Associations between diet and handgrip strength: a cross-sectional study from UK Biobank.

A. Gedmantaite[1], C.A. Celis-Morales[2,3,4], Frederick Ho[4], JP Pell[4], A. Ratkevicius[1] and S.R. Gray[2]

[1]Department for Applied Biology and Rehabilitation, Lithuanian Sports University, Kaunas, LT-44221, Lithuania, [2], Institute of Cardiovascular and Medical Science, University of Glasgow, Glasgow, G12 8TA, UK. [3] Research Unit on Education, Physical Activity and Health (GEEAFyS), Universidad Católica del Maule, Talca, Chile. [4] Institute of Health and Wellbeing, University of Glasgow, Glasgow, G12 8TA, UK

Abstract

The aim of the current study was to investigate the association between diet and handgrip strength. The current study included 68,002 participants (age 63.8 ± 2.7 years, 50.3% women, 49.7% men) from UK Biobank. Diet and nutritional data (carotene, retinol, potassium, vitamin C, foliate, vitamin B12, vitamin B6, iron, vitamin E, calcium, magnesium, carbohydrates, protein, polyunsaturated fat, fat, starch and saturated fat) were collected and handgrip strength measured. Associations were compared, stratified by sex, using regression analyses, after adjustment for age, sex, month of assessment, ethnicity, deprivation index, height, comorbidities and total energy intake. The current data revealed negative associations between carbohydrate intake and handgrip strength as well as positive associations between oily fish, retinol and magnesium intake and grip strength in both sexes. In women, positive associations were observed between intake of red meat, fruit and vegetables, vitamin E, iron, vitamin B12, folate and vitamin C and hand grip strength. In men only negative associations were seen between bread and processed meat with grip strength. We have shown associations of several nutrients and food items with muscle strength and appropriately designed trials are needed to investigate whether these nutrients/food items may be beneficial in the maintenance of muscle during ageing.

Introduction

Skeletal muscle has an important role in the maintenance of metabolic health (Wolfe, 2006) and muscle strength is associated with a broad range of health outcomes (Celis-Morales et al., 2018). The most important role of muscle is to allow body movements via the generation of force, with this highlighted by the deleterious effects of conditions such as sarcopenia, the age related loss of muscle mass and function (O'Loughlin et al., 1993). Normal ageing is associated with a loss of muscle mass of 0.5-2% per year, after the age of 40-50 years, with the decrease even greater as age increases (Baumgartner et al., 1998). The prevalence of sarcopenia is reported to be between 4.6 and 7.9% in community dwelling older British men and women (Patel et al., 2013). Sarcopenia had an estimated economic cost of $18.5 billion in the year 2000 in the USA with a recent report from the UK estimating that muscle weakness results in an estimated annual excess cost of £2.5billion (Pinedo-Villanueva et al., 2018).

The exact aetiology of the loss of muscle mass with age remains to be established but there is data to suggest that diet may be an important for the maintenance of muscle mass during the ageing process (Mitchell et al., 2012). Indeed, several studies have found associations between diet and muscle strength in older people (Ni Lochlainn, Bowyer, & Steves, 2018; Scott, Blizzard, Fell, Giles, & Jones, 2010). For example, in an analysis of 2,983 men and women (59-73 years), from the Hertfordshire study, it was shown that oily fish consumption is positively associated with grip strength in both men and women, with the magnitude of the association was higher in women (Robinson et al., 2008). On top of this it has been found that hand grip strength is positively associated with protein intake and diet quality, assessed by either the dietary approaches to stop hypertension (DASH) adherence or Health Eating Index-2010 scores (Tak et al., 2018). There are also data demonstrating the positive associations of certain micronutrients, such as magnesium, zinc, iron, vitamin B_6, folic acid, vitamin E, vitamin D and vitamin B_{12} with muscle mass and strength (Hayhoe et al., 2019; Scott et al., 2010; ter Borg et al., 2016; Verlaan et al., 2017; Welch et al., 2017). These studies are, however, relatively small in their sample size and so the conclusions that can be drawn are limited. The UK Biobank, a large (~500,000 people) general population cohort study allows us the opportunity to investigate associations of diet and muscle in a single large cohort and verify the findings of previous studies with smaller sample sizes.

The aim of the current study, therefore, is to investigate the associations of diet with handgrip strength, in older (≥60 years) adult participants from the UK Biobank.

Methods

Study design

The UK Biobank (http://www.ukbiobank.ac.uk) is a large general-population cohort study with a wide range of data collected (Sudlow et al., 2015). Of the 502,628 participants 68,002 (33,815 men and 34,187 women) were included in the current study. These were participants who were ≥60 years old and had full data for the outcome (grip strength), the exposures (dietary intake) and confounding factors of interest (age, ethnicity, deprivation index, comorbidities, height and total energy intake). This study was performed under generic ethical approval obtained by UK Biobank investigators from the National Health Service National Research Ethics Service (Ref: 11/NW/.0382) with the current analyses carried out under application number 7155.

Study procedures

Grip strength was assessed using a hydraulic hand dynamometer (Jamar J00105, Lafayette Instrument Company, Lafayette, Indiana), and the mean of the right-hand and left-hand values, expressed as kg per kg body weight, was used in the analyses.

Nutritional intake

The Oxford WebQ, a Web-based 24-hour-recall questionnaire, was used to measure nutritional intake (Bradbury et al., 2018). For participants who completed more than 1 online dietary questionnaire, mean values were calculated from all of the information provided.

Food intake

The intake of food items was obtained via touchscreen questionnaire containing questions about the frequency of consumption of the following food groups: fruits and vegetables, oily fish, other fish, processed meats, poultry, beef, lamb, pork, cheese, coffee, water, as well as questions on the type of milk most commonly consumed, type of spread most commonly consumed, number of slices and type of bread and type of breakfast cereal most commonly consumed over the past year.

Height was measured to the nearest centimetre. Race/ethnicity was self-reported and categorized into white, south Asian, black, Chinese, other, and mixed ethnic background. Socioeconomic deprivation was determined from the participant's postcode of residence using the Townsend deprivation index (Townsend et al., 1987). Medical history (physician's diagnosis of depression, stroke, angina, heart attack, hypertension, cancer, diabetes, hypertension, chronic obstructive pulmonary disease, or longstanding illness) was self-reported.

Statistical methods

Hand-grip strength (expressed in absolute terms as kg) was the outcome variable and it was treated as a continuous variable. To explore the association between nutritional and food item intake and grip strength we performed linear regression analysis. Due to differences in handgrip strength between men and women all analyses were stratified by sex. Continuous nutritional intake variables were standardised to z-score (1-SD) to allow for comparison within each dietary factor. Each of the 26 standardised dietary variables were then fitted separately into the regression model as exposures with the outcome of grip strength and results presented as beta coefficient per 1-SD change in the dietary intake variable. Analyses were adjusted for age, sex, monthly assessment, ethnicity, deprivation index, height, comorbidities and total energy intake. The p-value at which to accept significance was adjusted for Bonferroni to account for multiple testing ($p<0.0019$). Statistical analyses were performed using STATA MP14 (Stata Corp LLC, College Station, Texas).

Results

Of the 502,648 participants recruited to the UK biobank, 68,002 (33,815 men and 34,187 women) who were 60 years of age or older and had full data available and so were included in this study. Table 1 summarises the primary characteristics of these participants.

Table 1. Cohort characteristics

	All	**Women**	**Men**
Socio-demographics			
Total n	68,002	34,187	33,815
Age (years), mean (SD)	63.8 (2.7)	63.6 (2.7)	64.0 (2.7)
Weight (kg), mean (SD)	77.3 (14.5)	70.2 (12.5)	84.4 (12.9)
Height (cm), mean (SD)	168.8 (9.1)	162.2 (6.0)	175.5 (6.5)
Deprivation index,n (%)			
Middle	26,681 (39.24)	12,887 (37.70)	13,794 (40.79)
Lower	23,975 (35.26)	12,188 (35.65)	11,787 (34.86)

Higher	17,346 (25.51)	9,112 (26.65)	8,234 (24.35)
Ethnicity, n (%)			
White	66,688 (98.07)	33,507 (98.01)	33,181 (98.13)
South Asian	543 (0.8)	225 (0.66)	318 (0.94)
Black	271 (0.4)	154 (0.45)	117 (0.35)
Chinese	35 (0.10)	44 (0.13)	35 (0.10)
Mixed background/Other	164 (0.48)	257 (0.75)	164 (0.48)
Obesity-related markers			
BMI, mean (SD)	27.0 (4.2)	26.6 (4.6)	27.3 (3.8)
BMI Categories, n (%)			
Under weight (<18.5)	267 (0.39)	225 (0.66)	42 (0.12)
Normal weight (18.5-24.9)	23,011 (33.84)	13,771 (40.28)	9,204 (27.33)
Overweight (25.0 to 29.9)	30,702 (45.15)	13,342 (39.03)	17,360 (51.34)
Obese (≥30.0)	14,022 (20.62)	6,849 (20.03)	7,173 (21.21)
Waist Circumference (cm)	90.5 (12.6)	84.4 (11.5)	96.7 (10.6)
Central Obesity, n (%)			
Yes	22,151 (32.58)	12,087 (35.36)	10,064 (29.26)
No	45,843 (67.42)	22,093 (64.64)	23,750 (70.24)
% Body fat, mean (SD)	31.1 (8.1)	36.7 (6.3)	25.4 (5.4)
Fitness and Physical activity			
MVPA, n (%)			
Active	41,780 (61.44)	21,093 (61.70)	20,687 (61.18)
Inactive	26,222 (38.56)	13,094 (38.30)	13,128 (38.82)
Handgrip (kg), mean (SD)	29.7 (10.4)	21.8 (5.5)	37.6 (7.8)
Total PA (MET.h^{-1}.$week^{-1}$), mean (SD)	46.1 (53.1)	44.7 (49.4)	47.6 (56.5)
Total Sedentary behaviour (h.day^{-1}) , mean (SD)	5.1 (2.0)	4.8 (1.9)	5.5 (2.1)
Dietary intakes, mean (SD)			
Total energy intake d/kcal	2125.5 (616.8)	1979.8 (559.9)	2272.8 (636.4)
Carbohydrate intake (g)	47.4 (7.8)	48.0 (7.7)	46.9 (7.8)
Fat intake(g)	31.7(6.4)	31.9(6.5)	31.4(6.4)
Protein intake(g)	15.5 (3.4)	15.9(3.5)	15.1 (3.2)

Saturated fat intake(g)	12.3 (3.2)	12.3(3.2)	12.2(3.2)
Polyunsaturated fat intake(g)	5.7 (2.1)	5.8 (2.2)	5.6 (2.1)
Sugar intake (g)	23.1 (6.7)	24.0 (6.8)	22.14 (6.5)
Starch intake (g)	22.4 (5.9)	21.9 (5.9)	23.0 (5.8)
Comorbidities, n (%)			
Yes	17,199 (25.29)	8,399 (24.57)	8,800 (26.02)
No	50,803 (74.71)	25,788 (75.43)	25,015 (73.98)

Data presented as mean and (SD) for continuous variable and as frequency of observations and % for categorical variables.

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

Food intake

In men positive associations between foods and grip strength were observed for poultry (p<0.0001) and oily fish (p<0.0001) (Figure 1). No associations were observed for intake of cereal (p=0.699), cheese (p=0.177), fruit and vegetables (p=0.041), non-oily fish (p=0.008) and red meat intake (p=0.245). Negative associations were seen between intake of bread (p<0.0001) and processed meat (p<0.0001) and grip strength.

For women, oily fish (p<0.0001), fruits and vegetables (p<0.0001), and red meat (p<0.0001) were positively associated with grip strength (Figure 1). No associations were seen for intake of cereal (p=0.922), bread (p=0.606), processed meat (p=0.026), non-oily fish (p=0.031), cheese (p=0.006) and poultry (p=0.359).

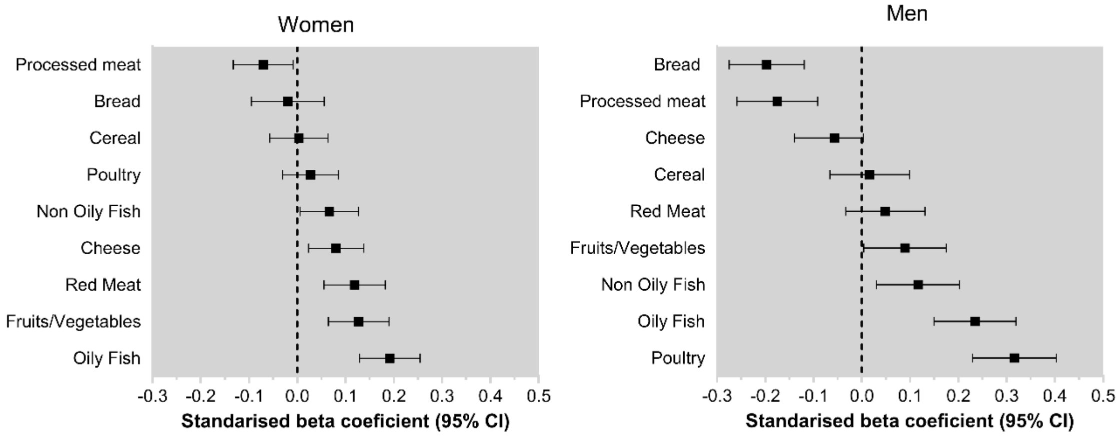

Figure 1. Association between food items and grip strength in men and women.

Data presented as beta-coefficient and their 95% CI. Analysis were adjusted for age, sex, monthly assessment, ethnicity, deprivation index, height, comorbidities and total energy intake. The p-value at which to accept significance was adjusted for Bonferroni to account for multiple testing ($p<0.0019$).

Macro and micro nutrient intake

The associations of grip strength with macro- and micro-nutrient intake are reported in Figure 2. In both men and women, carbohydrate intake ($p<0.0001$ in both men and women) was negatively associated with grip strength. Retinol and magnesium intake were the two variables that showed positive associations, in both men ($p=0.001$) and women ($p<0.0001$), with grip strength.

Furthermore, there were positive associations, in women, of vitamin C ($p=0.0001$), folate ($p=0.001$), vitamin B12 ($p<0.0001$), iron ($p<0.0001$) and vitamin E ($p<0.0001$) intake with grip strength. In women no associations were seen for intake of carotene ($p=0.038$), potassium ($p=0.01$), vitamin B6 ($p=0.475$), calcium ($p=0.375$), sugar ($p=0.244$), protein ($p=0.048$), polyunsaturated fat ($p=0.052$), fat ($p=0.104$) and saturated fat ($p=0.571$).

In men no associations were seen with intake of carotene ($p=0.011$), potassium ($p=0.008$), vitamin C ($p=0.271$), folate (p=0.0.867), vitamin B12 ($p=0.014$), vitamin B6 ($p=0.051$), iron ($p=0.03$), vitamin E ($p=0.672$), calcium ($p=0.256$), sugar ($p=0.773$), protein ($p=0.002$), polyunsaturated fat ($p=0.855$), fat ($p=0.641$) and saturated fat ($p=0.698$)

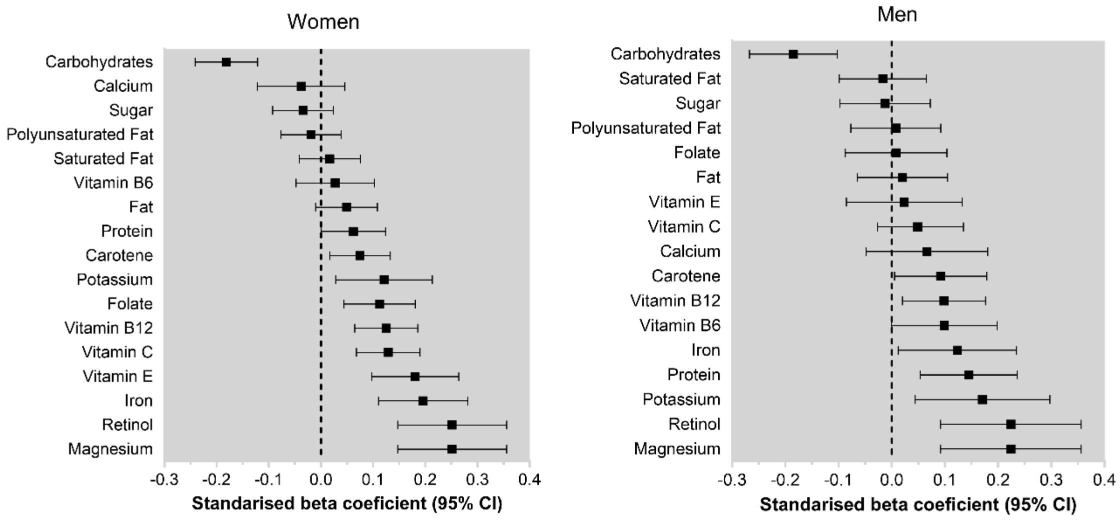

Figure 2. Association of macro- and micro-nutrients with grip strength in men and women.

Data presented as beta-coefficient and their 95% CI. Analysis were adjusted for age, sex, monthly assessment, ethnicity, deprivation index, height, comorbidities and total energy intake. The p-value at which to accept significance was adjusted for Bonferroni to account for multiple testing ($p<0.0019$).

Discussion

The current study has examined the cross-sectional associations between diet and hand grip strength in men and women aged ≥60 years. Looking at associations of food intake with grip strength the only food item that positively associated with grip strength was the intake of oily fish, with a similar strength of association in men and women. Some other food intake items were also associated with grip strength, with associations generally weaker and different between sexes. For nutritional intake there was a negative association of carbohydrate intake with grip strength and positive associations of retinol and magnesium with grip strength in both men and women. Again, there were some differences in associations between the sexes, with retinol, vitamin C, folate, vitamin B12, iron and vitamin E positively associated in only women. It appears, therefore, that importance of some nutrients and food items for muscle strength differs between men and women. Grip strength was chosen to be investigated due to its strength as marker of general health (Celis-Morales et al., 2018), although it is debated whether it is a useful marker for overall muscle strength.

The current finding that oily fish intake was positively associated with muscle strength in both sexes is in agreement with the findings of Robinson et al. (2008). In their study the strongest association of dietary factors with grip strength was seen for fatty fish consumption. For each additional portion of fatty fish consumed per week grip strength was 0.43 kg greater in men and 0.48kg greater in women. Further data has indicated that this association may represent a beneficial effect of the omega-3 fatty acids, found in oily fish, on muscle (Gray and Mittendorfer, 2018). Indeed a recent randomised controlled trial showed that omega-3 fatty supplements results in increases in muscle mass and function in older people (Smith et al., 2015). Due to the weaker and sex-differences in associations between intake of other food items with grip strength, interpretation of whether these food items have any role in determining muscle mass in older people is problematic, although one could conclude any beneficial effect is unlikely.

It may be surprising that in our study we did not find an association of protein intake with grip strength. However, in spite of the wealth of evidence that protein intake is key in acutely stimulating the metabolic processes promoting muscle growth (Bohé et al., 2003) the long term evidence looking at dietary protein intake and muscle mass is less consistent, when considered in the absence of resistance exercise. Indeed the previous work of Robinson and colleagues found that dietary protein intake was not associated with grip strength in either sex (Robinson et al., 2008). Similarly, Scott et al. (2010) found no association between protein intake and muscle strength, although positive associations were found with lean mass. On top of this, a meta-analysis by Tieland et al. (2017) found that protein or amino acid supplementation, without concomitant exercise training, has no effect on muscle mass or strength in predominantly healthy elderly people.

Our findings relating to the associations between micronutrients/vitamins (retinol and magnesium positively associated in both sexes and vitamin C, folate, vitamin B12, iron and vitamin E in women only) are partially in line with several other studies. For example, a study of 66 volunteers has shown that a lower intake of magnesium and vitamin B12, similar to the current study, were associated with sarcopenia status although these authors also found associations which were not evident in the current study such as an association between vitamin D intake and muscle strength (Verlaan et al., 2017) . Furthermore, in another study n-3 fatty acid, vitamin B^6, folic acid, vitamin E and magnesium intake were also found to be associated with sarcopenia status (ter Borg et al., 2016). Further studies have also found associations of magnesium intake with skeletal muscle mass and function (Hayhoe et al., 2019; Welch et al., 2017), with these associations appearing to be the most consistent within the literature. These associations may be reflective of beneficial dietary patterns, such as the Mediterranean diet, as recently discussed by Granic and colleagues (Granic et al., 2019). We did not investigate such dietary patterns but this should be investigated in further work.

Recruitment to the UK Biobank aimed to be representative of the general United Kingdom population but was not representative in terms of lifestyle, with participants less likely to be obese and having a lower disease frequency— possibly indicating a “healthy volunteer” selection bias (Fry et al., 2017, 2016). The cross-sectional design of this study does not allow us to confirm causality in the observed associations. Handgrip strength was only measured once, and not three times, in each hand and so these values may be low. All methods of dietary assessment, including those employed in the current study, involve errors and biases which are diminished, but not eliminated, by studying large numbers of people (Ioannidis, 2013; Kipnis et al., 2002). In the current study, dietary intake was self-reported outside the clinic, which may encourage more truthful reporting, and information was collected using a validated 24-hour-recall questionnaire, which has been shown to produce more accurate results than a food frequency questionnaire (the usual approach adopted in large-scale studies) (Liu et al., 2011). Accuracy was further improved by administering the questionnaire on 4 occasions over the course of a year and deriving mean values. In addition, online administration of the questionnaires is expected to have minimized any reporting bias due to social desirability (Hébert et al., 2001).

Conclusion

In conclusion the current study has demonstrated that certain types of foods and nutritional intake (particularly oily fish) are associated muscle strength in older adults. Further appropriately designed randomised controlled trials are needed to test whether these foods and nutrients can be beneficial in the maintenance of muscle during ageing.

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