The association between dietary inflammatory index, muscle strength, muscle endurance, and body composition in Iranian adults

Shahinfar, H., Shahavandi, M., Tijani, A. J., Jafari, A., Davarzani, S., Djafarian, K., Clark, C. C. T. & Shab-Bidar, S.

Original citation & hyperlink:
Shahinfar, H, Shahavandi, M, Tijani, AJ, Jafari, A, Davarzani, S, Djafarian, K, Clark, CCT & Shab-Bidar, S 2022, 'The association between dietary inflammatory index, muscle strength, muscle endurance, and body composition in Iranian adults', Eating and Weight Disorders, vol. 27, pp. 463-472.
https://doi.org/10.1007/s40519-020-01096-y

DOI 10.1007/s40519-020-01096-y
ISSN 1124-4909
ESSN 1590-1262

Publisher: Springer

The final publication is available at Springer via http://dx.doi.org/10.1007/s40519-020-01096-y

The association between dietary inflammatory index, muscle strength, muscle endurance, and body composition in Iranian adults

Hossein Shahinfar[1,2], Aliyu Tijani[1], Mahshid Shahavandi[1], Alireza Jafari[1], Kurosh Djafarian[3], Cain C.T. Clark[4], Sakineh Shab-Bidar[1]

[1]Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences (TUMS), Tehran, Iran

[2]Students' Scientific Research Center (SSRC), Tehran University of Medical Sciences (TUMS), Tehran, Iran

[3]Department of Clinical Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences, Tehran, Iran

[4]Centre for Sport, Exercise, and Life Sciences, Coventry University, Coventry, CV15FB, U.K.

Corresponding author

Sakineh Shab-Bidar, Department of Community Nutrition, School of Nutritional Sciences and Dietetics, Tehran University of Medical Sciences (TUMS), Tehran, Iran. No 44, Hojjat-dost Alley, Naderi St., Keshavarz Blvd, Tehran, Iran. Tele:

Tel: +98-21- 88955975

Fax: +98-21- 88974462

E-mail address: s_shabbidar@tums.ac.ir

Keywords: Dietary inflammatory index**;** muscle endurance; muscle strength; body composition; Inflammation

Running title: Dietary inflammatory index and muscle endurance

Abstract

Objectives: To investigate the association between dietary inflammatory index (DII) and muscle strength (MS), muscle endurance (ME), and body composition.

Methods: This cross-sectional study was conducted in 270 middle-aged subjects living in Tehran, Iran. The DII was calculated using a validated semi-quantified food frequency questionnaire. Body composition was measured using body composition analyzer; muscle strength was measured by a digital handgrip dynamometer; socio-economic status, anthropometric measures and blood pressure were also recorded.

Results: A significant decrease was found for MS ($p<0.01$) and MSR ($p<0.01$) across tertiles of DII. Participants who had greater scores of DII also had lower MER ($p<0.01$), even after adjustment for confounding factors ($p<0.02$). Higher DII was significantly related to MSL ($p<0.01$), ME ($p<0.01$), and MEL ($p=0.02$) in the crude model, which disappeared after controlling for covariates. There were no significant differences for FFM, SMM, and WC ($p<0.01$) among tertiles of DII after adjusting for confounding factors.

Conclusions: Higher DII scores were associated with less muscle strength and endurance among Iranian middle-aged adults. Further studies are needed to be conducted to confirm the veracity of our results.

Introduction

Chronic inflammation is associated with several diseases, such as obesity, cardiovascular disease, and insulin resistance (1). Indeed, studies have shown that higher circulating levels of inflammatory markers, such as interleukin (IL)-6 and C-reactive protein (CRP), are correlated with lower muscle mass and strength (MS) (2-6). Moreover, accumulating evidence suggests that higher inflammatory markers are associated with lower muscle mass (7). Modifiable lifestyle factors, such as diet, affect the inflammatory response process; components of diet, such as saturated, trans fatty acid and refined grain, can modify inflammation status to pro-inflammatory, whilst fiber, omega 6 and antioxidant vitamin, can modify inflammation status to anti-inflammatory -inflammatory (8). There are several dietary indices to evaluate quality of diet (9, 10); indeed, the relationship between diet and inflammation can be examined with dietary patterns using the dietary inflammatory index (DII) (11). DII was developed by Cavicchia et al, and updated by Shivappa et al with thirty-six nutrients and nine food items, and can be used to predict inflammatory potential of the diet, including C-reactive protein (CRP), IL-6, and tumor necrosis factor (TNF)-α(9, 12), where higher DII scores indicate higher inflammatory potential (4, 13-15). In one study, it was suggested that DII score is inversely associated with skeletal muscle mass in boys (16). Results of a large study also showed that a pro-inflammatory diet was associated with higher body mass index (BMI) z-score, wrist circumference, waist circumference (WC), hip circumference (HC), and parental BM(17). Moreover, higher serum levels of anti-inflammatory markers are considered to play a protective role on fat free mass (FFM) (18, 19). Given that there is currently no study that has evaluated the association between DII and muscle and anthropometric indices, in an Iranian population, the aim of the present study was to analyze the relationship between DII and muscle endurance, strength, and body composition in middle aged adults in Iran.

Subjects and methods

Study design

This cross-sectional study was conducted on 270 adults (118 males and 152 females), aged between 18-60 years' old, who lived in Tehran, Iran between February 2018 and December 2019. Participants were recruited using local advertisement, distribution of flyers in common rooms, and information sessions held at residential facilities. The participants were selected based on the following inclusion criteria: 1) age range of 18-70 years, 2) no alcohol or drug abuse, 3) participants with special diets, such as weight loss or weight gain diets, adults with chronic diseases including diabetics, hormonal, and cardiovascular diseases, pregnant and lactating women, receiving any special medication or supplements (slimming medicine, hormone, sedative, supplements containing thermogenic substances such as caffeine and green tea, linoleic acid conjugate etc.), were excluded from the study. All necessary explanations about the project were given to the participants and all participants signed a written informed consent prior to the start of the study. All procedures were in accord with the ethical standards of the Tehran University of Medical Sciences TUMS.VCR.REC.1396.4085), who approved the protocol and informed consent form.

Dietary assessment

A validated 147-item food frequency questionnaire was used to assess usual food intake (20). Nutritional information was collected by experienced and trained nutritionist through interviews; where participants reported their intake frequency for each food item during the past year on a daily, weekly, monthly or yearly basis. Portion sizes of consumed foods that were reported in household measures were converted to grams. The food items were analyzed for their energy content using the Nutritionist 4 software, modified for Iranian foods.

Anthropometric measures and body composition

Weight, BMI, WC, skeletal muscle mass, waist-hip ratio, and body composition (including fat free mass (FFM), fat mass (FM), percent body fat (PBF), skeletal muscle mass (SMM), trunk fat (TF), visceral fat level (VFL)) were measured using a body composition analyzer (In Body 720, Bio space, Tokyo, Japan). MS was measured using a digital handgrip dynamometer (Saehan, model SH5003; Saehan Corporation, Masan, South Korea). In a standing position, with their arm hanging normally beside the body and an elbow angle of approximately 180°, participants were asked to squeeze the dynamometer as hard as possible to measure the maximal force for each hand. The procedure was repeated 3 times for each hand, totally, hand grip strength was measured 6 times and the average of three measurements in both hands, including muscle strength of right (MSR) hand and muscle strength of left (MSL) hand was used for data analyses(21). Subjects were then instructed to squeeze the digital handgrip dynamometer as hard as possible and to maintain maximal pressure during the test. Muscle endurance was recorded as the time (in seconds) for grip strength to reach 50% of maximum (22).

Blood pressure

To assess blood pressure, first, we asked participants to sit for 10 min. Blood pressure was then measured using a standard mercury sphygmomanometer, twice with a 5 min interval, while participants were sitting. The mean of the two measurements was recorded as the participant's blood pressure.

Other measurements

Information on lifestyle was collected via self-administered questionnaires included amongst others age, sex, educational level, physical activity, smoking, medical history and current use of medications. Smoking status was divided into current or never smoking. Education level was indicated as the highest level of school achieved and participants were classified into either; under diploma, diploma, or educated.

Physical activity

We used a valid and reliable short form of the International Physical Activity Questionnaire (IPAQ) to assess the level of physical activity. Vigorous physical activity, moderate physical activity, walking, and sitting in the past seven days was recorded using this questionnaire (24). Then, the Metabolic Equivalents (METs) was calculated to estimate total physical activity per week for each participant. Finally, METs were classified as weak (< 600 MET-minutes/week), moderate (600 - 3000 MET-minutes/week), and vigorous (> 3000 MET-minutes/week).

Calculation of DII

Dietary inflammatory weights (12) of 29 nutrients/food items were calculated, and subsequently, these values were summed to indicate DII. First, the daily intake of macro- and micronutrients (carbohydrate, protein, total fat, cholesterol, saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), n-3 fatty acids, n-6 fatty acids, β-carotene, vitamin A, vitamin C, vitamin D, vitamin E, vitamin B6, vitamin B12, fiber, folic acid, niacin, riboflavin, thiamin, iron, zinc, selenium ,magnesium, onion, caffeine) were calculated in order to reduce the between-person variation in dietary intake; some nutrients that were not available in our records (trans FAs, flavan-3-ol, flavones, flavonols, flavonones, anthocyanidins, isoflavones, pepper, thyme/oregano, rosemary, garlic, ginger, saffron, and turmeric and tea) were excluded. Adjusted intake of food parameters for each individual was standardized to its corresponding global mean and standard deviation. The derived Z score values were converted to percentile and centered by doubling the values and subtracting one to normalize the scoring system and to avoid skewness. The centered percentile value for each food parameter was then multiplied by its respective overall food parameter score to obtain the food parameter-specific DII score. Finally, the DII score was determined by summing all of the food parameter-specific DII score. The greater the DII score, the more pro-inflammatory the diet, and more negative scores indicate a more anti-inflammatory diet.

Statistical analysis

Participants were grouped based into tertiles of DII. To compare general characteristics among tertiles, we used one-way ANOVA and chi-square tests for quantitative and qualitative variables, respectively. An analysis of covariance (ANCOVA) test was performed to evaluate the association of DII score with muscle strength and muscle endurance after adjusting for potential confounders. All statistical analysis was performed with the SPSS (Statistical Package for Social Sciences) for Windows 25.0 software package (SPSS, Chicago, IL). The level of statistical significance was defined, *a priori*, at $p < 0.05$.

Results

The demographic and anthropometric characteristics of the participants in the study are detailed in **Table 1**. A total of 270 participants (118 men and 152 women) were included in this study. Participants were, on average, 36.77 ± 13.19 years old (152 women), and mean BMI was 25.62 ± 4.66. A significant decrease was found for blood pressure ($p<0.001$), weight ($p<0.001$), body mass index (BMI) ($p<0.001$), fat free mass (FFM) ($p<0.001$), waist circumference (WC) ($p<0.001$), and waist to hip ratio (WHR) ($p<0.001$) across tertiles of DII.

Dietary intake of participants by tertiles of DII are indicated in **Table 2**. Participants in the highest tertile of DII had less intake of vitamins, macronutrients, and minerals ($p<0.001$). A significant decrease was found for total cholesterol, energy, SFA, PUFA, MUFA, omega 3 and omega 6 across tertiles of DII (p-value<0.001).

Table 3 shows multivariate-adjusted means for muscle strength and endurance (MS, MSL, MSR, ME, MEL and MER) across tertiles of DII. A significant decrease was found for both MS (p-value<0.01) and MSR (p-value<0.01) across tertiles of DII, after adjustment for confounding factors, including age, sex, education status, income, smoking, physical activity, BMI, and energy intake (P_{ANCOVA}<0.01). A significant decrease was also found for MSL (p-value<0.01) and MEL (p-value=0.02) across tertiles of DII, but after adjustment for confounding factors, this result was attenuated (P_{ANCOVA} = 0.08 for MSL and P_{ANCOVA}= 0.4 for MEL).

Multivariate adjusted means for FFM, FM, PBF, SMM, TF, VFL, and WC across tertiles of DII are detailed in **Table 4**. There was a significant decrease in mean of FFM (p<0.001), SMM (p<0.001), and WC (p<0.001) across tertiles of DII. However, after adjustment for confounding factors, no significant associations were observed in anthropometric measures and body composition.

Discussion

To the best of our knowledge, this is the first study conducted to assess the relationship between DII and both muscle strength and endurance among an Iranian population. The present study highlighted that the DII scores, indicating inflammatory diet, were significantly and inversely associated muscle strength, even after all confounding variables were controlled for. When data was analysed by hand strata, the result was similar for right-hand muscle strength, but was not significant for the left-hand muscle strength. We also found that participants in the highest DII tertile had lower FFM, WC, and SMM compared to those in the lowest DII tertile; however, after adjusting for covariance, no significant difference was seen across tertiles.

Consistent with the results of the present study, previous studies among adults or elderly populations have reported positive associations between the DII and muscle strength; for instance, it has reported that DII scores were positively associated with the risk of weight loss, low walking speed, and low grip strength particularly in older individuals with poor nutritional status (25). However, in a study by Amakye and colleagues (2018) among Chinese children aged 6-9 years, no associations were observed between DII and hand grip strength (16). Unlike the present study, the age, muscle mass, and physical activity level of the subjects in the study by Amakye, (2018) may contributing factors for the lack of significant association between the DII and muscle strength. Prior to this, no study, to the authors knowledge, has investigated the association of the DII and muscle endurance. In our study, we found a statistically significant inverse association between the pro-inflammatory capacity of the diet (as measured by the DII) and muscle endurance in the combined sample. However, after adjusting for confounding variables, the result became non-significant. When data were analysed by hand strata, the observed association was still significant for right-hand muscle endurance, even after adjusting for confounders. Changes in fiber composition brought about by consistent overuse associated with side dominance have been suggested as an explanation for differences in neuromuscular endurance features associated with dominant and non-dominant muscles of the hand (26-29). In a study by De Luca and colleges, they reported that the median frequency of the electromyography (EMG) signal decreased faster with sustained activity in the non-dominant first dorsal interosseous of right-handed subjects, whereas non-significant differences were found in left-handed individuals (26). Merletti et al. examined the longissimus dorsi muscle and found a statistically significant effect of hand dominance on fatigue indexes of longissimus dorsi in right hand dominant, but not left hand dominant, subjects. Indeed, these findings are all consistent with a greater type I muscle fiber content in muscles of the dominant compared with non-dominant side (27), and likely explains the discordance between hand strata observed in this study.

Previous studies have shown that muscle endurance, expressed as fatigue resistance or grip work, may be significantly related to circulating markers of inflammation in community-dwelling elderly persons (30), frail elderly nursing home residents (31), hospitalized geriatric patients(32, 33), and patients post abdominal surgery (34). In a cross-sectional study in 686 young healthy men, Vaara and colleagues (2014) found a weak inverse association of muscular endurance with CRP and IL-6 in individuals without abdominal obesity, and a moderate inverse association of muscular endurance with IL-6 in those with abdominal obesity (35). Additional muscle weakness caused by acute inflammatory conditions can lead to a disability at older ages very quickly (36); indeed, hospitalized geriatric patients with inflammation-induced acute infections and elevated circulation levels of IL-6 reported reduced muscle strength and endurance, relative to patients with no inflammation (32). Moreover, Mets et al reported evidence of a negative impact of inflammation on muscle endurance in hospitalized geriatric patients (33).

Higher DII scores, indicating pro-inflammatory diets, have been associated with increased levels of inflammatory cytokines such as interleukin-6 (IL-6) (37, 38), C-reactive protein (CRP) (9, 12, 39), and tumor necrosis factor-alpha (TNF-a) (11). Chronic inflammation contributes to the loss of muscle mass, strength, and functionality, by affecting muscle protein degradation and synthesis through several signalling pathways (40). Indeed, numerous epidemiological studies have attributed poor muscular strength to high levels of inflammatory markers in middle-aged and older individuals (41). In a cross-sectional study, Visser and colleagues reported lower muscle mass and strength to be associated with higher plasma concentrations of IL-6 and TNF-α in 3075 healthy older population (6). Whilst in another cross sectional study by Volaklis *et al*. (2105), in elderly individuals with and without cardiac disease, lower levels of muscular strength were associated with higher concentrations of IL-6 and hs-CRP (41). Ruiz et al found that CRP, complement factor

C 3, and ceruloplasmin levels were negatively associated with muscle strength in Spanish adolescents (42); in addition, Steene-Johannessen et al also reported muscle strength to be independently associated with the CRP in 1306Norwegian children (43).

The strengths of our study include the use of a validated dietary assessment method to generate the DII. The validated Iranian FFQ reflects the study subjects' usual intake over 12 months, which may accurately represent previous long-term dietary intake. The DII, derived after extensive literature reviewing, standardizes individuals' dietary intakes of inflammatory foods to world referent values. Furthermore, this is, to the authors knowledge, the first study conducted to assess the relationship between DII and both muscle strength and endurance among an Iranian population. However, despite numerous strengths, the present study has several limitations. First, the relatively small sample size might have attenuated the strength of, or underestimated, our results. Second, due to our sample size, we were not able to analyze based on gender; indeed, some studies have posited that pro-inflammatory diets may be more detrimental to musculoskeletal health in older men than in women (44). Finally, because of the cross-sectional study design, this study was not able to identify the causal relationship between DII with muscle strength and endurance in the study population.

Conclusion

In conclusion, consumption of a pro-inflammatory diet, as indicated by higher DII scores, is associated with lower muscle strength and endurance among Iranian healthy men and women. These findings support the need for the development of dietary interventions targeting consumption of anti-inflammatory foods in the general population.

References

1. Amor S, Puentes F, Baker D, Van Der Valk P. Inflammation in neurodegenerative diseases. Immunology. 2010;129(2):154-69.
2. Santoro A, Guidarelli G, Ostan R, Giampieri E, Fabbri C, Bertarelli C, et al. Gender-specific association of body composition with inflammatory and adipose-related markers in healthy elderly Europeans from the NU-AGE study. Eur Radiol. 2019;29(9):4968-79.
3. Perna S, Guido D, Grassi M, Rondanelli M. Association between muscle mass and adipo-metabolic profile: a cross-sectional study in older subjects. Clin Interv Aging. 2015;10:499-504.
4. Dutra MT, Avelar BP, Souza VC, Bottaro M, Oliveira RJ, Nobrega OT, et al. Relationship between sarcopenic obesity-related phenotypes and inflammatory markers in postmenopausal women. Clin Physiol Funct Imaging. 2017;37(2):205-10.
5. Schaap LA, Pluijm SM, Deeg DJ, Visser M. Inflammatory markers and loss of muscle mass (sarcopenia) and strength. Am J Med. 2006;119(6):526.e9-17.
6. Visser M, Pahor M, Taaffe DR, Goodpaster BH, Simonsick EM, Newman AB, et al. Relationship of interleukin-6 and tumor necrosis factor-α with muscle mass and muscle strength in elderly men and women: the Health ABC Study. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences. 2002;57(5):M326-M32.
7. Zembron-Lacny A, Dziubek W, Wolny-Rokicka E, Dabrowska G, Wozniewski M. The Relation of Inflammaging With Skeletal Muscle Properties in Elderly Men. American journal of men's health. 2019;13(2):1557988319841934.
8. Kopf JC, Suhr MJ, Clarke J, Eyun S-i, Riethoven J-JM, Ramer-Tait AE, et al. Role of whole grains versus fruits and vegetables in reducing subclinical inflammation and promoting gastrointestinal health in individuals affected by overweight and obesity: a randomized controlled trial. Nutrition journal. 2018;17(1):72.
9. Shivappa N, Steck SE, Hurley TG, Hussey JR, Ma Y, Ockene IS, et al. A population-based dietary inflammatory index predicts levels of C-reactive protein in the Seasonal Variation of Blood Cholesterol Study (SEASONS). Public health nutrition. 2014;17(8):1825-33.
10. Tabung FK, Smith-Warner SA, Chavarro JE, Wu K, Fuchs CS, Hu FB, et al. Development and Validation of an Empirical Dietary Inflammatory Index. J Nutr. 2016;146(8):1560-70.
11. Shivappa N, Hebert JR, Marcos A, Diaz LE, Gomez S, Nova E, et al. Association between dietary inflammatory index and inflammatory markers in the HELENA study. Molecular nutrition & food research. 2017;61(6):1600707.
12. Cavicchia PP, Steck SE, Hurley TG, Hussey JR, Ma Y, Ockene IS, et al. A new dietary inflammatory index predicts interval changes in serum high-sensitivity C-reactive protein. The Journal of nutrition. 2009;139(12):2365-72.
13. Ferreira YAM, Kravchychyn ACP, Vicente SCF, Campos R, Tock L, Oyama LM, et al. An Interdisciplinary Weight Loss Program Improves Body Composition and Metabolic Profile in Adolescents With Obesity: Associations With the Dietary Inflammatory Index. Front Nutr. 2019;6:77.
14. Kendel Jovanovic G, Pavicic Zezelj S, Klobucar Majanovic S, Mrakovcic-Sutic I, Sutic I. Metabolic syndrome and its association with the Dietary Inflammatory Index (DII)((R)) in a Croatian working population. J Hum Nutr Diet. 2019.
15. Pocovi-Gerardino G, Correa-Rodriguez M, Callejas-Rubio JL, Rios-Fernandez R, Martin-Amada M, Cruz-Caparros MG, et al. Dietary Inflammatory Index Score and Cardiovascular Disease Risk Markers in Women with Systemic Lupus Erythematosus. J Acad Nutr Diet. 2019.

16. Amakye WK, Zhang Z, Wei Y, Shivappa N, Hebert JR, Wang J, et al. The relationship between dietary inflammatory index (DII) and muscle mass and strength in Chinese children aged 6-9 years. Asia Pacific journal of clinical nutrition. 2018;27(6):1315.
17. Aslani Z, Qorbani M, Hébert JR, Shivappa N, Motlagh ME, Asayesh H, et al. Association of Dietary Inflammatory Index with anthropometric indices in children and adolescents: the weight disorder survey of the Childhood and Adolescence Surveillance and Prevention of Adult Non-communicable Disease (CASPIAN)-IV study. British Journal of Nutrition. 2019;121(3):340-50.
18. Rossi AP, Budui S, Zoico E, Caliari C, Mazzali G, Fantin F, et al. Role of Anti-Inflammatory Cytokines on Muscle Mass and Performance Changes in Elderly Men and Women. J Frailty Aging. 2017;6(2):65-71.
19. Mueller SM, Herter-Aeberli I, Cepeda-Lopez AC, Fluck M, Jung HH, Toigo M. The effect of body composition and serum inflammatory markers on the functional muscle-bone unit in premenopausal women. Int J Obes (Lond). 2017;41(8):1203-6.
20. Mirmiran P, Esfahani FH, Mehrabi Y, Hedayati M, Azizi F. Reliability and relative validity of an FFQ for nutrients in the Tehran lipid and glucose study. Public health nutrition. 2010;13(5):654-62.
21. Pedrero-Chamizo R, Albers U, Tobaruela JL, Meléndez A, Castillo MJ, González-Gross M. Physical strength is associated with M ini-M ental S tate E xamination scores in S panish institutionalized elderly. Geriatrics & gerontology international. 2013;13(4):1026-34.
22. Bautmans I, Mets T. A fatigue resistance test for elderly persons based on grip strength: reliability and comparison with healthy young subjects. Aging clinical and experimental research. 2005;17(3):217-22.
23. Wareham NJ, Jakes RW, Rennie KL, Schuit J, Mitchell J, Hennings S, et al. Validity and repeatability of a simple index derived from the short physical activity questionnaire used in the European Prospective Investigation into Cancer and Nutrition (EPIC) study. Public health nutrition. 2003;6(4):407-13.
24. Moghaddam MB, Aghdam FB, Jafarabadi MA, Allahverdipour H, Nikookheslat SD, Safarpour S. The Iranian Version of International Physical Activity Questionnaire (IPAQ) in Iran: content and construct validity, factor structure, internal consistency and stability. World applied sciences journal. 2012;18(8):1073-80.
25. Kim D, Park Y. Association between the dietary inflammatory index and risk of frailty in older individuals with poor nutritional status. Nutrients. 2018;10(10):1363.
26. De Luca CJ, Sabbahi MA, Roy SH. Median frequency of the myoelectric signal. European journal of applied physiology and occupational physiology. 1986;55(5):457.
27. Merletti R, De Luca CJ, Sathyan D. Electrically evoked myoelectric signals in back muscles: effect of side dominance. Journal of Applied Physiology. 1994;77(5):2104-14.
28. Tanaka M, McDonagh M, Davies C. A comparison of the mechanical properties of the first dorsal interosseous in the dominant and non-dominant hand. European Journal of Applied Physiology and Occupational Physiology. 1984;53(1):17-20.
29. Zijdewind C, Bosch W, Goessens L, Kandou T, Kernell D. Electromyogram and force during stimulated fatigue tests of muscles in dominant and non-dominant hands. European journal of applied physiology and occupational physiology. 1990;60(2):127-32.
30. Brochu M, Malita MF, Messier V, Doucet E, Strychar I, Lavoie J-M, et al. Resistance training does not contribute to improving the metabolic profile after a 6-month weight loss program in overweight and obese postmenopausal women. The Journal of Clinical Endocrinology & Metabolism. 2009;94(9):3226-33.
31. Bautmans I, Njemini R, Predom H, Lemper JC, Mets T. Muscle Endurance in Elderly Nursing Home Residents Is Related to Fatigue Perception, Mobility, and Circulating Tumor Necrosis Factor-Alpha,

Interleukin-6, and Heat Shock Protein 70: (See editorial comments by Drs. Hermes Florez and Bruce R. Troen, pp 558–560). Journal of the American Geriatrics Society. 2008;56(3):389-96.
32. Bautmans I, Njemini R, Lambert M, Demanet C, Mets T. Circulating acute phase mediators and skeletal muscle performance in hospitalized geriatric patients. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences. 2005;60(3):361-7.
33. Mets T, Bautmans I, Njemini R, Lambert M, Demanet C. The influence of celecoxib on muscle fatigue resistance and mobility in elderly patients with inflammation. The American journal of geriatric pharmacotherapy. 2004;2(4):230-8.
34. Bautmans I, Njemini R, De Backer J, De Waele E, Mets T. Surgery-induced inflammation in relation to age, muscle endurance, and self-perceived fatigue. Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences. 2009;65(3):266-73.
35. Vaara J, Vasankari T, Fogelholm M, Häkkinen K, Santtila M, Kyröläinen H. Maximal strength, muscular endurance and inflammatory biomarkers in young adult men. International journal of sports medicine. 2014;35(14):1229-34.
36. Thomas DR. The relationship between functional status and inflammatory disease in older adults. Oxford University Press; 2003.
37. Tabung FK, Steck SE, Zhang J, Ma Y, Liese AD, Agalliu I, et al. Construct validation of the dietary inflammatory index among postmenopausal women. Annals of epidemiology. 2015;25(6):398-405.
38. Shivappa N, Hébert JR, Rietzschel ER, De Buyzere ML, Langlois M, Debruyne E, et al. Associations between dietary inflammatory index and inflammatory markers in the Asklepios Study. British Journal of Nutrition. 2015;113(4):665-71.
39. Na W, Kim M, Sohn C. Dietary inflammatory index and its relationship with high-sensitivity C-reactive protein in Korean: Data from the health examinee cohort. Journal of clinical biochemistry and nutrition. 2018;62(1):83-8.
40. Wang J, Leung K-S, Chow SK-H, Cheung W-H. Inflammation and age-associated skeletal muscle deterioration (sarcopaenia). Journal of orthopaedic translation. 2017;10:94-101.
41. Volaklis K, Halle M, Koenig W, Oberhoffer R, Grill E, Peters A, et al. Association between muscular strength and inflammatory markers among elderly persons with cardiac disease: results from the KORA-Age study. Clinical Research in Cardiology. 2015;104(11):982-9.
42. Ruiz JR, Ortega FB, Wärnberg J, Moreno LA, Carrero JJ, Gonzalez-Gross M, et al. Inflammatory proteins and muscle strength in adolescents: the Avena study. Archives of pediatrics & adolescent medicine. 2008;162(5):462-8.
43. Steene-Johannessen J, Kolle E, Andersen LB, Anderssen SA. Adiposity, aerobic fitness, muscle fitness, and markers of inflammation in children. 2013.
44. Cervo MM, Shivappa N, Hebert JR, Oddy WH, Winzenberg T, Balogun S, et al. Longitudinal associations between dietary inflammatory index and musculoskeletal health in community-dwelling older adults. Clinical Nutrition. 2019.