.week <sup>-1</sup> ), mean (SD)              | 1.77 (1.29)                           | 1.85 (1.39)                            |
| Oily fish (portion.week <sup>-1</sup> ), mean (SD)             | 1.11 (0.99)                           | 1.12 (1.05)                            |
| <b>Health status, n (%)</b>                                    |                                       |  |
| Diabetes history   | 2,072 (2.6)                           | 7,021 (4.5)                            |
| CVDs history   | 16,315 (20.3)                         | 45,331 (28.9)                          |

|                             |               |               |
|-----------------------------|---------------|---------------|
| High blood pressure history | 14,756 (18.4) | 38,036 (24.3) |
|-----------------------------|---------------|---------------|

BMI body mass index; PA physical activity; MET basal metabolic-equivalent; TE total energy intake. SD standard deviation; n number

**Supplementary Table S3. Baseline characteristics of men from the UK Biobank who were included or excluded from the analyses.**

|                                | Participants<br>included | Participants<br>excluded |
|--------------------------------|--------------------------|--------------------------|
| <b>Socio-demographics</b>      |                          |                          |
| Total n                        | 66,315                   | 134,620                  |
| Age (years), mean (SD)         | 56.1 (8.10)              | 56.8 (8.30)              |
| Age categories                 |                          |                          |
| <45 years                      | 7,645 (11.5)             | 14,151 (10.5)            |
| 45-50 years                    | 8,991 (13.6)             | 17,415 (12.9)            |
| 51-55 years                    | 10,111 (15.2)            | 19,242 (14.3)            |
| 56-60 years                    | 12,191 (18.4)            | 22,671 (16.8)            |
| 61-65 years                    | 16,097 (24.3)            | 31,505 (23.5)            |
| >65 years                      | 11,280 (17.0)            | 29,636 (22.0)            |
| Deprivation index, mean (SD)   | -1.67 (2.85)             | -1.01 (3.30)             |
| Deprivation                    |                          |                          |
| 1 (Least Deprived)             | 18,496 (27.9)            | 31,671 (23.6)            |
| 2                              | 17,409 (26.3)            | 32,057 (23.8)            |
| 3                              | 16,853 (25.4)            | 32,442 (24.1)            |
| 4 (Most Deprived)              | 13,557 (20.4)            | 38,277 (28.5)            |
| Ethnicity, n (%)               |                          |                          |
| White                          | 63,449 (96.1)            | 125,062 (93.7)           |
| Mixed background               | 315 (0.5)                | 652 (0.5)                |
| South Asian                    | 1,058 (1.6)              | 3,751 (2.8)              |
| Black                          | 642 (1.0)                | 2,356 (1.8)              |
| Chinese                        | 156 (0.2)                | 373 (0.2)                |
| Other                          | 427 (0.6)                | 1,352 (1.0)              |
| Smoking status, n (%)          |                          |                          |
| Never                          | 35,316 (53.3)            | 62,974 (47.2)            |
| Previous                       | 25,026 (37.7)            | 50,599 (37.9)            |
| Current                        | 5,973 (9.0)              | 19,870 (14.9)            |
| <b>Obesity-related markers</b> |                          |                          |

|  |               |               |
|--|---------------|---------------|
| Height (meters), mean (SD)                                     | 1.76 (0.07)   | 1.75 (0.07)   |
| Body weight (kg), mean (SD)                                    | 84.3 (13.0)   | 86.2 (14.6)   |
| BMI, mean (SD)   | 27.1 (3.80)   | 28.1 (4.33)   |
| BMI Categories, n (%)  |               |               |
| Under weight (<18.5 kg.m <sup>-2</sup> )                       | 127 (0.2)     | 349 (0.3)     |
| Normal weight (18.5-24.9 kg.m <sup>-2</sup> )                  | 20,361 (30.7) | 30,152 (22.7) |
| Overweight (25.0 to 29.9 kg.m <sup>-2</sup> )                  | 33,303 (50.2) | 65,642 (49.3) |
| Obese (≥30.0 kg.m <sup>-2</sup> )                              | 12,524 (18.9) | 36,895 (27.7) |
| Waist Circumference (cm)                                       | 94.9 (10.5)   | 97.6 (11.5)   |
| Central Obesity, n (%)   | 15,767 (23.8) | 43,635 (32.7) |
| % Body fat, mean (SD)  | 24.2 (5.57)   | 25.7 (5.82)   |
| Body fat-free mass (%), mean (SD)                              | 75.8 (5.57)   | 74.3 (5.86)   |
| Body fat-free mass (kg), mean (SD)                             | 63.4 (7.35)   | 63.5 (7.94)   |
| <b>Fitness and Physical activity</b>                           |               |               |
| Total PA (MET.h <sup>-1</sup> .week <sup>-1</sup> ), mean (SD) | 47.1 (59.3)   | 58.7 (81.6)   |
| Physically active individuals n,(%)                            | 39,050 (58.9) | 72,836 (54.1) |
| Grip Strength (kg), mean (SD)                                  | 40.1 (8.32)   | 39.1 (9.12)   |
| Grip strength (kg.kg body mass <sup>-1</sup> ), mean (SD)      | 0.48 (0.11)   | 0.46 (0.12)   |
| TV viewing (h.day <sup>-1</sup> ), mean (SD)                   | 2.47 (1.47)   | 3.01 (1.79)   |
| Total Sedentary behaviour (h.day <sup>-1</sup> ) , mean (SD)   | 5.34 (2.37)   | 5.50 (2.62)   |
| <b>Dietary intakes</b>   |               |               |
| Total energy intake (kcal.day <sup>-1</sup> ), mean (SD)       | 2,382 (581)   | 2,142 (754)   |
| Carbohydrate intake (% of TE), mean (SD)                       | 46.6 (7.97)   | 47.7 (8.85)   |
| Fat intake (% of TE), mean (SD)                                | 31.9 (6.49)   | 31.7 (7.37)   |
| Protein intake (% of TE), mean (SD)                            | 15.0 (3.23)   | 15.4 (3.98)   |
| Alcohol intake (% of TE), mean (SD)                            | 6.49 (7.17)   | 5.19 (7.34)   |
| Alcohol frequency (times.week <sup>-1</sup> ), mean (SD)       | 3.52 (1.37)   | 3.25 (1.48)   |
| Fruit and vegetable intake (g.day <sup>-1</sup> ), mean (SD)   | 309.3 (185.4) | 297.0 (205.3) |
| Processed meat intake (portion.week <sup>-1</sup> ), mean (SD) | 2.14 (1.05)   | 2.22 (1.04)   |
| Red meat (portion.week <sup>-1</sup> ), mean (SD)              | 2.03 (1.41)   | 2.13 (1.58)   |
| Oily fish (portion.week <sup>-1</sup> ), mean (SD)             | 1.10 (1.03)   | 1.09 (1.58)   |
| <b>Health status, n (%)</b>                                    |               |               |
| Diabetes history   | 3,419 (5.2)   | 10,560 (7.9)  |
| CVDs history   | 19,436 (29.3) | 49,457 (36.9) |

|                             |               |               |
|-----------------------------|---------------|---------------|
| High blood pressure history | 15,422 (23.3) | 35,589 (26.6) |
|-----------------------------|---------------|---------------|

BMI body mass index; PA physical activity; MET basal metabolic-equivalent; TE total energy intake. SD standard deviation; n number

**Supplementary Table S4. Association between protein intake and fat-free mass by age and sex in the UK Biobank cohort**

| Age categories | Beta (95%CI) per % of fat-free mass increment | P-value |
|----------------|---|---------|
| <b>Women</b>   |   |         |
| <45y           | 8.17 (7.9; 8.4)                               | <0.0001 |
| 45-50y         | 7.98 (7.8; 8.2)                               | <0.0001 |
| 50-55y         | 7.79 (7.6; 7.9)                               | <0.0001 |
| 55-60y         | 7.75 (7.6; 7.9)                               | <0.0001 |
| 60-64y         | 7.45 (7.3; 7.6)                               | <0.0001 |
| >64y           | 6.95 (6.7; 7.1)                               | <0.0001 |
| <b>Men</b>     |   |         |
| <45y           | 5.15 (4.9; 5.4)                               | <0.0001 |
| 45-50y         | 5.08 (4.9; 5.3)                               | <0.0001 |
| 50-55y         | 5.07 (4.8; 5.3)                               | <0.0001 |
| 55-60y         | 5.33 (5.1; 5.5)                               | <0.0001 |
| 60-64y         | 4.99 (4.8; 5.2)                               | <0.0001 |
| >64y           | 4.92 (4.7; 5.1)                               | <0.0001 |

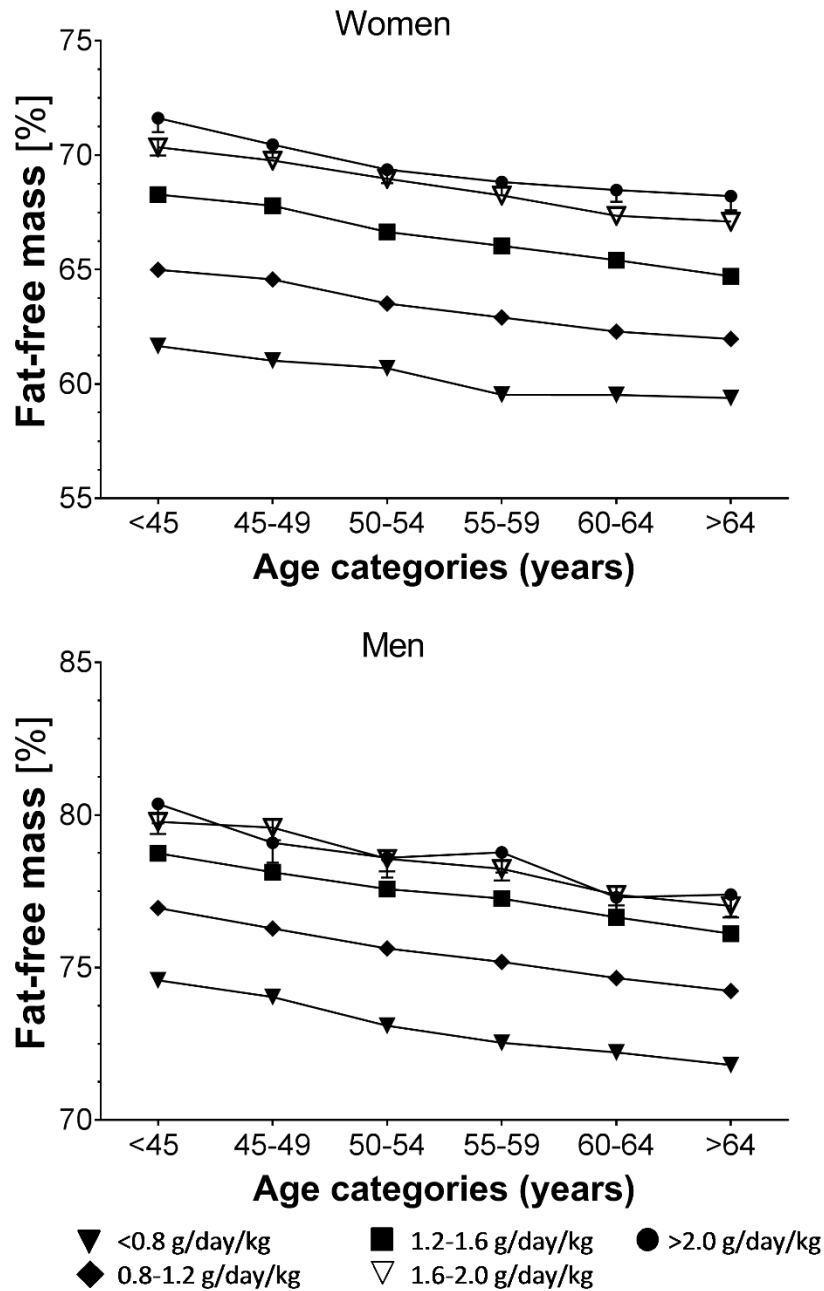
Data presented as beta coefficient and their 95% CI per 0.5 increment in protein intake (g/kg/day) and stratified by age groups. Fat-free-mass was expressed as %. Analyses were adjusted for month of assessment, ethnicity, socioeconomic status (Townsend deprivation index, education qualification and gross income), smoking, total physical activity, discretionary sedentary time, height, dietary intake (total energy intake, carbohydrates, total fat, alcohol intake, oily fish, red meat, processed meat, fruit and vegetables ) and comorbidities (diabetes, hypertension, medication for CVD and CVD illness).

**Supplementary Table S5. Association between protein intake and grip strength by age and sex in the UK Biobank cohort**

| Age categories | Beta (95%CI) per 0.5 g/kg/day of protein | trend   |
|----------------|--|---------|
| <b>Women</b>   |  |         |
| <45y           | 0.079 (0.075; 0.082)                     | <0.0001 |
| 45-50y         | 0.075 (0.072; 0.078)                     | <0.0001 |
| 50-55y         | 0.071 (0.068; 0.074)                     | <0.0001 |
| 55-60y         | 0.066 (0.063; 0.069)                     | <0.0001 |
| 60-64y         | 0.061 (0.059; 0.064)                     | <0.0001 |
| >64y           | 0.054 (0.051; 0.058)                     | <0.0001 |
| <b>Men</b>     |  |         |
| <45y           | 0.072 (0.071; 0.081)                     | <0.0001 |
| 45-50y         | 0.077 (0.069; 0.078)                     | <0.0001 |
| 50-55y         | 0.074 (0.069; 0.078)                     | <0.0001 |
| 55-60y         | 0.075 (0.071; 0.079)                     | <0.0001 |
| 60-64y         | 0.071 (0.067; 0.074)                     | <0.0001 |
| >64y           | 0.066 (0.061; 0.069)                     | <0.0001 |

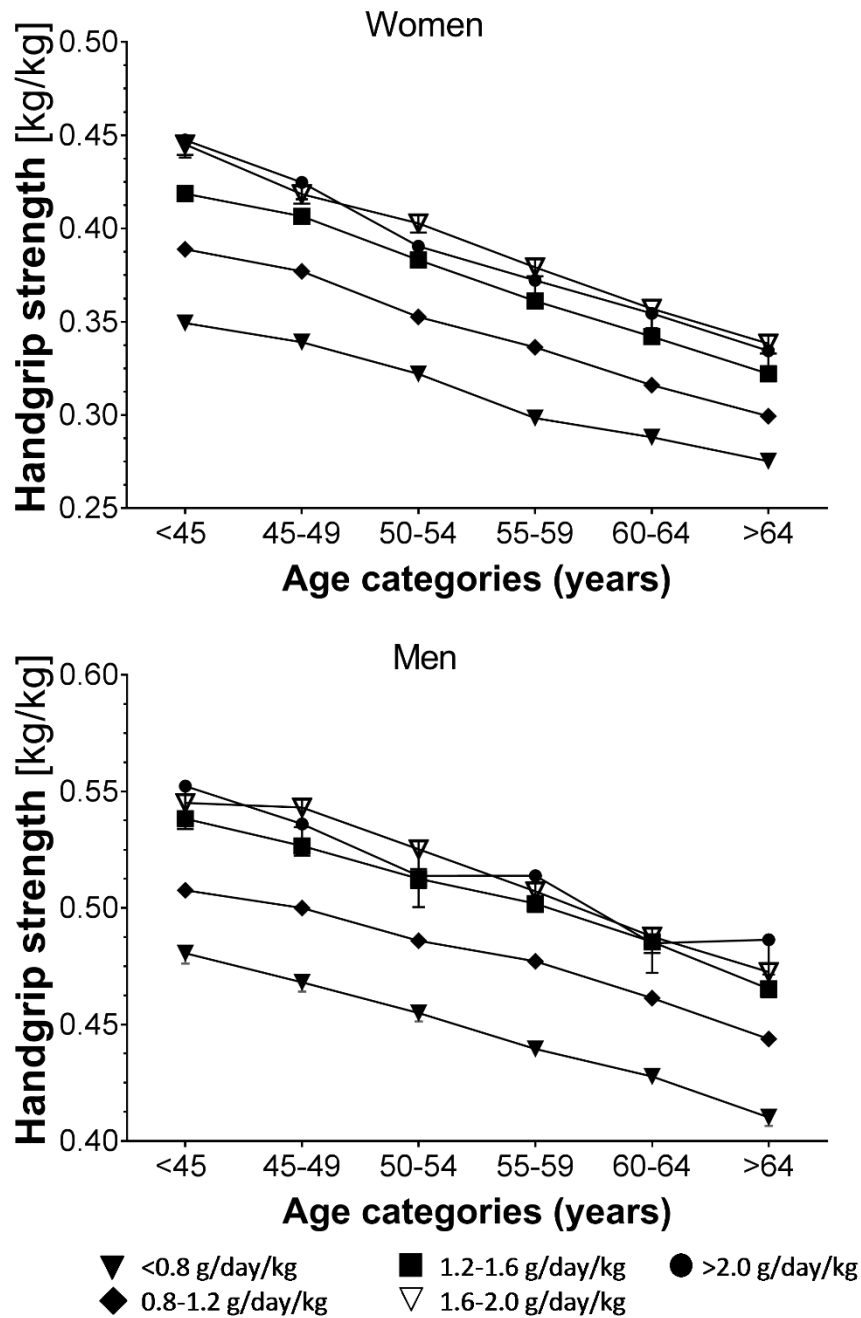
Data presented as beta coefficient and their 95% CI per 0.5 increment in protein intake (g/kg/day) and stratified by age groups. Handgrip strength was expressed as kg of grip strength divided by body weight (kg). Analyses were adjusted for month of assessment, ethnicity, socioeconomic status (Townsend deprivation index, education qualification and gross income), smoking, total physical activity, discretionary sedentary time, height, dietary intake (total energy intake, carbohydrates, total fat, alcohol intake, oily fish, red meat, processed meat, fruit and vegetables) and comorbidities (diabetes, hypertension, medication for CVD and CVD illness).





**Supplementary Figure 2. Fat-free mass by protein intake and age categories in women and men**

Data presented as adjusted mean and their 95%CI. Fat-free mass is presented as % of total body weight. Analyses were adjusted for month of assessment, ethnicity, socioeconomic status (Townsend deprivation index, professional qualification and gross income), smoking, total physical activity, discretionary sedentary time, height, dietary intake (total energy intake, carbohydrate intake, total fat intake, alcohol intake, oily fish, red meat, processed meat, fruit and vegetables), and comorbidities (diabetes, hypertension, medication for CVD and CVD illness).



**Supplementary Figure 3. Hand grip strength by protein intake and age categories in women and men**

Data presented as adjusted mean and their 95%CI. Handgrip strength was expressed as kg of grip strength divided by body weight (kg). Analyses were adjusted for month of assessment, ethnicity, socioeconomic status (Townsend deprivation index, professional qualification and gross income), smoking, total physical activity, discretionary sedentary time, height, dietary intake (total energy intake, carbohydrate intake, total fat intake, alcohol intake, oily fish, red meat, processed meat, fruit and vegetables), and comorbidities (diabetes, hypertension, medication for CVD and CVD illness).