

Adherence to Mediterranean-DASH Intervention for Neurodegenerative Delay Diet Can Decreased Risk of Age Associated Poor Muscle Strength; A Cross-Sectional from Kurdish Cohort Study

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Abstract

The Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diet aims to reduce dementia and the decline in brain health that often occurs as people get older. Loss of muscle strength (sarcopenia) is a geriatric syndrome that has associated with the loss of skeletal muscle mass and strength. The current study aimed to investigate the association between adherence to MIND diet and decrease the risk of age-associated poor muscle strength. This cross-sectional study was performed using data from Ravansar's non-communicable diseases (RaNCD) cohort study on 3181 adults (48.5% men) aged 35–65 years. The dietary intake of the studied participants was assessed by the use of a 114-item food frequency questionnaire (FFQ) developed by RaNCD cohort study. The MIND diet and the major dietary patterns were computed based on their dietary intake and three dietary patterns were identified including plant-based diet, high protein diet, and unhealthy diet. Hand grip strength (HGS) was measured using a hand-held hydraulic handgrip dynamometer and poor HGS was defined as HGS less than 32.8 and 20.5 kg in men and women, respectively. We found that greater adherence to MIND diet was associated with lower risk of poor HGS (OR: 0.65; CI 95%: 0.51-0.83). Furthermore, participants who were in third tertiles of plant-based and high protein diet were more likely 37% and 33% lower risk of poor HGS (OR: 0.63; CI 95%: 0.5-0.79), (OR: 0.67; CI 95%: 0.54-0.84), respectively. On the other hand, greater following to unhealthy diet was related to higher risk of poor HGS (OR: 1.39; CI 95%: 1.11-1.74). Overall, our findings provide that adhere to plant-based and high protein diet, as well as MIND diet had protective effects on age related poor HGS, while adherence to unhealthy diet can developed age related poor HGS.

Introduction

Muscle mass is known to be linearly correlated with muscle strength has reported a strong association between low muscle mass and poor physical function ^{1,2}. Therefore, as an indicator of muscular quality and functionality, low muscle strength represents an important public health problem ³. It may therefore be expected that the coexistence of low muscle mass and poor muscle strength would identify a population of older persons at especially high risk of adverse health outcomes ⁴. Hand grip strength (HGS) is the best validated technique to measure muscle strength ⁴ that applied in many epidemiological studies to measure muscle strength ⁵. Low HGS is associated with sarcopenia ⁶. The relation between reduced HGS and the presence of hypertension, cardiovascular diseases, diabetes, insomnia ^{3,7}, and depression ⁸ has been reported. Therefore, HGS known as a means of tracking muscle strength, diseases, and health problems to minimize the impacts of morbidity and mortality of the population ^{9,10}.

Although no definite treatment guidelines are presently available for sarcopenia ¹¹, appropriate lifestyle such as adherence to healthy dietary can delay the process of low muscle mass and strength ^{5,12}. Recently, the Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diet has been suggested to emphasize foods that impact brain health ¹³. The MIND diet is a plant-based, antioxidant-rich diet, and focuses on limiting the intake of animal products and foods high in saturated fat ¹³. Components of the MIND diet include vegetables and especially green leafy vegetables, fruits, tree nuts,

legumes, berries, whole grains, olive oil, beans, and a moderate intake of fish and poultry¹³. The MIND diet could be improved neuronal physiology and anatomy¹⁴ and the protective association of the MIND diet with the brain, and cognitive health has been demonstrated in previous studies^{13,15,16}. It has been shown that conservation of skeletal muscle strength and physical function to be associated with cognitive health¹⁷. However, limited data are available examining adherence to the MIND diet in relation to muscle strength and sarcopenia.

Since the impact of the MIND diet on other aspects of aging such as cognitive health has been reported and it has been shown that muscle strength to be associated with cognitive health, we hypothesized that adherence to the MIND dietary pattern would be protective effects on age associated poor muscle strength. Therefore, this cross-sectional observational study was designed to associations of MIND diet adherence with the risk of age associated poor muscle strength in the Kurdish population. For this purpose, we examined associations of MIND diet adherence with muscle strength assessed by HGS.

Methods

Study design and population

The study population of this cross-sectional study was extracted from the baseline phase data from the RaNCD cohort study. Since 2014, this study is the first Kurdish population-based study on 10,047 Kurdish participants' aged 35–65 (4764 men and 5283 women) years living in Ravansar city, Kermanshah province, Western Iran. The RaNCD is a branch of PERSIAN (Prospective Epidemiological Research Studies in Iran) mega-cohort study was developed to evaluate non-communicable diseases. The protocol of the RaNCD cohort study was described in the previous studies^{18,19}. The ethical approval has been granted by the Ethics Committee of Kermanshah University of Medical Sciences (ethics approval number: KUMS.REC.1394.318).

Participants

In the present study, After excluding 4817 participants due to lack of their muscle strength measurement in the baseline study phase of the RaNCD cohort study, participants with cardiovascular diseases (CVDs), diabetes, thyroid diseases, cancer, renal failure, and rheumatoid arthritis²⁰⁻²³ did not include to this study. Pregnant women, alcohol consumers, and body builder participants were not included in this study. These mentioned diseases and conditions seem lead to changes of diet. Moreover, the participants consuming energy intake out of range 800- 4200 Kcal/day for men and 600-3500 Kcal/day for women were considered under and over energy intake reporters, therefore, they were not included in this study. Seven participants with missing data were excluded from the study. Ultimately, 3181 participants took part in the study. (Fig. 1)

Data sources/measurements

The basic data including demographics, dietary intake, physical activity (PA), dynamometry, anthropometric indices, and body composition were obtained from RaNCD cohort study¹⁹.

Anthropometric indices

InBody 770 device (Inbody Co, Seoul, Korea) was applied to measure weight and body composition including, body fat mass (BFM), free fat mass (FFM), percentage body fat (PBF), soft lean mass (SLM), and skeletal muscle mass (SMM) while participants were minimally clothed. The height of RaNCD participants was measured using the automatic stadiometer BSM 370 (Biospace Co., Seoul, Korea) in a standing position without shoes with a precision of 0.1 cm. Body mass index (BMI) was computed using this formula: weight (kg) divided by height squared (m^2). Furthermore, waist circumference (WC) was measured by non-stretched and flexible tape in a standing position at the level of the iliac crest by trained nutritionist.

Hand grip strength

Hand grip strength (HGS) was evaluated with the dominant hand using a hand-held calibrated hydraulic hand grip dynamometer (model SH5003, Saehan Corporation, Masan, Korea). To measure HGS, participants were asked to sit on a chair and flexed their elbows at a 90° to the arm of the chair handle. Then participants were asked to press the dynamometer handle with maximum power for 10 seconds. After 30 seconds, the measurement was repeated and the average values recorded by the dynamometer were reported as the individual's final HGS. Calibration and validation of this device was published in the previous study²⁴. We considered cut off point reported by Lauretani et al.²⁵ to assess age related poor muscle strength.

Dietary intake assessment

A validated semi- quantitative 118 items food frequency questionnaire (FFQ) was applied to evaluate dietary intake of RaNCD participants²⁶. As far foods nutrients, these 118 food items were grouped to thirty- one food groups (principal component)²⁷. The major dietary patterns were extracted by principal component analysis (PCA) and factors were rotated using the varimax method to minimize the number of variables. As a result, the first three major dietary patterns with eigenvalues more than 1.5 were extracted based on the screen diagram and the interpretability of the factors. The factor loading is actually the degree of correlation between food groups with each dietary pattern. We explained and named the dietary patterns considering a factor load more than 0.3. Finally, for each participant, the factor load for each dietary pattern was calculated. Factor loading indicates the extent to which each participant adheres to a known dietary pattern. A higher and positive factor loading for a dietary pattern means more adherence to this pattern, while a low factor loading score indicates a lower following of the dietary pattern.

MIND diet

To calculate the MIND diet, we used the data derived from RaNCD cohort FFQ according to the method that was first invented by Morris et al ¹³. The MIND diet components that we used in this study consisted of two parts: a) 10 healthy food groups for the brain (green leafy vegetables, other vegetables, berries, nuts, whole grains, fish, beans, poultry, olive oil and wine, and b) 5 unhealthy food groups for the brain (butter and margarine, cheese, red meat and product, fast fried foods, pastries and sweets). Each of the mentioned food groups was divided into three categories. To score the MIND diet, the participants who consumed the healthiest food for the brain in the lowest tertile were given a score of 0, a score of 0.5 for middle tertile of these food groups intake and those who received these food groups in third tertile were given a score of 1. In the case of unhealthy brain food groups, the scoring was reversed. In this way, the participants who received these unhealthy foods in the highest tertile were given a score of zero. In the present study, due to lack of wine consumption information was not included in the main data set. Overall, the scores of each component were summed together and the final score of MIND diet was reported between 0 and 14.

Statistical analysis

Basic characteristics of participants including quantitative variables were reported by mean \pm standard deviation (SD), and qualitative variables were presented using frequency (%). These characteristics were compared based on the tertiles of MIND diet using one-way ANOVA and Chi-square tests. Multiple-crude and adjusted odds ratios (OR) and 95% confidence intervals (CI 95%) was applied to evaluate risk of age related poor muscle strength across of the MIND diet and major identified dietary patterns.

In these analyses potential confounders were adjusted in Model 1 (adjusted for age and gender) and model 2 (adjusted for variables in model 1, physical activity, BMI, and smoking). Radar graph was drawn to better show the relationship between the components of MIND diet and HGS.

All statistical analyses were performed using SPSS 20 (IBM Corp, Chicago, IL, USA). P-values were considered significant at the level of < 0.05 .

Results

A total of 3181 adults (48.5% men) were included in this present cross-sectional study. Mean of SLM, FFM, and SMM significantly increased with higher adherence to the MIND diet. In addition, HGS in the third tertile was significantly higher than the first tertile ($P<0.001$). There was no significant difference in the mean of physical activity in tertiles of the MIND diet. Other baseline participant's characteristics are reported in Table 1.

Table 1
Basic characteristics of participants

Characteristics	Total (n=3181)	Tertiles of MIND Diet			P- value**
		T1 (<6)	T2 (6-7.5)	T3 (7.5-12.5)	
Age (year)	46.17±8*	46.81±8.35	45.93±7.94	45.45±7.36	<0.001
Gender, male (%)	48.5	37	52	63.1	<0.001
Weight (kg)	70.7±13.71	68.68±13.45	70.90±13.44	73.90±13.94	<0.001
BMI (kg/m ²)	26.62±4.63	26.47±4.67	26.56±4.62	26.95±4.56	0.072
WC ⁵⁵	96.83±10.38	96.41±10.57	96.59±10.24	97.93±10.17	0.004
BFM (kg)	23.47±9.29	23.45±9.32	23.29±9.35	23.77±9.16	0.542
SLM (kg)	44.69±8.95	42.82±8.68	45.01±8.65	47.43±9.09	<0.001
FFM (kg)	47.24±9.44	45.27±9.14	47.58±9.14	50.14±9.60	<0.001
SMM (kg)	26.13±5.72	24.93±5.54	26.34±5.54	27.90±5.81	<0.001
PBF (%)	32.57±9.41	33.48±9.46	32.20±9.46	31.59±9.10	<0.001
HGS (kg)	32.61±11.31	30.12±10.52	33.21±11.36	36.01±11.54	<0.001
PA (MET hour/ day)	41.67±7.77	41.89±7.09	41.58±8.33	41.44±8.04	0.398
Smoking (%)	18.4	16	18.7	22.1	0.003
*Mean± SD					
**P-values were obtained one-way ANOVA and Chi square.					
BMI: body mass index; WC: waist circumference; BFM: body fat mass; SLM: soft lean mass; FFM: free fat mass; SMM: skeletal muscle mass; PBF: percentage body fat; HGS: hand grip strength; PA: physical activity					

Three major dietary patterns were extracted using PCA including: 1) plant- based diet that was high in leafy vegetables, fresh fruits, starchy vegetables, dried fruits, potato, nuts, tomato, carotene-rich vegetables and so on; 2) high protein diet was dominated by red meat, organ meat, processed meat, fish, poultry, and legumes; and 3) unhealthy diet with high loadings for hydrogenated fats, sweets and desserts, tea and coffee, salt, refined grain, and low loading for fruits, vegetable, vegetable oil and olive. (Table 2)

Table 2
Factor loading of food groups in the major identified dietary patterns

Food groups	Major dietary patterns		
	Plant- based dietary pattern	High protein dietary pattern	Unhealthy dietary pattern
Leafy vegetables	.654		
Fresh fruits	.600	.259	-.215
Starchy vegetables	.568		
Dried fruits	.469		-.250
Potato	.452		.270
Nuts	.448	.364	
Tomato	.422		.213
Carotene-rich vegetables	.420	.213	-.375
Condiments	.397		
Dairy	.396		
Butters	.378		
Pickles	.327		
Egg	.314	.239	
Poultry	.285	.241	
Whole grains	.236	.224	
Red meat		.672	
Organ meat		.621	
Fish		.617	
Soft drinks		.462	.244
Processed meat		.387	
Legumes	.333	.378	
Natural juices	.230	.289	
snack		.240	
Hydrogenated fats			.587
Factor loading less than 0.2 have been removed for clarity.			

Food groups	Major dietary patterns		
	Plant- based dietary pattern	High protein dietary pattern	Unhealthy dietary pattern
Sweets and desserts	.244	.225	.549
Tea and coffee			.538
Vegetable oil	.243		-.403
Olive		.216	-.328
Salt			.317
Refined grains		.258	.278
Variance %	11.04	8.48	6.73
Factor loading less than 0.2 have been removed for clarity.			

Table 3 provides the association between adherence to the MIND diet and major identified dietary patterns with HGS. We found that participants who were in third tertile of MIND diet were 43% lower risk of poor HGS (OR: 0.57; CI 95%: 0.45-0.71). In addition, after controlling for potential confounders including age, gender, physical activity, BMI, and smoking, this diet had a preventive significant association with poor HGS (OR: 0.65; CI 95%: 0.51-0.83). Similarly, plant-based and high protein dietary pattern decreased risk of poor HGS either before (OR: 0.53; CI 95%: 0.43-0.66), (OR: 0.51; CI 95%: 0.41-0.63) or after controlling for potential confounders (OR: 0.63; CI 95%: 0.5-0.79), (OR: 0.67; CI 95%: 0.54-0.84), respectively. Nevertheless, greater adherence to unhealthy dietary pattern were 1.49 times more at risk of poor HGS (OR: 1.49; CI 95%: 1.21-1.84). This association was remained after controlling for mentioned potential confounders (OR: 1.39; CI 95%: 1.11-1.74). (Table 3)

Table 3
Multiple-adjusted odds ratios and 95% confidence intervals for hand grip strength across
of the MIND diet and major identified dietary patterns

Dietary patterns		Odds ratio (95% CI)			P- trend
		T1	T2	T3	
MIND diet	Crude	1	0.82 (0.68-0.99)	0.57 (0.45-0.71)	<0.001
	Model 1	1	0.89 (0.73-1.08)	0.63 (0.5-0.81)	<0.001
	Model 2	1	0.9 (0.73-1.1)	0.65 (0.51-0.83)	0.001
Plant- based diet	Crude	1	0.79 (0.65-0.97)	0.53 (0.43-0.66)	<0.001
	Model 1	1	0.9 (0.73-1.11)	0.61 (0.49-0.77)	<0.001
	Model 2	1	0.92 (0.74-1.13)	0.63 (0.5-0.79)	<0.001
High protein diet	Crude	1	0.75 (0.62-0.92)	0.51 (0.41-0.63)	<0.001
	Model 1	1	0.88 (0.71-1.08)	0.66 (0.53-0.83)	<0.001
	Model 2	1	0.88 (0.71-1.09)	0.67 (0.54-0.84)	0.001
Unhealthy diet	Crude	1	1.21 (0.98-1.49)	1.49 (1.21-1.84)	<0.001
	Model 1	1	1.11 (0.88-1.38)	1.33 (1.07-1.66)	0.008
	Model 2	1	1.12 (0.89-1.4)	1.39 (1.11-1.74)	0.003
* Model 1 adjusted for age and gender.					
* Model 2 adjusted for variables in model 1, physical activity, BMI, and smoking					

We also examined the association between components of MIND diet and HGS. (Table 4) Among them, higher score of green leafy vegetables, other vegetables, berries, whole grains, fish, and olive was related with lower risk of poor HGS. Although, the brain unhealthy foods including red meat and products, fast fried foods, pastries, and sweets increased risk of poor HGS. (Table 4)

Table 4
Multiple-adjusted odds ratios and 95% confidence intervals
for hand grip strength across of the components of MIND
diet

Components of MIND diet	OR (CI 95%)*	P- value
Brain healthy foods		
Green leafy vegetables	0.79 (0.62-0.99)	0.048
Other vegetables	0.57 (0.45-0.72)	<0.001
Berries	0.65 (0.52-0.81)	<0.001
Nuts	0.95 (0.75-1.2)	0.693
Whole grains	0.77 (0.67-0.97)	0.027
Fish	0.69 (0.55-0.86)	0.001
Beans	0.9 (0.71-1.12)	0.364
Poultry	1.08 (0.88-1.32)	0.427
Olive	0.51 (0.4- 0.65)	<0.001
Brain unhealthy foods		
Butter, margarine	1.06 (0.85-1.33)	0.558
Cheese	0.93 (0.73-1.12)	0.384
Red meat and products	1.43 (1.12-1.83)	0.004
Fast fried foods	1.33 (1.07-1.67)	0.01
Pastries and sweets	1.42 (1.12-1.8)	0.003
*Adjusted for all variables in Table 3.		

Figure 2 showed radar graph for differences of MIND diet components between participants with poor and optimal HGS.

Discussion

In this cross-sectional study, we investigated the relationship between adherence to MIND diet patterns and the risk of age associated poor muscle strength. Among the components of the MIND diet, green leafy vegetables, other vegetables, berries, whole grains, fish, and olive were associated with lower risk of poor HGS. Although, the brain unhealthy foods including red meat and products, fast fried foods, pastries, and sweets were associated with the risk of poor HGS. Our findings showed that adherence to the MIND diet significantly was lower risk of poor HGS and had protective effects on age related poor HGS.

Dietary patterns can play a critical role in maintaining skeletal muscle health and strength ²⁸. In agreement with our findings, a study has shown a positive association between adherence to the Mediterranean diet (MED) and muscle strength ⁵. Furthermore, It has been demonstrated that older Korean men who higher intake of fruits, vegetables, potatoes, whole grains, fish (main components of MIND diet), eggs, seaweed, mushrooms, legumes had higher muscle mass compared to those belonging to a 'Westernized' dietary pattern ²⁹. The MIND diet is a mainly plant-based dietary pattern, which has been designed as a combination of Mediterranean and dietary approaches to stop hypertension (DASH) dietary patterns. It has been shown that adherence to the MIND diet has been inversely associated with the risk of cognitive decline, depression, and psychological distress ^{15, 30}. Although the MIND diet was explicitly created for prevention of cognitive decline, its dietary components may also benefit physical functional health and muscle strength.

In agreement with our findings, resent study has been reported a significant correlation between adherence to the MIND diet and HGS ³¹. In our study, among the components of the MIND diet, green leafy vegetable berries, whole grains, fish, and olive were associated with lower risk of poor HGS. Vegetables are rich in inorganic nitrate, and higher dietary nitrate has been associated with better physical function and HGS ³². Moreover, fish intake has been associated with HGS in older men and women ³³, and n-3 fatty acids have been demonstrated beneficial effects on muscle mass and strength ³⁴. Similarly, the higher intake of fruits as a component of the MIND diet had beneficial effects on better HGS, muscle strength, as well as FFM ^{5, 35}.

In our study, green leafy vegetables, other vegetables, berries, whole grains, fish, and olive that are sources of folate, vitamin E, carotenoids, and flavonoids ³⁶, were significant inversely associated with the risk of age related poor HGS. These dietary components have been shown to protect the brain through their anti-inflammatory and antioxidant properties ^{37, 38} and inhibition of b-amyloid deposition ³⁹. In recent years, several studies have discussed the potential role of nutrition, nutritional supplements, and nutrients from foods in skeletal muscle health and age-related muscle loss e.g., ^{40, 41}. However, fewer studies have examined the relationships between plant-based dietary (e.g., fruits and vegetables, grains, olive) ^{42, 43}, and muscle health in older adults ^{44, 45}. Moreover, the associations between bioactive compounds including curcumin, folate, and antioxidant compounds (vitamin E, carotenoids, and flavonoids) as potential factors relevant for muscle ageing are poorly understood ²⁸. Therefore, these novel dietary candidates that acting via some mechanisms including anti-inflammatory, anti-oxidative, and anabolic-promoting functions suggested to prevent age-related muscle loss.

In the present study, plant-based and high protein dietary patterns decreased the risk of poor HGS. Nevertheless, greater adherence to the unhealthy dietary pattern was 1.49 times more at risk of poor HGS. Previous studies has been reported association between high protein intake and skeletal muscle function in the older adults ^{46, 47} that this agrees with our results in current study. Additionally, HGS can be influenced by intake of specific single nutrients including protein ⁴⁸, which may be due to positive

associations between muscle protein synthesis and dietary protein intake ⁴⁹. High protein intake between 1.0–1.2 g/kg/day is appropriate for musculoskeletal health ⁵⁰. Our recent finding has been demonstrated that adherence to the healthy eating index (HEI)-2015 could promote muscle strength ¹². Among the HEI-2015 components, higher intake of fruit and lower adherence to added sugar had dramatically positive effects on HGS ¹².

Adherence to unhealthy dietary patterns such as butter, margarine, red meat and products, fast fried foods, pastries, and sweets leads to the accumulation of free radicals and reactive oxygen and nitrogen species (ROS/NRS) by oxidative stress in several organelles in myofibres ²⁸. Accumulation of ROS/NRS in skeletal muscle leads to impaired cellular homeostasis and damage to key cell macromolecules such as proteins, nucleic acid, and lipids, affecting their structure ⁵¹. A higher intake of beneficial foods in a healthy diet may provide not only adequate energy but also sufficient levels of relevant myo- protective nutrients and bioactive compounds ²⁸. The interaction between the nutrients acting upon the muscle might help to preserve or improve myofibre quality and quantity by counteracting the loss of muscle strength and pathophysiology of sarcopenia ^{51–53}. A diet rich in antioxidants such as vitamins, carotenoids, flavonoids, and minerals ⁴¹ from fruits, green leafy vegetables, berries, whole grains olive oil, and nuts such as the MED diet can help in restoring the redox homeostasis ⁵⁴ in the muscle and counteract reactive ROS/NRS-induced damage ²⁸. Therefore, plant- based diet such as the MED and MIND diets may provide the right combination of antioxidants in the amounts beneficial to redox homeostasis in the myofibrils.

Limitations

This current study was the first on a large sample size to evaluate the relationship between the MIND dietary pattern and age related poor HGS among Kurdish population. However, this study suffered from some limitations. First, this is a cross- sectional study and the cause-and-effect relationship was not clear, therefore, it is not possible to infer that adherence to MIND and high protein diets decreased lower risk of poor HGS or contrariwise. Second, dietary intake was assessed by FFQ, and the error of recalling food intake should not be ignored. However, the questionnaire was presented by trained nutritionists. Nevertheless, our findings need to be confirmed in prospective studies. Therefore, further studies are recommended without these limitations.

Conclusion

To sum up, the results of the present study support that the MIND diet, plant-based, and high protein dietary patterns are associated with protective effects on age related poor HGS. Although the role of MIND pattern has been recently reported in disease prevention, especially in cognitive decline, the present study demonstrated that this pattern diet could be potentially beneficial for the prevention of age related poor HGS and loss of muscle strength (sarcopenia).

Declarations

Compliance with Ethical Standards

Funding: This study was supported by Ministry of Health and Medical Education of Iran and Kermanshah University of Medical Science (Grant No: 92472).

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Written informed consent was obtained from each studied subject after explaining the purpose of the study. The right of subjects to withdraw from the study at any time and subject's information is reserved and will not be published.

Competing interests

The author(s) declare no competing interests.

Availability of data and materials

Data will be available upon request from the corresponding author.

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Authors' contributions: S. Saedi, S. Moradi and Y. Pasdar equally contributed to the conception and design of the research, F. Njafi, B. Hamzeh, and Y. Pasdar contributed to data collection, S. Moradi and F. Najafi contributed to the acquisition and analysis of the data, S. Saedi, and S. Moradi contributed to the interpretation of the data, S. Saedi, and S. Moradi, Y. Pasdar contributed to draft the manuscript. All authors are in agreement with the manuscript and declare that the content has not been published elsewhere.

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Figures

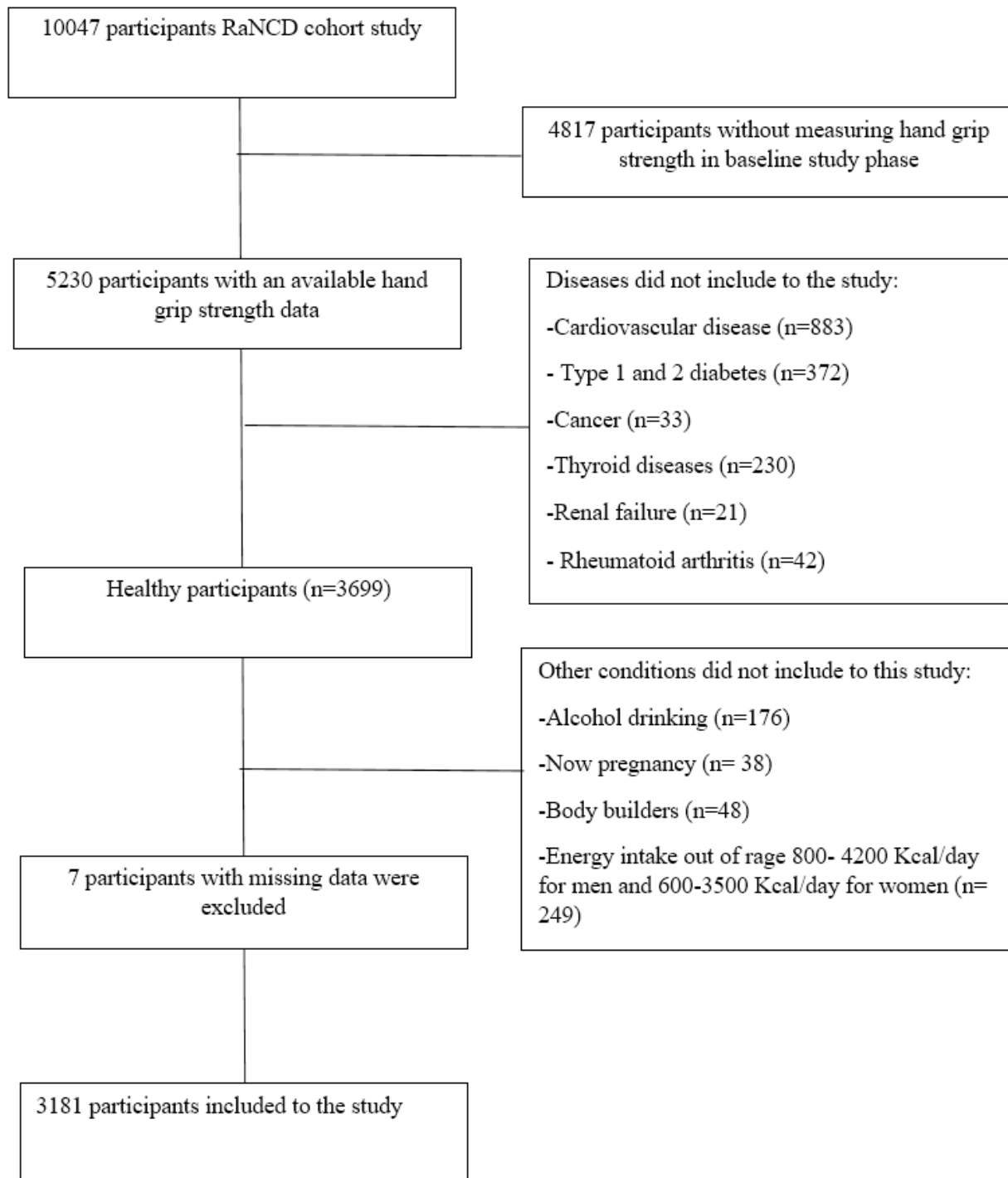


Figure 1

Flow chart of participants selection for this study

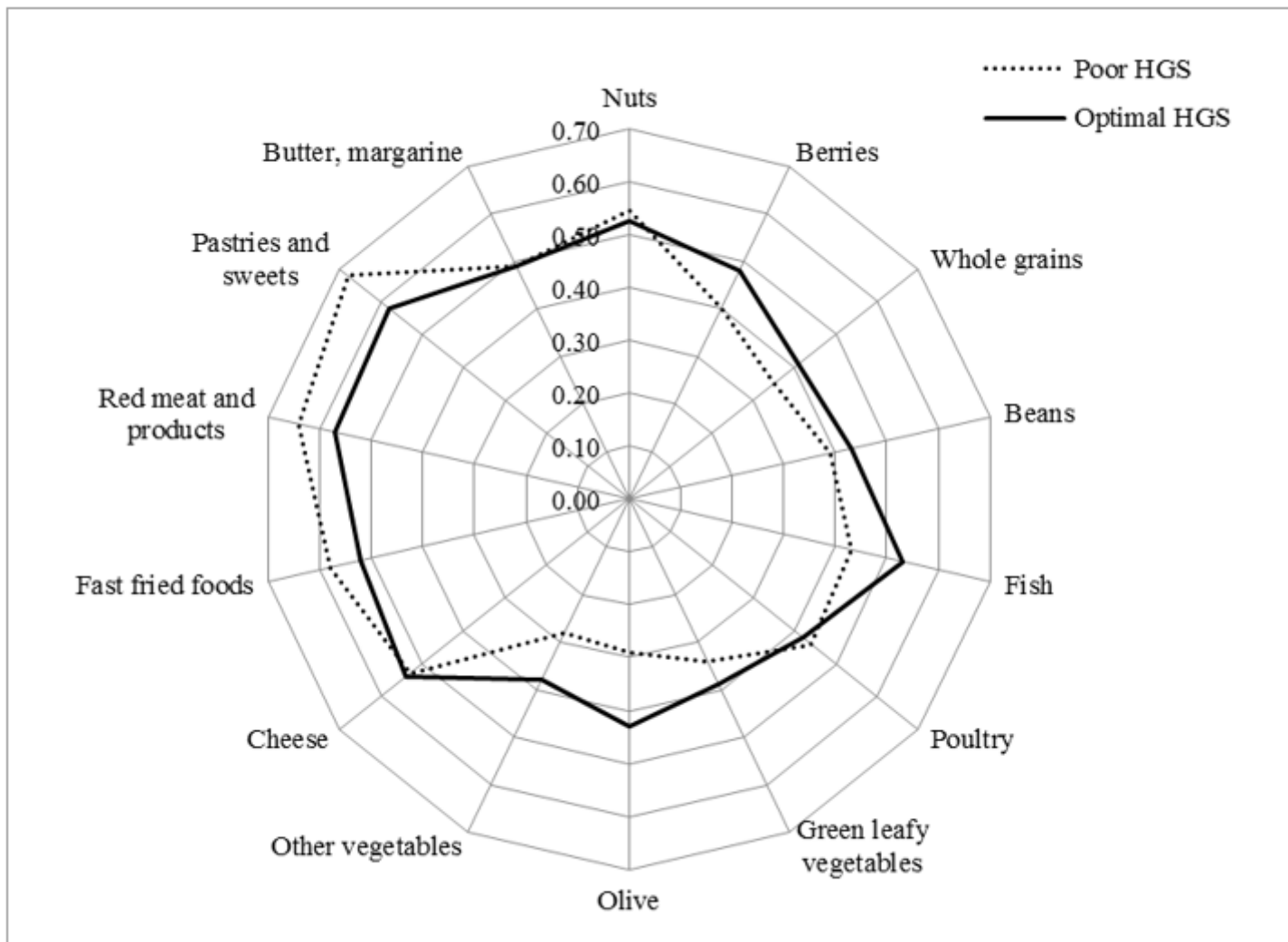


Figure 2

Radar graph for the mean of components of MIND diet in weak and optimal hand grip strength (HGS).