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Original article

Association between Mediterranean diet and hand grip strength in older adult women

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SUMMARY

Background & aims: Mediterranean Diet (MD) is an eating pattern associated with multiple healthy benefits, including the conservation of skeletal muscle. Frailty is a major geriatric syndrome characterized by low muscle strength. The Hand Grip Strength (HGS) is the most frequently used indicator of muscle functional capacity for clinical purposes. The association between the adherence to the MD and HGS in elderly has not yet fully investigated. The goal of this study was to examine the association between the adherence to the MD and HGS in a not hospitalized elderly who participated in the project **PER**sonalised ict **S**upported **S**ervices for **I**ndependent **L**iving and **A**ctive **A**geing (PERSSILAA).
Methods: Eighty-four elderly women were consecutively enrolled (aged 60–85 years) in this cross-sectional observational study. Anthropometric measures were evaluated. A validated 14-item questionnaire PREDIMED (PREvención con DIeta MEDiterránea) was used for the assessment of adherence to the MD. Dietary data were collected by a 7-day food records. Muscle strength was measured by HGS using a grip strength dynamometer (KERN & SOHN GmbH).
Results: The majority of participants were overweight (46.4%). An average adherence to the MD was found in 52.4% of participants, while the minority of them showed a low adherence (21.4%). HGS > cut-point of 20 kg were found in 43 subjects (51.2%). According to the adherence to MD, 39% participants with HGS values higher than cut-point presented a high adherence score compared with 14% of those with lower values of HGS ($p = 0.018$). The participants with HGS > cut-point presented significantly higher PREDIMED score than those with HGS < cut-point ($p < 0.001$). Based on ROC curves, the most sensitive and specific cut-point for the PREDIMED score to predict HGS categories was ≥8. No evident correlations were observed between HGS and age, while HGS was negatively correlated with hip circumference ($r = -0.233$, $p = 0.033$) and BMI ($r = -0.219$, $p = 0.045$), and positively correlated with PREDIMED score ($r = 0.598$, $p < 0.001$). At binomial logistic regression analysis almost all 14-items of PREDIMED questionnaire were significantly associated with HGS adjusted for BMI. At multinomial logistic regression analysis to assess the association of the three classes of adherence to the MD with the HGS, after adjusting for BMI the lowest adherence to MD was associated with the lowest Odds Ratio of HGS ($p < 0.001$).
Conclusions: This study evidenced a positive association between the adherence to the MD and muscle strength in a sample of active elderly women, stratified according to the HGS > cut-point of 20 kg. Our study highlights the usefulness of the developing health services to detect and prevent age-associated decline in physical performance in elderly subjects by addressing nutritional and physical intervention.

Abbreviations: MD, Mediterranean Diet; HGS, Hand Grip Strength; PERSSILAA, PERsonalised ict Supported Services for Independent Living and Active Ageing; BMI, Body Mass Index; WC, Waist Circumference; NCEP-ATP III, According to the National Cholesterol Education Program's Adult Treatment Panel III; HC, Hip circumference; WHR, Waist to Hip Ratio; PREDIMED, PREvención con DIeta MEDiterránea; FFQ, Food Frequency Questionnaire; LEP, Limb Extension Power; SPPB, Short Physical Performance Battery.

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1. Introduction

Nutrition is one of the major modifiable environmental risk factors for several non-communicable diseases and represents a mainstay for their prevention and also their initial treatment [1]. In particular, in the elderly population nutrition is an important element of health and there is increasing scientific and clinical evidence showing the link between nutrition and health as part of aging [2,3].

The Mediterranean diet (MD) is a plant-based, antioxidant-rich diet known for its several health benefits. This dietary pattern is considered a nutritionally adequate, complete and easy to follow, as it is based on the traditional foods that people used to eat in their countries [4]. In particular, the MD features a high intake of whole grains, fruits, vegetables, tree nuts, legumes, and olive oil on a daily basis; a moderate intake of fish and poultry, low consumption of dairy products, red meat, processed meat and sweets, and moderate consumption of wine with meals [5,6]. Large observational prospective epidemiological studies support that the Mediterranean dietary pattern increases life expectancy, reduce the risk of major chronic diseases, and improve quality of life and well-being [7,8]. However, it should be considered that the Mediterranean dietary patterns may vary according to age, gender, ethnicity, culture and other lifestyle factors [9]. Indeed, previous studies have identified gender as a key determinant of food choices [10] with females having more motivation towards healthy eating and are more aware of healthy eating compared with males [11,12]. In elderly subjects numerous studies have reported that higher adherence to the MD is associated with lowest mortality [13–16], although most of these studies were not conducted specifically to determine the MD effects in elderly subjects. Higher adherence to the MD has been also proven to be effective in preserving the skeletal muscle mass in healthy women likely due to the potential anti-inflammatory and anti-oxidant properties of micronutrients (e.g. carotenoids and vitamins C and E) or through their direct role in muscle metabolism and physiology, such as with magnesium and potassium [17].

Nutrition plays a decisive role in the development of frailty [18,19]. Frailty or “the frailty syndrome” are commonly used terms to denote a clinical entity in elderly subjects. Frailty has been reported to be associated with increased risk for adverse outcomes, such as onset of disability, morbidity, institutionalization or mortality [20]. In particular, the presence of frailty has been associated with increased all-cause mortality [21–24] and increased incident cardiovascular disease [25], as well as poor survival after cardiac and surgical procedures. The effectiveness of the adherence to a Mediterranean dietary pattern on the risk of development of frailty in elderly adults has been demonstrated in different clinical settings. In particular, using the MD score, a high adherence to a MD was associated with a slower decline of mobility and to the development of frailty over time in community-dwelling elderly persons of both gender participating to the InCHIANTI Study [26,27].

The Hand Grip Strength (HGS) is an objective component of the frailty syndrome in the elderly subjects, thereby representing the most frequently used indicator of muscle functional capacity for clinical purposes [28]. HGS is a non-invasive and reliable method for assessment of muscle power and nutritional status and portable HGS devices are quick and easy to use [29]. The association between nutrition status and HGS is well documented [30] and HGS is currently considered as a marker of the nutrition status [30,31]. In particular, HGS reflects early nutrition deprivation and nutrition repletion also before changes in body composition parameters can be detected [30]. The Academy of Nutrition and Dietetics and the American Society for Parenteral and Enteral Nutrition has recently recommended reduced HGS values as a criterion for the identification and documentation of undernutrition in clinical practice [31]. Besides nutrition, other parameters, such as sex and age, have also been identified to be associated with HGS in elderly subjects [32–36]. HGS is associated with increased all-cause mortality [37], disability and increased length of hospital stay [38]. Thus, it is essential for public health to implement screenings and multidisciplinary treatments of frailty, especially through indirect but reliable measures, such as HGS.

This cross-sectional observational study was designed to capture the association between a Mediterranean dietary pattern with HGS in elderly women participants in the PERsonalised ict Supported Services for Independent Living and Active Ageing (PERSSILAA), an European project developing health services to detect and prevent frailty in elderly subjects by addressing cognitive, physical and nutritional domains in Campania Region, Italy and Enschede, the Netherlands [39].

2. Subjects and methods

2.1. Design and setting

PERSSILAA is an European project developing health services to detect and prevent frailty in elderly subjects by addressing cognitive, physical and nutritional domains in Campania Region, Italy and Enschede, the Netherlands [39]. In particular, PERSSILAA is a Community-Based, Technology-Supported Service Model for Detecting and Preventing Frailty in elderly [40] and the evaluation of the association between MD and HGS is based only from the Italian population data. In Italy, elderly are invited for the first screening *via* the church, after which they can complete this screening at the church with the help of a trained volunteer or online. As elderly subjects in Italy frequently visit the church, where many activities take place, this appeared to be the best way to reach them. This community based healthcare service has been provided in Campania Region, in collaboration with the Department of Gastroenterology, Endocrinology and Surgery of Federico II University Hospital (Italy). The work has been carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans, and it has been approved by the Ethical Committee of the University of Naples “Federico II” Medical School (n. 178/14). The purpose of the protocol was explained to all elderly subjects enrolled, and written informed consent was obtained.

2.2. Population study

Our study population consisted of 183 residents of the Campania Region, Italy, who were healthy elderly with active lifestyles (age $\geq$ 60 years), and who were enrolled at local catholic churches in the same district of Naples and were involved in the first screening of PERSSILAA project, from October 2016 to March 2017. All potential subjects were invited to participate in a full medical history, including cognitive testing (Mini-Mental State Examination (MMSE) and AD8 Informant Questionnaire for Cognitive Impairment), physical performance (Short Physical Performance Battery), pharmacological history, physical activity, smoking habits, and a complete clinical examination. Criteria for exclusion from the study were:

a. Male individuals;
b. Absence of mild-severe cognitive impairment;
c. Severe-moderate limitation of physical performance;
d. Individuals who needed assistance with their daily activities;
e. Subject unable to perform the HGS test, defined as situations that led to an inability in understanding verbal instructions or

having clinical conditions that could influence performing the HGS technique correctly, including osteoarticular or musculoskeletal diseases, pain, confusion, and moderate/severe neurological and/or cognitive impairment, stroke or hand injury, cancer, acute or chronic inflammatory diseases, endocrine diseases, in particular altered thyroid hormone function tests;

f. Underweight (BMI $\leq$ 20.0 kg/m^2) or with obesity grade II/III (BMI $\geq$ 35.0 kg/m^2);
g. Hypocaloric diet in the last three months or specific nutritional regimens, including vegan, vegetarian hyperproteic or ketogenic diets;
h. Vitamin/mineral antioxidant or protein supplementation;
i. Individuals occasionally or currently taking medications that could influence musculoskeletal system and hand grip strength (i.e. anticonvulsivants and psychotropic drugs, steroidal and non-steroidal anti-inflammatory drugs, hormone replacement therapy, anti-thyroid agents, weight-loss medications, dopaminergic drugs, Parkinson's disease drugs, or statins);
j. Alcohol abuse according to the Diagnostic and Statistical Manual of Mental Disorders (DSM)-V diagnostic criteria.

On the basis of these criteria, 99 subjects were excluded and the final study population consisted of 84 women.

2.3. Anthropometric measurements

The measurements were performed between 8 and 11 AM and were made in a standard way by one operator (a nutritionist experienced in providing nutritional assessment). All anthropometric measurements were recorded with subjects wearing only light clothes and without shoes. In each subject, weight and height were assessed in order to calculate the Body Mass Index (BMI) [weight (kg) divided by height squared (m^2), kg/m^2]. Height was measured to the nearest 0.5 cm using a wall-mounted stadiometer (Seca 711; Seca, Hamburg, Germany). Body weight was determined to the nearest 0.1 kg using a calibrated balance beam scale (Seca 711; Seca, Hamburg, Germany). BMI was classified according to WHO's criteria with normal weight: 18.5–24.9 kg/m^2; overweight, 25.0–29.9 kg/m^2 and grade I obesity, 30.0–34.9 kg/m^2. Waist Circumference (WC) was measured to the nearest 0.1 cm with a non-stretchable measuring tape, at the end of several consecutive natural breaths, at the level parallel to the floor, midpoint between the top of the iliac crest and the lower margin of the last palpable rib in midaxillary line [41]. According to the National Cholesterol Education Program's Adult Treatment Panel III (NCEP-ATP III) criteria, abdominal obesity was defined as WC $\geq$ 88 cm in women [42]. Hip Circumference (HC) was measured as the maximum circumference around the buttocks posteriorly and the symphysis pubis anteriorly, and measured to the nearest 0.5 cm. Waist to Hip Ratio (WHR) was calculated by dividing WC (in cm) by HC (cm). The cutoffs points (Caucasian) of WHR used (>0.85 in women) [43] denote abdominal obesity. Average of two readings was used for analysis.

2.4. Adherence to the MD

The adherence to the MD was assessed using the previously validated 14-item questionnaire for the assessment of PREvención con DIeta MEDiterránea (PREDIMED) [44]. A qualified Nutritionist provided the questionnaire during a face-to-face interview to all the subjects included in the study. Briefly, score 1 and 0 was assigned for each items; PREDIMED score was calculated as follows: 0–5, lowest adherence; score 6–9, average adherence; score $\geq$10, highest adherence [44].

2.5. Dietary assessment

Data were obtained during a face-to-face interview between the patient and a qualified Nutritionist. The dietary interview was used in order to quantify foods and drinks by using a photographic food atlas ($\approx$1000 photographs) of known portion sizes and to be sure of accurate completion of the records (21). Moreover, dietary data, including beverage intakes consumption, were collected by a 7-day food records. The subjects returned the records to the nutritionist who asked supplemental questions if necessary. Data were stored and processed using a commercial software (Terapia Alimentare Dietosystem® DS-Medica, http://www.dsmedica.info). Considering quantities and qualities of foods consumed, the software is able to calculate not only the daily caloric intake but also the quantities of macronutrients (protein; total, complex and simple carbohydrates; total fat, saturated fat (SFA)), unsaturated fat (Monounsaturated Fatty Acids, MUFA; Polyunsaturated Fatty Acids, PUFA: n-6 PUFA, n-3 PUFA and n-6/n-3 PUFAs ratio; cholesterol and fibers).

2.6. Hand grip strength

HGS (kg) was quantified by measuring the amount of static force that the hand and forearm can squeeze around a hand-held dynamometer [45] using a Collins dynamometer (KERN & SOHN GmbH). All measurements were performed under strictly standardized conditions by the operator, using the same device in order to avoid inter-observer and inter-device variability, after explaining the procedure to each patient. The participants were seated, their elbow by their side and flexed to right angles, and a neutral wrist position [46] for 3 s. The maximum value of 3 consecutive measurements in the non-dominant arm was registered. Patients used their dominant hand when they were unable to perform HGS with their non-dominant hand. Brief pauses were taken between measurements. The maximum value (kg) out of three trials using the dominant hand was recorded. Between two consecutive trials, a 1-min recovery was provided. The instrument was routinely checked with resistors and capacitors of known values. The coefficient of variation (CV) of repeated measurements of HGS was assessed in 10 patients and resulted 1.8%. Cut-point used for low HGS in women was <20 kg [47].

2.7. Statistical analysis

The minimum required total sample was calculated using the pooled standard deviation with the level test 0.05 and power 80% of means of the measurements of HGS. With a type I error of 0.05 and a type of II (β) error of 0.10, the resulting size was 84 women.

Results are expressed as mean ± SD or as median plus range, according to the variable distributions evaluated by Kolmogorov–Smirnov test ($p < 0.01$).

1. The chi square (χ^2) test was used to determine the significance of differences in response frequency of dietary components included in the PREDIMED questionnaire and in PREDIMED categories (low adherence, average adherence and high adherence to the MD) in the study population grouped according to HGS values dichotomized in two categories, above and below the cut-point (20 kg).
2. Receiver operator characteristic (ROC) curve analysis was performed to determine sensitivity and specificity, area under the curve (AUC), and Interval Confidence (CI), as well as cut-point for PREDIMED score in detecting HGS cut-point (<20 kg and >20 kg) in the participants. Test AUC for ROC analysis was also performed. We want show that AUC resulted 0.752 for a particular test is significant from the null hypothesis value 0.5

(meaning no discriminating power), than we enter 0.957 for AUC ROC and 0.5 for null hypothesis values. For α level we selected 0.05 type I error and for β level we selected 0.20 type II error.

3. Differences in PREDIMED score, total energy and daily nutrients intake of participants, and HGS values dichotomized in two categories, above and below the cut-point (20 kg) among participants, were analyzed by unpaired Student's t test or Wilcoxon signed-rank test, when appropriate.
4. Bivariate proportional odds ratio (OR) models, 95% IC, and R^2, were performed to assess the association among quantitative variables (single items of PREDIMED questionnaire) with HGS, after adjusting for BMI.
5. Multinomial logistic regression, 95% IC, and R^2, was performed to model the relationship between the HGS and the three categories of PREDIMED score (low adherence, average adherence and high adherence to the MD).
6. The correlations between study variables were performed using Pearson *r* or Spearman's *rho* correlation coefficients according to the variable's distribution.
7. A multiple linear regression analysis model (stepwise method), expressed as R^2, *Beta* (β) and *t*, with HGS as dependent variables was used to estimate the predictive value of food items included in the PREDIMED, the score of adherence to the MD, and the daily nutrients intake (protein, fat, unsaturated fat, PUFA, n-3 PUFA and cholesterol).

In these analyses, we entered only those variables that had a p value < 0.05 in the univariate analysis (partial correlation). To avoid multicollinearity, variables with a variance inflation factor (VIP) > 10 were excluded. Values ≤ 5% were considered statistically significant. Data were stored and analyzed using the MedCalc® package (Version 12.3.0 1993–2012 MedCalc Software bvba – MedCalc Software, Mariakerke, Belgium).

3. Results

Study population consisted of 84 elderly women, aged 60–85 years (mean age 71.7 ± 5.5 yrs), with 20 participants (24%) with age ≥75 yrs. Concerning their marital status and education status, the vast majority of these subjects were married (n.43; 51%) or widowed (n.36; 43%) with middle school diploma (n.95; 94%), while the rest 5% of them were single or have higher school diploma. Eighteen subjects were normal weight (21.4%), 39 were overweight (46.4%), and 27 presented grade I obesity (32.1%). The PREDIMED questionnaires, the 7-day food records, and HGS were assessed in all participants. All participants were retired and declared to have never smoked. No participants engaged in any regular physical activity for more than once a week in the 6 months preceding the beginning of the study or in mild-moderate daily physical activities, like walking or gardening. WC and WHR > cut-off values were found in 51 subjects (60.7%) and 54 subjects (64.3%), respectively. According to PREDIMED score, the majority of participants reached an average adherence to the MD (52.4%), while the minority of them showed a low adherence (21.4%). HGS > cut-point values were found in 43 subjects (51.2%).

In Supplementary file S1 we reported the responses of each item included in PREDIMED questionnaire. Extra-virgin olive oil was the most consumed food item, followed by vegetables. The participants were grouped according to the responses to each item included in PREDIMED questionnaire and to the HGS (Table 1). As showed in the table, the participants with HGS values higher than cut-point exhibited significant differences compared with those with higher values for the intake of the following dietary components: soda drinks (p = 0.003), legumes (p = 0.045) and commercial sweets and confectionery (p = 0.029). Considering the adherence to MD, 39% participants with HGS values higher than cut-point presented a high adherence score compared with 14% of those with lower values of HGS (p = 0.018). Accordingly, participants with HGS > cut-point presented significantly PREDIMED score than those with HGS < cut-point (p < 0.001) (Fig. 1).

ROC analysis for predictive values of the adherence to MD in detecting the HGS categories, was reported in Fig. 2. The number of cases required was set at 30, from the AUC 0.752. Based on ROC curves, the most sensitive and specific cut-point for the PREDIMED score to predict HGS categories was ≥8 (sensitivity 63.4, specificity 81.4; p < 0.001). In Table 2 we reported the total energy and the daily nutrients intake obtained from the 7-day food records. As showed in table, the participants with HGS < cut-point had significantly lower percentage of energy from protein (p < 0.001),

Table 1
Response frequency of dietary components included in the PREDIMED questionnaire according to amount of cut-off points of HGS.

	Questions PREDIMED questionnaire	HGS < 20 n = 43		HGS > 20 n = 41		χ^2	*p* values
		n	%	n	%		
1	Use of extra-virgin olive oil as main culinary lipid	40	93.0	40	97.6	0.22	0.643
2	Extra virgin olive oil >4 tablespoons	34	79.1	35	85.4	0.22	0.639
3	Vegetables ≥2 servings/day	26	60.5	32	78.0	2.27	0.132
4	Fruits ≥3 servings/day	26	60.5	30	73.2	1.01	0.316
5	Red/processed meats <1/day	25	58.1	31	75.6	2.15	0.143
6	Butter, cream, margarine <1/day	20	46.5	27	65.9	2.45	0.118
7	Soda drinks <1/day	18	41.9	31	75.6	8.50	**0.003**
8	Wine glasses ≥7/week	18	41.9	21	51.2	0.41	0.522
9	Legumes ≥3/week	19	44.2	28	68.3	4.02	**0.045**
10	Fish/seafood ≥3/week	18	41.9	23	56.1	1.18	0.277
11	Commercial sweets and confectionery ≤2/week	15	34.9	25	61.0	4.73	**0.029**
12	Tree nuts ≥3/week	7	16.3	11	26.8	0.83	0.362
13	Poultry more than red meats	24	55.8	24	58.5	0.01	0.975
14	Use of sofrito sauce ≥2/week	11	25.6	15	36.6	0.73	0.393
	PREDIMED score						
	Low – adherence	14	32.6	4	9.8	5.20	**0.022**
	Average – adherence	23	53.5	21	51.2	0.01	0.992
	High – adherence	6	14.0	16	39.0	5.59	**0.018**

Differences in the intake of single items of the PREDIMED score according to HGS values in the study participants. Results are expressed as number and percentage of responses obtained with PREDIMED questionnaire. The differences were analyzed by χ^2 test. A p value in bold type denotes a significant difference (p < 0.05). Cut-point used for low HGS in women was <20 kg [47].
PREDIMED, PREvención con DIetaMEDiterránea; ***HGS,*** Hand Grip Strength.

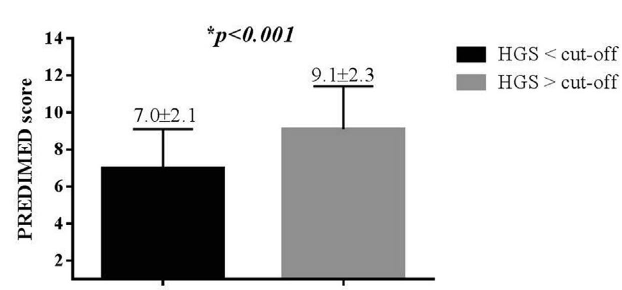

Fig. 1. Differences in PREDIMED score between the two groups of participants stratified according to the HGS cut-point. Participants with HGS > cut-point presented significantly higher adherence to MD than those with HGS < cut-point. Results are expressed as mean ± SD according to the variable distributions evaluated by Kolmogorov–Smirnov test. The unpaired *t*-test was used to test the significance of differences between the two groups. A *p* value in bold type denotes a significant difference (*p* < 0.05). Cut-point used for low HGS in women was <20 kg [47]. ***PREDIMED,*** PREvención con DIeta MEDiterránea; ***MD,*** Mediterranean Diet; ***HGS,*** Hand Grip Strength.

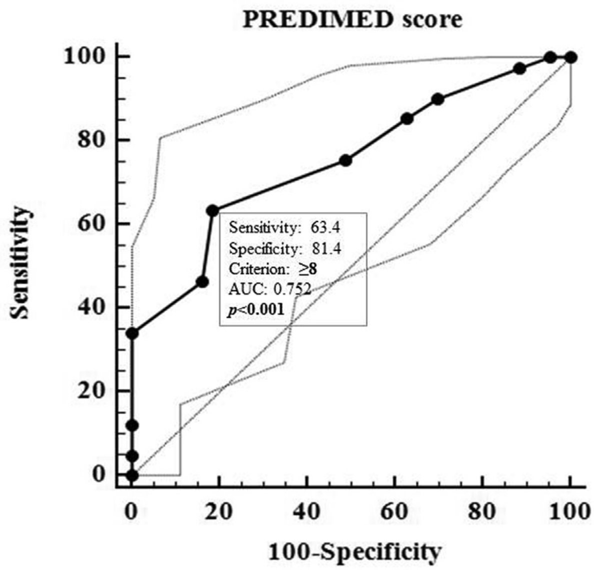

Fig. 2. ROC for predictive values of PREDIMED score in detecting HGS values. The most sensitive and specific cut-off of the PREDIMED score to predict HGS cut-off point (20 Kg), was ≥8 (sensitivity 63.4, specificity 81.4; $p < 0.001$). A *p* value in bold type denotes a significant difference ($p < 0.05$). Cut-point used for low HGS in women was <20 kg [47]. ***ROC,*** Receiver operating characteristic analysis; ***PREDIMED***, PREvención con DIeta MEDiterránea; ***HGS,*** Hand Grip Strength, ***AUC,*** Area Under Curve.

total carbohydrate ($p < 0.001$), unsaturated fat ($p = 0.018$) and n-3 PUFA ($p = 0.031$), and a significantly higher total fat ($p < 0.001$) and cholesterol intake ($p = 0.006$) than HGS > cut-point.

3.1. Correlation studies

No evident correlations were observed between HGS and age. Among anthropometric measures, HGS was negatively correlated with HC (r = −0.233, $p = 0.033$) and BMI (r = −0.219, $p = 0.045$); HGS was also positively correlated with PREDIMED score, independently of BMI (Fig. 3). The results of binomial logistic regression model performed to assess the association of dietary components included in the PREDIMED questionnaire with HGS, adjusted for BMI, were reported in Table 3. The traditional foods of the MD, when consumed more frequently, were significantly associated with HGS.

The results of multinomial logistic regression model to assess the association of the three classes of PREDIMED score with the HGS, adjusted for BMI, were reported in Table 4. The lowest adherence to MD was associated with the lowest OR of HGS ($p < 0.001$).

In Supplementary file S2 we reported the correlations among HGS, total energy and daily nutrients intake, evaluated by using the 7-day food records. HGS correlated with some the dietary nutrients intake, in particular protein ($p < 0.001$), fat ($p < 0.001$), unsaturated fat ($p = 0.008$), PUFA ($p = 0.015$), n-3 PUFA ($p = 0.027$), cholesterol ($p = 0.014$), also after adjusting for total energy intake and BMI. In addition, the correlation between PREDIMED score and HGS was independent of protein intake (r = 0.472; $p < 0.001$).

To compare the relative predictive power of the food items included in the PREDIMED, the score of adherence to the MD, and the daily nutrients intake associated with the HGS, we performed a multiple linear regression analysis using models that included as measures the consumption frequency of each food items of PREDIMED questionnaire, the PREDIMED score along with the daily nutrients intake (protein, fat, unsaturated fat, PUFA, n-3 PUFA and cholesterol). Using these model PREDIMED score entered at the first step ($p < 0.001$), followed by the protein intake ($p < 0.001$); results were reported in Table 5.

4. Discussion

In this cross-sectional observational study we evaluated the association between the adherence to the MD, using the PREDIMED score, and the HGS in a sample of active elderly women. The novel finding of this study is the association between adherence to the MD and its individual foods with the HGS. In particular, when grouping the study participants according to the mean reference value for HGS, defined as 20 kg in women, we observed that subjects with HGS above the cut-point presented lower intake of energy-dense nutrient-poor "junk food" and soda drinks, higher consumption of legumes, and higher adherence to the MD when compared to their counterpart with HGS below the cut-point. By using ROC analysis, a PREDIMED score ≥8 was found as the most sensitive and specific cut-point to predict value of HGS above the

Table 2
Total energy and daily nutrients intake of participants grouped on the basis of HGS cut-point.

Parameters	Total n = 84	HGS < 20 n = 43	HGS > 20 n = 41	*p*-value*
Total energy (kcal)	2032.52 ± 257.00	2040.01 ± 273.88	2024.68 ± 241.19	0.787
Protein (% of total kcal)	13.47 ± 2.17	12.24 ± 2.04	14.75 ± 1.45	**<0.001**
Carbohydrate (% of total kcal)	55.05 (50.90–61.90)	55.10 (50.91–60.0)	56.00 (51.00–61.90)	**<0.001**
Complex (% of total kcal)	30.80 (21.01–39.32)	30.61 (23.70–39.30)	30.60 (21.00–38.20)	0.788
Simple (% of total kcal)	25.60 (16.40–37.70)	25.70 (18.70–35.60)	25.40 (16.40–37.70)	0.957
Fat (% of total kcal)	30.95 ± 3.61	32.34 ± 3.38	29.50 ± 3.27	**<0.001**
SFA (% of total kcal)	9.07 ± 1.46	9.24 ± 1.62	8.89 ± 1.28	0.271
Unsaturated fat (% of total kcal)	21.89 ± 3.65	20.98 ± 3.96	22.83 ± 3.05	**0.018**
MUFA (% of total kcal)	15.75 (10.01–22.14)	15.69 (10.21–22.14)	15.95 (10.01–20.70)	0.405
PUFA (% of total kcal)	13.41 ± 8.96	5.21 ± 4.25	6.67 ± 2.99	0.070
n-6 PUFA (g/day)	8.52 ± 8.31	7.77 ± 9.77	9.30 ± 6.47	0.398
n-3 PUFA (g/day)	4.90 ± 2.71	4.28 ± 2.85	5.54 ± 2.42	**0.031**
n-6/n-3 PUFAs ratio	2.35 ± 3.37	2.56 ± 4.33	2.14 ± 1.95	0.563
Cholesterol (mg/day)	321.37 ± 38.10	332.42 ± 34.91	309.78 ± 38.24	**0.006**
Fiber (g/day)	18.54 ± 5.36	18.00 ± 5.69	19.09 ± 4.99	0.357

Differences in total energy and daily nutrients intake of participants grouped on the basis of HGS cut-point. Results are expressed as mean ± standard deviation or as median plus range according to variable distributions evaluated by Kolmogorov–Smirnov test. Differences between groups were analyzed by unpaired Student's *t* test or Wilcoxon signed-rank test, when appropriate. **p*-value indicates comparison between those with low HGS < cut-point versus those with HGS > cut-point. A *p* value in bold type denotes a significant difference ($p < 0.05$).
HGS, Hand Grip Strength; ***SFA,*** Saturated Fatty Acids; ***MUFA,*** MonoUnsaturated Fatty Acids; ***PUFA***, PolyUnsaturated Fatty Acids.

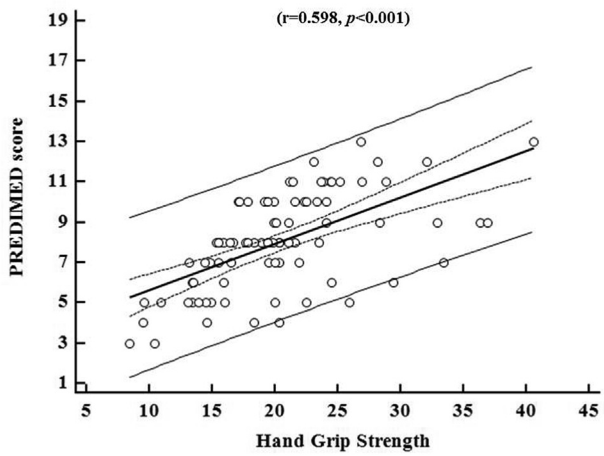

Fig. 3. Correlation between PREDIMED score and HGS, adjusted for BMI. A significant positive correlation was observed between PREDIMED score and HGS, independently of BMI. A p value in bold type denotes a significant difference ($p < 0.05$). ***PREDIMED,*** PREvención con DIeta MEDiterránea; ***HGS,*** Hand Grip Strength, ***BMI,*** Body Mass Index.

Table 3
Binomial Logistic Regression model to assess the association of dietary components included in the PREDIMED questionnaire with the HGS, after adjusting for BMI.

	Questions	OR	95% IC	R^2	p value
1	Use of extra virgin olive oil as main culinary lipid	1.59	1.11–2.26	0.13	**0.011**
2	Extra virgin olive oil >4 tablespoons	1.09	0.98–1.21	0.03	0.125
3	Vegetables ≥2 servings/day	1.12	1.02–1.23	0.08	**0.020**
4	Fruits ≥3 servings/day	1.11	1.01–1.21	0.07	**0.024**
5	Red/processed meats <1/day	1.17	1.07–1.30	0.13	**0.003**
6	Butter, cream, margarine <1/day	1.12	1.03–1.23	0.09	**0.008**
7	Soda drinks <1/day	1.16	1.06–1.28	0.14	**0.002**
8	Wine glasses ≥7/week	1.08	0.98–1.14	0.03	0.135
9	Legumes ≥3/week	1.07	0.99–1.16	0.04	0.077
10	Fish/seafood ≥3/week	1.01	0.94–1.08	0.01	0.756
11	Commercial sweets and confectionery ≤2/week	1.11	1.02–1.20	0.08	**0.015**
12	Tree nuts ≥3/week	1.09	1.00–1.19	0.05	**0.041**
13	Poultry more than red meats	1.06	0.98–1.14	0.03	0.149
14	Use of sofrito sauce ≥2/week	1.04	0.96–1.12	0.01	0.320

Higher values of HGS were positively associated with a higher consumption of almost all of the Mediterranean food items, after adjusting for BMI. A p value in bold type denotes a significant difference ($p < 0.05$).
PREDIMED, PREvención con DIeta MEDiterránea; ***HGS,*** Hand Grip Strength; ***BMI,*** Body Mass Index; ***ODDs,*** Odds; ***IC,*** Interval Confidence.

Table 4
Multinomial Logistic Regression model to assess the association of the three classes of PREDIMED score with the HGS, after adjusting for BMI.

Adherence of MD	OR	95% IC	R^2	p value
Low adherence of MD	0.73	0.61–0.86	0.24	**<0.001**
Average adherence of MD	1.02	0.95–1.09	0.01	0.611
High adherence	1.14	1.04–1.25	0.11	**0.003**

The lowest adherence to MD was associated with the lowest OR of HGS, after adjusting for BMI. A p value in bold type denotes a significant difference ($p < 0.05$). ***PREDIMED,*** PREvención con DIeta MEDiterránea; ***HGS,*** Hand Grip Strength; ***BMI,*** Body Mass Index; ***MD,*** Mediterranean Diet; ***ODDs,*** Odds; ***IC,*** Interval Confidence.

Table 5
Multiple regression analysis models (stepwise method) with the HGS as dependent variable to estimate the predictive value of a food items of PREDIMED questionnaire, PREDIMED score and nutrients intake (protein, fat, unsaturated fat, PUFA, n-3 PUFA and cholesterol).

Parameters	Multiple Regression analysis			
Model 1	R^2	β	t	p value
PREDIMED SCORE	0.358	0.598	6.8	**<0.001**
Protein intake (% of total kcal)	0.474	0.432	4.8	**<0.001**

Variable excluded: Other items of PREDIMED score; fat, unsaturated fat, PUFA, n-3 PUFA and cholesterol.
Among adherence to the MD, single food items of PREDIMED questionnaire, and among dietary nutrients intake, HGS were well predicted by PREDIMED score and protein intake. A p value in bold type denotes a significant difference ($p < 0.05$).
HGS, Hand Grip Strength; ***PREDIMED,*** PREvención con DIeta MEDiterránea; ***PUFA,*** Polyunsaturated fatty acids.

mean reference values. To the best of our knowledge, no previous studies provided a specific cut-point for the PREDIMED score to predict the highest HGS values.

In this study, we took advantage of two easy and reliable tools to evaluate the adherence to the MD, on the one side, and the muscle functional capacity on the other side. The quantitative score (14-item) of adherence to the MD PREDIMED score is a key element in the interventions conducted in the PREDIMED trials and that has been previously validated against the full-length Food Frequency Questionnaire (FFQ). PREDIMED is less time-demanding, less expensive and requires less collaboration from participants than the usual FFQ or other more comprehensive methods [44], characteristics that make this questionnaire particularly suitable for elderly population. Moreover, PREDIMED questionnaire allows providing feedback to the participant immediately after the interview is completed under the control of an expert Nutritionist. HGS evaluates the maximum isometric strength of the hand and forearm muscles and is commonly used in clinical as well as research settings [48]. As the strength of the forearm muscles does not necessarily represent the strength of other muscle groups, the validity of this test as a measure of general strength has been questioned [45], particularly among obese women [49]. However, results of the InCHIANTI study demonstrated that HGS equally well identified subjects with poor mobility as did lower extremity muscle power and knee extension torque, and thresholds of 30 kg for men and 20 kg for women were recommended for use in clinical practice [50]. Thus, when standardized methods and calibrated equipment are used, HGS represents a reliable and inexpensive surrogate of overall muscle strength and a valid predictor of physical disability and mobility limitation [51], remaining an objective measure of physical performance, even when performed by different operators [52] or different brands of dynamometers [53]. Of interest, HGS is also negatively associated with physical frailty even when the effects of BMI and arm muscle circumference are removed [54].

Is it well-known that the muscle strength is largely affected by nutrition, and specific dietary food components have been suggested to play an important role in the age-associated decline in physical performance [55]. Previous studies have focused on either individual nutrients, such as protein [56–58] or individual food groups [59,60]. However, diet includes a complex combination of several foods from various groups and nutrients, and some nutrients have highly similar properties, thus it is very challenging, in free-living populations, to separate the effect of a single nutrient or food group from others [61]. Consequently, there has been an increasing interest in using dietary pattern to evaluate the effects of nutrition on age-associated decline in physical performance.

The health benefits of a Mediterranean-style diet have been well documented for chronic disease morbidity and mortality [62,63]. Nevertheless, the large body of existing literature concerning MD and body weight focused on young individuals, with the aim of preventing and reducing obesity and cardiovascular diseases [64]. However, the World's population is ageing individuals older than 65 yrs represent an important and growing proportion and pose a considerable healthcare expense [65]. Dietary pattern-based interventions have the potential of being a cost-effective solution for preventing or potentially slowing age-associated declines, including physical performance [27]. Several studies have investigated the association between Mediterranean-style diet, muscle mass, muscle strength, and muscle quality of older population living in different geographic areas. In these studies, the adherence to the MD was assessed using different questionnaires, mainly the 9-item MD according to the method developed by Trichopoulou et al. [66], while the muscular fitness was measured by means of different methods, such as free-fat mass, lower Limb Extension Power (LEP) or Short Physical Performance Battery (SPPB: standing balance, walking speed, and chair stand tests), and HGS [26,27,67]. These studies revealed some discrepancies in the relationship between adherence to the MD and the measures of physical performance. Bollwein et al. detected an association between a high dietary quality and a lower risk of low walking speed and low physical activity in community-dwelling older adults of both sexes living in the North Europe, but not with HGS [68]. More recently, Fougère et al. examined the association between adherence to the MD and two physical performance measures (i.e. SPPB score and HGS) among older individuals of adults of both sexes aged 77 years and older from the TRELONG study in the North Italy. Accordingly, the Authors found a statistically significant association between higher adherence to the MD and higher performance lower limbs, but again not with HGS [69]. In line with these findings, Keilaiti et al. correlated the intake of the individual food components of the MD in relation to the arm muscle quality in a large sample of women distributed over a wide age range (18–79 yrs) from the Twins UK registry, and found that fruit and alcohol intake were significantly associated with arm muscle quality, without significant associations with intakes of legumes, fish, or dairy products. However, in this study, the Authors failed to found any correlation with HGS and MD [17].

Our study is the first to report a strong correlation between the adherence the MD and HGS. It is well known that the development of frailty and the age-associated declines in physical function and skeletal muscle strength have been partially due to inflammation and oxidative stress that invariably is associated to aging [27]. Therefore, in line with other clinical studies, the higher intakes of several antioxidant micronutrients, including β-carotene and vitamins C and E, and other food bioactives, such as polyphenolic compounds present in plant foods or n3-PUFA present in fish and nuts, the low to moderate intake of alcohol and oils, such as extra-virgin olive oil, associated with a Mediterranean-style diet may also be responsible for the positive association between the adherence to the MD and HGS in our group of elderly women. Conversely, our study did not evidence any association between age and HGS. A possible explanation of this discrepancy could be due to the very homogeneous characteristics of our study sample. It is well known that gender, age, and educational status represent strong determinants in cross-sectional studies; in particular, gender influences food choice behaviours and it is a consolidated assumption that women's dietary profiles are characterized by higher carbohydrates intake, including fruit and vegetables compared to males [70,71]. It is also known that marital status influences the dietary behaviours, as married women and those who shared food preparation with family members had higher MD scores, compared to those who were single or had sole responsibility for food preparation, respectively [72]. In order to improve the power of the study, we increased the homogeneity of the subjects sample by including females only to avoid the effect of gender-specific food choice in dietary intake and anthropometric measures. The age range of the community-dwelling elderly women was relatively low, since only 24% of them were ≥75 yrs. In addition, as all participants were recruited at the local church, most of them lived in the same neighbourhood, were more likely to be in the same social network, the vast majority were married/widowed, the educational level was very similar, and were not engaged in any physical activities. The lack of daily physical activities was not surprising in our study population of elderly women, taking also into consideration that this study was carried out during the winter season. Of interest, the association between HGS and PREDIMED score was also independent of protein intake. This finding, the lack of association between HGS and total energy intake, and the lack of physical activity, let us to exclude that, in our study population of elderly women, the positive association between the adherence the MD and HGS could be the result of higher energy or protein intake or physical activity, which, in the elderly population is likely associated with better muscle strength, rather than any Mediterranean diet effect.

We are aware that there are some limitations in the current study. First, the cross-sectional nature of this study did not allow any statements on a causal relationship between MD and HGS. Second, the sample size is relatively small and dietary intake is related to a larger number of other lifestyle factors. Nevertheless, the sample size was calculated using 80% power; in addition, the association between MD and HGS was independent of the effects of other health-related behaviours (physical activity, BMI) and protein intake. Third, the PREDIMED score, although easy to be accepted by the participants, allows only relative but no absolute statements about the degree of adherence to the MD. Fourth, the study sample, stratified according to HGS, included different BMI ranges. It is well-known that obesity is associated to increased risk of functional limitation. Thus, HGS cut-points for increased risk for mobility limitation may need to be examined separately for normal-weight, overweight and obese subjects in old population. However, as also reported by Sallinen J et al., while among men the HGS cut-points for mobility increased along with BMI, in women a single HGS threshold seemed to be sufficient at any level of BMI was identified [73]. In any case, in our study, the association between the adherence to the MD or its single items with HGS was adjusted for BMI. In addition, not only the PREDIMED questionnaire was face-to-face administered and not self-reported but, to avoid the inter-operator variability, only one expert Nutritionist administered the questionnaires, evaluated the anthropometric measures and determined the HGS. Anyway, the suggested cut-point for the PREDIMED score for identify the highest HGS values should be viewed with caution until results of studies in larger population samples have become available to perform an appropriate cross-validation.

4.1. Conclusions

This is the first study to evidence a positive association between adherence to the MD evaluated by PREDIMED score and its individual foods with the HGS in elderly active women. These results would recommend the evaluation of adherence of MD in the nutrition assessment as good clinical practice in clinical setting, thereby supporting the beneficial effects of nutritional interventions promoting a Mediterranean food pattern as an inexpensive and safe adjuvant prevention and treatment for age-related decline in physical performance. In this respect, this study i) suggests that, also without specific HGS measurements, the determination of a specific cut-point for the score of adherence to MD might help identifying subjects at high-risk for low muscle strength, who could get benefit of personalized dietary interventions; ii) further supports the collaborative role of Nutritionists in the evaluation and management of elderly population, highlighting the usefulness of the development of health services to detect and prevent age-associated decline in physical performance in elderly subjects by carefully addressing nutritional.

Future studies on male elderly or dietary intervention trials on large series population of both sexes will be critical for unravelling the beneficial effects of the MD on the HGS in elderly population.

Conflict of interest

None of the authors had a conflict of interest.

Authors' contributions

The authors' responsibilities were as follows LB and SS: were responsible for the concept and design of the study and interpreted data and drafted the manuscript;

LB: conducted statistical analyses; CDS, GM, GT, VDL, MI and AC: provided a critical review of the manuscript.

All authors contributed to and agreed on the final version of the manuscript.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.clnu.2018.03.012

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