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Physical activity and metabolic syndrome severity among older adults at cardiovascular risk: 1-Year trends

Laura Gallardo-Alfaro [a,b,c], Maria del Mar Bibiloni [a,b,c], Cristina Bouzas [a,b,c], Catalina M. Mascaró [a,b,c], Miguel Ángel Martínez-González [a,d,e], Jordi Salas-Salvadó [a,f], Dolores Corella [a,g], Helmut Schröder [h,i], J. Alfredo Martínez [a,j,k], Ángel M. Alonso-Gómez [a,l], Julia Wärnberg [a,m], Jesús Vioque [i,n], Dora Romaguera [a,c], José Lopez-Miranda [a,o], Ramon Estruch [a,p], Francisco J. Tinahones [a,q], José Lapetra [a,r], Luís Serra-Majem [a,s], Aurora Bueno-Cavanillas [i,t], Rafael M. Micó [u,v], Xavier Pintó [a,w], José J. Gaforio [i,x], María Ortíz-Ramos [y], Andreu Altés-Boronat [z], Bogdana L. Luca [aa], Lidia Daimiel [ab], Emilio Ros [a,ac], Carmen Sayon-Orea [d,ad], Nerea Becerra-Tomás [a,f], Ignacio Manuel Gimenez-Alba [a,g], Olga Castañer [a,h], Itziar Abete [a,k], Lucas Tojal-Sierra [a,l], Jéssica Pérez-López [a,m], Laura Torres-Collado [n], Antoni Colom [a,c], Antonio Garcia-Rios [a,o], Sara Castro-Barquero [a,p], Rosa Bernal [a,q], José Manuel Santos-Lozano [a,r], Cesar I. Fernandez-Lazaro [d], Pablo Hernández-Alonso [a,f], Carmen Saiz [a,g], Maria Dolors Zomeño [a,h], Maria Angeles Zulet [a,k], Maria C. Belló-Mora [a,l], F. Javier Basterra-Gortari [d,ad], Silvia Canudas [a,f], Albert Goday [a,h], Josep A. Tur [a,b,c,*] on behalf of the PREDIMED-Plus investigators

[a] *CIBER Fisiopatología de la Obesidad y Nutrición (CIBEROBN), Instituto de Salud Carlos III (ISCIII), 28029 Madrid, Spain*
[b] *Research Group on Community Nutrition & Oxidative Stress, University of Balearic Islands, 07122 Palma de Mallorca, Spain*
[c] *Health Research Institute of the Balearic Islands (IdISBa), 07120 Palma de Mallorca, Spain*
[d] *University of Navarra, Department of Preventive Medicine and Public Health, IDISNA, 31008 Pamplona, Spain*
[e] *Department of Nutrition, Harvard T. H. Chan School of Public Health, Boston, USA*
[f] *Human Nutrition Unit, Biochemistry and Biotechnology Department, IISPV, Hospital Universitari de Sant Joan. Universitat Rovira I Virgili, 43201 Reus, Spain*
[g] *Department of Preventive Medicine, University of Valencia, 46100 Valencia, Spain*
[h] *Unit of Cardiovascular Risk and Nutrition, Institut Hospital del Mar de Investigaciones Médicas Municipal d'Investigació Mèdica (IMIM), 08003 Barcelona, Spain*
[i] *CIBER Epidemiología y Salud Pública (CIBERESP), Instituto de Salud Carlos III (ISCIII), 28029 Madrid, Spain*
[j] *Cardiometabolics Nutrition Program, IMDEA Food, CEI UAM + CSIC, 28049 Madrid, Spain*
[k] *Department of Nutrition, Food Sciences, and Physiology, Center for Nutrition Research, University of Navarra, 31008 Pamplona, Spain*
[l] *Bioaraba Health Research Institute, Osakidetza Basque Health Service, Araba University Hospital, University of the Basque Country UPV/EHU, 48013 Vitoria-Gasteiz, Spain*
[m] *Department of Nursing, School of Health Sciences, University of Málaga-IBIMA, 29071 Málaga, Spain*
[n] *Miguel Hernández University, Instituto de Investigación Sanitaria y Biomédica de Alicante, ISABIAL-UMH, 46020 Alicante, Spain*
[o] *Lipids and Atherosclerosis Unit, Department of Internal Medicine, Maimonides Biomedical Research Institute of Cordoba (IMIBIC), Reina Sofia University Hospital, University of Cordoba, 14004 Córdoba, Spain*
[p] *Department of Internal Medicine, IDIBAPS, Hospital Clinic, University of Barcelona, 08036 Barcelona, Spain*
[q] *Virgen de la Victoria Hospital, Department of Endocrinology, University of Málaga, 29010 Málaga, Spain*
[r] *Department of Family Medicine, Research Unit, Distrito Sanitario Atención Primaria Sevilla, 41013 Sevilla, Spain*

Abbreviations: ANOVA, analysis of variance; BDI-II, Beck Depression Inventory-II; BMI, body mass index; BP, blood pressure; CHD, coronary heart disease; CRP, C-Reactive Protein; CVD, cardiovascular disease; DBP, diastolic blood pressure; DII, dietary inflammatory index; FA, fatty acid; FFQ, food frequency questionnaire; HDL-c, high-density lipoprotein cholesterol; HR, heart rate; IQR, interquartile range; LDL-c, low-density lipoprotein cholesterol; MD, Mediterranean diet; MetS, metabolic syndrome; MetSSS, metabolic syndrome severity score; MUFA, monounsaturated fatty acid; PREDIMED, PREvención con DIeta MEDiterránea; PA, physical activity; PI, physical inactivity; PUFA, polyunsaturated fatty acids; RAPA, Rapid Assessment of Physical Activity Questionnaires; SBP, systolic blood pressure; SD, standard deviation; SFA, saturated fatty acids; TFA, trans fatty acid; TG, triglycerides; T2DM, type 2 diabetes mellitus; VAI, visceral adiposity index; WC, waist circumference; ω-3 FA, omega-3 fatty acids.

* Corresponding author. Research Group on Community Nutrition and Oxidative Stress, University of the Balearic Islands, IDISBA& CIBEROBN, Guillem Colom Bldg, Campus E-07122 Palma de Mallorca, Spain. Fax: +34 971 173184.
E-mail address: pep.tur@uib.es (J.A. Tur).

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[s] Institute for Biomedical Research, University of Las Palmas de Gran Canaria, 35016 Las Palmas, Spain
[t] Department of Preventive Medicine, University of Granada, 18071 Granada, Spain
[u] CIBER Diabetes y enfermedades metabólicas (CIBERDEM), Instituto de Salud Carlos III (ISCIII), 28029 Madrid, Spain
[v] Institute of Biomedicine (IBIOMED), University of León, 24071 Leon, Spain
[w] Lipids and Vascular Risk Unit, Internal Medicine, Hospital Universitario de Bellvitge, Hospitalet de Llobregat, 08907 Barcelona, Spain
[x] Department of Health Sciences, Center for Advanced Studies in Olive Grove and Olive Oils, University of Jaen, 23071 Jaen, Spain
[y] Department of Endocrinology and Nutrition, Instituto de Investigación Sanitaria San Carlos (IdISSC), 28040 Madrid, Spain
[z] Department of Endocrinology, IDIBAPS, Hospital Clinic, University of Barcelona, 08036 Barcelona, Spain
[aa] Department of Endocrinology, Fundación Jiménez-Díaz, 28040 Madrid, Spain
[ab] Nutritional Control of the Epigenome Group, Precision Nutrition and Obesity Program.IMDEA Food, CEI UAM + CSIC, 28049 Madrid, Spain
[ac] Lipid Clinic, Department of Endocrinology and Nutrition, Institut d'Investigacions Biomèdiques August Pi Sunyer (IDIBAPS), Hospital Clínic, 08036 Barcelona, Spain
[ad] Servicio Navarro de Salud, Osasunbidea, 31003, Pamplona, Spain

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Sedentary behavior;
Dietary inflammatory index

Abstract *Background and aims:* Modifiable lifestyle factors, such as physical activity (PA) and Mediterranean diet (MD), decrease metabolic syndrome (MetS). The aim was to assess 1-year changes of leisure-time physical activity (LTPA), sedentary behavior, and diet quality according to MetS severity in older population at high cardiovascular risk.
Methods and results: Prospective analysis of 55–75-year-old 4359 overweight/obese participants with MetS (PREDIMED-Plus trial) categorized in tertiles according to 1-year changes of a validated MetS severity score (MetSSS). Anthropometrics, visceral adiposity index, triglycerides and glucose index, dietary nutrient intake, biochemical marker levels, dietary inflammatory index, and depression symptoms were measured. Diet quality was assessed by 17-item MD questionnaire. PAs were self-reported using the Minnesota-REGICOR Short Physical Activity Questionnaire and 30-s chair stand test. Sedentary behaviors were measured using the Spanish version of the Nurses' Health Study questionnaire. After 1-year follow-up, decreasing MetSSS was associated with an anti-inflammatory dietary pattern, high intake of vegetables, fruits, legumes, nuts, whole grain cereals, white fish, and bluefish and low intake of refined cereals, red and processed meat, cookies/sweets, and snacks/ready-to-eat-meals. It resulted in high intake of polyunsaturated fatty acids, omega-3 fatty acids, protein, fiber, vitamins B1, B6, B9, C, D, potassium, magnesium, and phosphorus and low glycemic index and saturated fatty acid, trans fatty acid, and carbohydrates intake. Regarding PA and sedentary behavior, decreasing MetSSS was associated with increased moderate-to-vigorous LTPA, chair stand test, and decreased sedentary and TV-viewing time.
Conclusion: Decreasing MetSSS was associated with an anti-inflammatory dietary pattern, high LTPA, high MD adherence, low sedentary time, and low depression risk.

Introduction

The metabolic syndrome (MetS) is a cluster of risk factors, including hyperglycemia, high blood pressure (BP), dyslipidemia, and abdominal obesity, which place a subject at risk of developing cardiovascular disease (CVD) and type-2 diabetes mellitus (T2DM) [1]. MetS is a worldwide epidemic due to its high prevalence among adult population, which is worldwide estimated to be around 20–25%. It shows an increased prevalence in advanced ages, which relates largely to increasing obesity, sedentary lifestyles, inadequate nutrition and ageing of the population [2].

Evidence shows that physical activity (PA) has an important impact on cardiometabolic diseases, reducing the risk of MetS [3,5]. PA and sedentary behavior are major modifiable CVD risk factors, with an association between sedentary behavior and CVD morbidity and mortality [4]. Exercise programs have been demonstrated to improve risk markers and in some individuals to an extent that they no longer meet the criteria for MetS. Exercise has an impact on insulin resistance, adipose fuel metabolism, inflammation, and epigenetic factors. Additionally, it decreases weight, BP, and improves insulin resistance and lipid disorders, including increasing high-density lipoprotein cholesterol (HDL-c) and lowering triglycerides (TG) [3,5].

Unhealthy nutrition habits have appeared together with the onset of the inactive lifestyle, and both are two important risk factors that increase MetS and obesity [6]. Dietary patterns may play important role in the prevention and treatment of MetS, being the Mediterranean diet (MD) capable to reduce its prevalence and enhancing its

reversion [7]. Nutrients found in MD have anti-obesity, anti-cancer, and anti-inflammatory properties, mostly due to the combination of fiber, polyunsaturated fats, and antioxidant elements [8]. MD decreases the prevalence and mortality of CVD, including coronary heart disease (CHD), myocardial infarction, and stroke [9]. People with MetS commonly showed a prothrombotic and pro-inflammatory state [2]. Accordingly, a pro-inflammatory dietary pattern has been associated with increased all cause-mortality [10,11] and CVD [11].

Therefore, evidence shows that sedentary lifestyle, depression, and unhealthy dietary pattern are among the most significant factors for the development of MetS [12]. Moreover, MetS has been bidirectionally associated with depression, which has been linked to central obesity, chronic inflammation, and insulin resistance [13].

Changes in MetS over time, as well as severity of MetS, were difficult to monitor due to the binary nature of MetS (presence/absence). Certain components may be associated with MetS [14], and the cumulative risk derived from the presence of different MetS factors has been quantified by the severity score (MetSSS) [15]. There is a lack of studies focused on changes in the severity of MetS in older population. Lately, our research group showed that the highest MetSSS was associated with lower moderate and vigorous leisure-time physical activity (LTPA) and higher sedentary time and depression risk, as they tended to a pro-inflammatory dietary pattern and lower MD adherence [16]. However, this last study was cross-sectional and then unable to elucidate a casual relationship between MetS and lifestyle factors. This current study aimed to assess 1-year trend in LTPA, sedentary behavior, and diet quality according to MetS severity in older population at high cardiovascular risk.

Methods

Study design

The present study is a 1-year longitudinal analysis within the frame of the PREDIMED-Plus trial, an ongoing 6-year multicenter, parallel-group, randomized trial conducted in Spain. The aim of this study is to assess the effect of an intensive weight loss intervention program based on an energy-restricted traditional MD, PA, and behavioral support on CVD morbidity–mortality, compared with a usual care intervention, consisting exclusively on an energy-unrestricted traditional MD (control group). The PREDIMED-Plus study protocol can be found elsewhere [17] and at http://predimedplus.com/. The trial was registered in 2014 at the International Standard Randomized Controlled Trial (ISRCT; http://www.isrctn.com/ISRCTN89898870) with number 89898870.

Participants, recruitment, randomization, and ethics

Participants were community-dwelling adults (55–75-year-old men and 60–75-year-old women), without CVD history at enrolment, who were overweight or obese (body mass index [BMI] $\geq$27 and $<$ 40 kg/m^2) and meeting $\geq$3 criteria for the MetS according to the International Diabetes Federation and the American Heart Association and National Heart, Lung and Blood Institute definition [1].

A total of 9677 people was contacted, of which 6874 participants were recruited and randomized from September 5, 2013 to December 31, 2016 in 23 Spanish centers (universities, hospitals, and research institutes). However, the present analysis included 4359 subjects (2046 women; Fig. 1). Participants who did not respond to all PA questionnaires (n = 445) and participants reporting outliers for total PA (n = 613) expressed as metabolic equivalents of task [METs·min/week (at 3 or more standard deviations (SDs) from the mean for each sex)] were excluded. Participants recording extreme total energy intakes ($<$500 or $>$3500 kcal/day in women or $<$800 or $>$4000 kcal/day in men) or participants without information from food frequency questionnaire (FFQ; n = 455), and those without total information on cardiovascular risk factors along 1 year (n = 1002) were also excluded.

The study protocol was approved by the Ethical Committees of all participating institutions and followed the ethical standards of the Declaration of Helsinki. Written informed consent was obtained from all participants.

Anthropometric and blood pressure measurements

Weight and height were measured by registered dieticians with calibrated scales and a wall-mounted stadiometer, respectively. BMI was calculated as weight in kilograms divided by the square of height in meters. Waist circumference (WC) was measured halfway between the last rib and the iliac crest by using an anthropometric tape. BP and heart rate (HR) were measured in triplicate with a validated semi-automatic oscillometer (Omron HEM-705CP, Lake Forest, IL, USA) after 5 min of rest in-between measurements while the participant was in a seated position. All anthropometric variables were determined in duplicate, except for BP and HR (in triplicate).

Blood collection analysis

Blood samples were collected after an overnight fasting and measurements of glucose, glycated hemoglobin (HbA1c), total cholesterol, HDL-c, and TG concentrations were performed in local laboratories using standard enzymatic methods, whereas low-density lipoprotein cholesterol (LDL-c) was calculated by the Friedewald formula.

Additional health outcomes

Socioeconomic and lifestyle aspects (education level, civil status, smoking habits, sleeping time, individual and family medical history, and current medication use) were collected. Depressive symptoms were measured through the Beck Depression Inventory-II (BDI-II) validated in Spain. The BDI-II includes 21 questions with four possible answers sorted according to depressive symptom severity

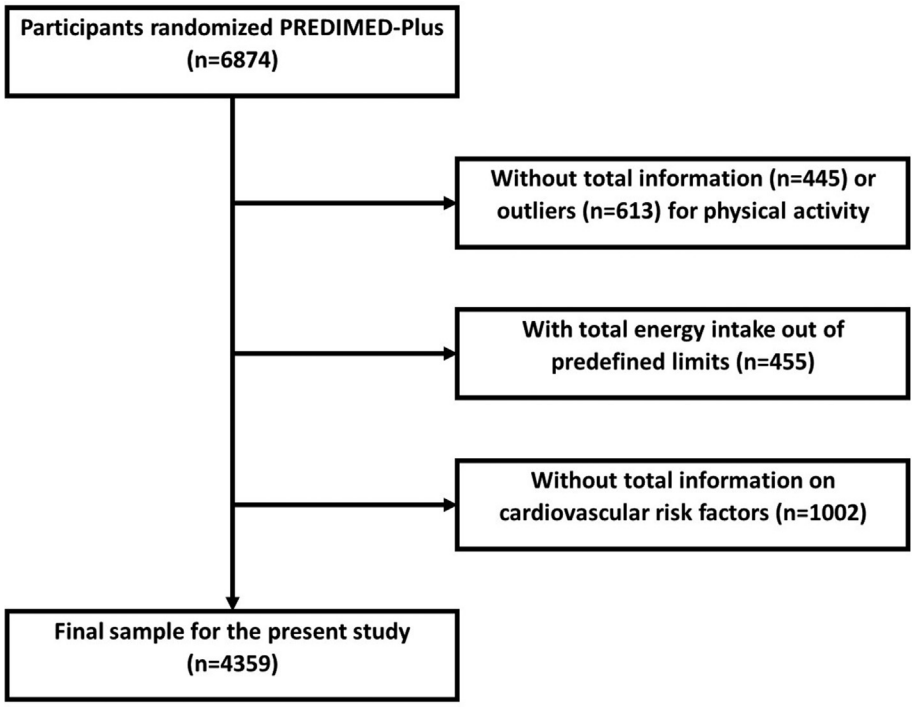

Figure 1 Flow chart of participants.

and score ranges from 0 to 63 points [18]. Participants reported their average daily sleeping time using the non-validated open question "How many hours do you sleep on average per day on weekdays and weekends?"

Visceral adiposity and T&G index

The visceral adiposity index (VAI) [16,19] assesses visceral adiposity according to previously validated and published equations. VAI was calculated assuming VAI = 1 for healthy non-obese subjects with normal adipose distribution and normal TG and HDL-c levels.

The triglycerides and glucose index (T&G index) is a simple measure of insulin resistance with high sensitivity and specificity. It is calculated according to a previously validated equation [20]: Ln[fasting TG (mg/dL) × fasting glucose (mg/dL)/2]. The T&G index is expressed by a logarithmic scale.

Physical activity and sedentary behavior

LTPA was measured using the Rapid Assessment of Physical Activity Questionnaires (RAPA-1 and RAPA-2) [21] and the validated Minnesota-REGICOR (Registre Gironí del Cor) Short Physical Activity questionnaire [22], including questions to collect information the type of activity, frequency (number of days) and duration (min/day). METs were calculated by multiplying the intensity (showed by the MET score) and the duration spent on that activity (measured in minutes). The intensity was assigned based on the compendium of PA [23] and activities were categorized in three groups: light PA $<$4.0 MET, moderate PA 4.0−5.9 MET, and vigorous PA $\geq$6.0 MET.

The 30-s chair stand test was used as an indicator of the lower-limb muscle strength, and it is based on the number of times that participants stand and sit in a chair in 30 s [24].

Sedentary behaviors were measured using the validated Spanish version of the Nurses' Health Study questionnaire [25], which allowed to assess the average daily time spent over the last year in watching TV, sitting while using computer, sitting on journeys, and total sitting. Answers included 12 categories ranging from 0 to $\geq$9 h/day of sitting time for the corresponding activity.

Dietary assessment

A semi-quantitative 143-item FFQ was used to assess dietary habits over the previous 12 months. Detailed information about the development, reproducibility, and validity of FFQ in the PREDIMED cohort has been previously reported [16,26]. Energy and nutrient intake were calculated using a computer program based on available information in food composition tables [27]. The average intake of micronutrients from dietary supplements declared by participants in the FFQ was also considered.

Assessment of mediterranean diet adherence

A validated and previously published 17-item energy-restricted MD questionnaire was used to assess MD adherence [16,17]. The total score range was 0−17, with

0 meaning no adherence and 17 meaning maximum adherence.

Dietary inflammatory index

The previously described dietary inflammatory index (DII) [16,28] was used to calculate the inflammatory potential of a diet. The DII is based on dietary intake derived from the FFQ, excluding 15 food parameters that could not be measured with the FFQ used in the PREDIMED-Plus trial. The food parameters obtained a positive score according if its effect was pro-inflammatory, a negative score if its effect was anti-inflammatory, and 0 if no significant change in inflammatory biomarkers was found, and these values were converted to a percentile score, each percentile was doubled, and then 1 was subtracted to achieve a symmetrical distribution (from −1 to +1 and centered on 0), and each one of these values was multiplied by the overall food parameter-specific inflammatory score. The sum of all the food parameter-specific DII scores provided the overall DII score for everyone. Positive DII scores represent a pro-inflammatory diet and negative DII scores represent an anti-inflammatory diet.

Metabolic syndrome severity score

The MetSSS was calculated as previously described [15] for baseline and 1-year data. Similarity in scores across sex, age, and medication subgroups, confirms the validity of using this standard, robust, and generalizable formula, being recommended to measure change within individuals. A MetSSS value of zero indicates that subjects were at or below threshold for all MetS risk factors (WC, TG, HDL-c, systolic blood pressure (SBP), diastolic blood pressure (DBP), and glucose). MetSSS changes after 1-year follow-up were assessed as the difference between baseline and 1-year MetSSS values and categorized by tertiles. The first tertile (T1) represents the sample with the greatest decrease in MetSSS after 1 year, having the lowest severity of risk factors for cardio-metabolic disease. The third tertile (T3) represents the sample with higher increased MetSSS, having the highest severity of

Table 1 Baseline characteristics of participants according to tertiles of 1-year change in MetSSS.

	Tertile 1 Δ = −1.7 ± 0.8 (n = 1453)	Tertile 2 Δ = −0.4 ± 0.2 (n = 1453)	Tertile 3 Δ = 0.8 ± 0.8 (n = 1453)	*P-value*
Women, n (%)	612 (42.1)	462 (52.4)	672 (46.2)	<0.001
Age, years	64.7 ± 5.0[a]	65.5 ± 4.8[a,c]	65.0 ± 5.0[c]	<0.001
Prevalence of obesity, n (%)	1045 (71.9)	1100 (75.7)	1031 (71.0)	0.010
Education level, n (%)				0.531
Illiterate or primary education	691 (48.0)	730 (50.7)	715 (49.7)	
Secondary education	437 (30.3)	401 (27.9)	405 (28.1)	
Academic or graduate	312 (21.7)	308 (21.4)	319 (21.2)	
Smoking habit, n (%)				0.114
Never smoked	654 (45.2)	662 (45.7)	598 (41.3)	
Former smoker	614 (42.4)	622 (43.0)	662 (45.7)	
Current smoker	179 (12.4)	164 (11.3)	187 (12.9)	
Married status				0.546
Single or divorced	171 (11.8)	184 (12.7)	189 (13.1)	
Married	1143 (78.8)	1111 (76.6)	1104 (76.5)	
Widow	136 (9.4)	155 (10.7)	151 (10.5)	
Employment status, n (%)				0.419
Working	311 (21.6)	284 (19.6)	284 (19.7)	
Non-working	324 (22.5)	310 (21.4)	306 (21.3)	
Retired	805 (55.9)	852 (58.9)	850 (59.0)	
MetS components, n (%)				
High BP	1342 (92.4)	1327 (91.3)	1340 (92.2)	0.539
Hyperglycemia	1099 (75.6)	1080 (74.3)	1109 (76.3)	0.447
Hypertriglyceridemia	847 (58.3)	787 (54.2)	846 (58.2)	0.036
Low HDL-cholesterol	600 (41.3)	623 (42.9)	632 (43.5)	0.465
Abdominal obesity	1385 (95.3)	1409 (97.0)	1392 (95.8)	0.064
Medication				
Antihypertensive agents	1112 (76.5)	1124 (77.4)	1154 (79.4)	0.155
Lipid-lowering drugs	766 (52.7)	704 (48.5)	781 (53.8)	0.010
Insulin	68 (4.7)	47 (3.2)	82 (5.6)	0.007
Oral hypoglycemic agents	406 (27.9)	289 (19.9)	420 (28.9)	<0.001
Aspirin or antiplatelet drugs	218 (15.0)	196 (13.5)	224 (15.4)	0.358

Data presented as mean ± SD unless otherwise indicated. Abbreviations: BP: blood pressure; BMI: body mass index; HDL: high-density lipoprotein. Differences in means between tertiles of 1-year change were tested by 1-factor ANOVA with Bonferroni as a post-hoc correction. Differences in percentages were tested by chi-squared test. Different letters in rows (a and c) show significant difference between groups by the Bonferroni post-hoc test ($P < 0.05$).

Table 2 Cardiovascular risk factors and depression according to tertiles of 1-year change in MetSSS.

		Tertile 1 Δ = −1.7 ± 0.8 (n = 1453)	Tertile 2 Δ = −0.4 ± 0.2 (n = 1453)	Tertile 3 Δ = 0.8 ± 0.8 (n = 1453)	Repeated measures ANCOVA‡	*P* value for differences§		
		Mean ± SD	Mean ± SD	Mean ± SD	Time*Group	T1 vs. T2	T1 vs. T3	T2 vs. T3
Weight, kg	Baseline	86.8 ± 13.0	86.1 ± 12.9	86.4 ± 12.8	<0.001	<0.001	<0.001	<0.001
	1 year	82.0 ± 12.6[a,b]	83.9 ± 12.9[a,c]	86.3 ± 13.3[b,c]				
	Δ	−4.8 ± 4.4*[d,e]	−2.2 ± 3.1*[d,f]	−0.3 ± 3.4*[e,f]				
BMI, kg/m^2	Baseline	32.4 ± 3.4	32.6 ± 3.4[c]	32.3 ± 3.4[c]	<0.001	<0.001	<0.001	<0.001
	1 year	30.7 ± 3.5[a,b]	31.8 ± 3.5[a,c]	32.2 ± 3.6[b,c]				
	Δ	−1.7 ± 1.7*[d,e]	−0.8 ± 1.2*[d,f]	−0.1 ± 1.3*[e,f]				
WC, cm	Baseline	108.1 ± 9.4[b]	107.9 ± 9.5[c]	106.6 ± 9.4[b,c]	<0.001	<0.001	<0.001	<0.001
	1 year	102.0 ± 9.2[a,b]	105.1 ± 9.7[a,c]	106.9 ± 10.1[b,c]				
	Δ	−6.0 ± 5.3*[d,e]	−2.8 ± 3.4*[d,f]	0.3 ± 4.5*[e,f]				
Glucose, mg/dL	Baseline	118.7 ± 33.2[a,b]	110.3 ± 27.0[a]	111.1 ± 23.9[b]	<0.001	<0.001	<0.001	<0.001
	1 year	106.0 ± 21.3[b]	107.8 ± 22.4[c]	118.9 ± 35.4[b,c]				
	Δ	−12.7 ± 23.7*[d,e]	−2.5 ± 12.8*[d,f]	7.7 ± 22.6*[e,f]				
HbA1c (%)	Baseline	6.2 ± 1.0[a,b]	6.0 ± 0.8[a,c]	6.1 ± 0.8[b,c]	<0.001	<0.001	<0.001	<0.001
	1 year	6.0 ± 0.7[b]	6.0 ± 0.7[c]	6.2 ± 0.9[b,c]				
	Δ	−0.3 ± 0.6*[d,e]	−0.1 ± 0.4*[d,f]	0.1 ± 0.6*[e,f]				
Total cholesterol, mg/dL	Baseline	196.9 ± 37.7[b]	198.3 ± 37.6[c]	193.2 ± 36.9[b,c]	<0.001	0.001	<0.001	1.000
	1 year	191.6 ± 36.3[a]	197.1 ± 37.6[a]	193.7 ± 37.8				
	Δ	−5.3 ± 31.5*[d,e]	−1.2 ± 31.0[d]	0.6 ± 31.5[e]				
HDL-cholesterol, mg/dL	Baseline	47.4 ± 12.4	48.6 ± 12.1	47.8 ± 11.7	<0.001	<0.001	<0.001	0.005
	1 year	50.3 ± 12.1[a,b]	49.8 ± 12.1[a,c]	48.2 ± 12.2[b,c]				
	Δ	2.9 ± 8.0*[d,e]	1.2 ± 7.6*[d,f]	0.5 ± 6.9*[e,f]				
LDL-cholesterol, mg/dL	Baseline	120.8 ± 47.5	122.0 ± 33.5[c]	118.3 ± 37.2[c]	0.081	0.008	1.000	0.009
	1 year	116.5 ± 33.6[a]	121.2 ± 36.6[a,c]	115.8 ± 35.3[c]				
	Δ	−3.9 ± 46.5*	−0.6 ± 33.8	−2.0 ± 30.7				
TG, mg/dL	Baseline	163.9 ± 95.8[a,b]	144.8 ± 64.3[a]	144.6 ± 64.0[b]	<0.001	<0.001	<0.001	<0.001
	1 year	131.2 ± 59.1[a,b]	137.8 ± 59.9[a,c]	161.4 ± 93.0[b,c]				
	Δ	−32.2 ± 76.5*[d,e]	−7.1 ± 46.6*[d,f]	16.2 ± 73.4*[e,f]				
SBP, mmHg	Baseline	141.7 ± 18.3[a,b]	137.0 ± 16.1[a]	138.2 ± 16.2[b]	<0.001	<0.001	<0.001	<0.001
	1 year	134.2 ± 14.3[b]	134.0 ± 15.0[c]	141.6 ± 18.5[b,c]				
	Δ	−7.4 ± 16.1*[d,e]	−2.9 ± 14.9*[d,f]	3.4 ± 16.9*[e,f]				
DBP, mmHg	Baseline	83.1 ± 10.2[a,b]	80.9 ± 9.3[a]	81.3 ± 9.5[b]	<0.001	0.149	<0.001	<0.001
	1 year	77.6 ± 9.1[b]	76.8 ± 9.0[c]	80.8 ± 10.5[b,c]				
	Δ	−5.6 ± 9.5*[d,e]	−4.1 ± 9.0*[d,f]	−0.5 ± 10.1[e,f]				
HR, bpm	Baseline	70.8 ± 10.9[a]	69.6 ± 10.2[a]	70.1 ± 11.1	<0.001	<0.001	<0.001	0.003
	1 year	67.8 ± 10.7[b]	68.1 ± 10.3[c]	69.4 ± 11.3[b,c]				
	Δ	−3.0 ± 9.0*[d,e]	−1.5 ± 7.9*[d,f]	−0.7 ± 8.8*[e,f]				
VAI	Baseline	2.7 ± 2.3[a,b]	2.4 ± 1.4[a]	2.4 ± 1.5[b]	<0.001	<0.001	<0.001	<0.001
	1 year	2.0 ± 1.3[a,b]	2.3 ± 1.3[a,c]	2.7 ± 2.2[b,c]				
	Δ	−0.7 ± 2.0*[d,e]	−0.2 ± 1.0*[d,f]	0.3 ± 1.7*[e,f]				
T&G index	Baseline	9.0 ± 0.6[a,b]	8.9 ± 0.5[a]	8.9 ± 0.5[b]	<0.001	<0.001	<0.001	<0.001
	1 year	8.7 ± 0.5[a,b]	8.8 ± 0.5[a,c]	9.0 ± 0.6[b,c]				
	Δ	−0.3 ± 0.4*[d,e]	−0.1 ± 0.3*[d,f]	0.1 ± 0.4*[e,f]				
BDI-II	Baseline	8.1 ± 7.1	8.4 ± 7.4	8.4 ± 7.3	0.007	0.098	<0.001	0.181
	1 year	5.7 ± 6.2[b]	6.4 ± 6.6	6.7 ± 7.0[b]				
	Δ	−2.4 ± 5.9*[e]	−1.9 ± 6.5*	−1.6 ± 6.5*[e]				

Abbreviations: BDI-II: Beck Depression Index, BMI: body mass index; CI: confidence interval; COL: cholesterol; DBP: diastolic blood pressure; HbA1c: glycated hemoglobin; HDL: high-density lipoprotein; HR: heart rate; LDL: low-density lipoprotein; SBP: systolic blood pressure; TG: triglycerides; T&G index: triglyceride and glucose index; VAI: visceral adiposity index; WC: waist circumference. Different letters in rows show significant difference between groups (a, b, and c), between time (*) and between time*group interaction (d, e, and f) by the Bonferroni post-hoc test ($P < 0.05$). ‡Data analyzed by repeated-measures two-factor ANCOVA ($P < 0.05$) and adjusted for sex and age. §Data analyzed by ANCOVA ($P < 0.05$) and adjusted for sex, age, and baseline measurement.

risk factors for cardio-metabolic disease after 1-year follow-up.

Statistics

Analyses were performed with the SPSS statistical software package version 25.0 (SPSS Inc., Chicago, IL, USA). Qualitative data are shown as prevalence and baseline differences across tertiles of change in MetSSS were examined using the chi-squared test. Quantitative data are shown as mean and SD. Variables were examined for normality and homoscedasticity (Kolmogorov and Levene tests). Baseline differences in means among tertiles of change in MetSSS were tested by analysis of variance

Table 3 Physical activity parameters and sedentary behavior according to tertiles of 1-year change in MetSSS.

		Tertile 1 Δ = −1.7 ± 0.8 (n = 1453)	Tertile 2 Δ = −0.4 ± 0.2 (n = 1453)	Tertile 3 Δ = 0.8 ± 0.8 (n = 1453)	Repeated measures ANCOVA‡	*P*-value for differences§		
		Mean ± SD	Mean ± SD	Mean ± SD	Time*group	T1 vs. T2	T1 vs. T3	T2 vs. T3
Sedentary time, h/d	Baseline	8.2 ± 2.0	8.0 ± 1.9	8.0 ± 2.0	<0.001	0.089	<0.001	0.062
	1 year	7.9 ± 1.8[b]	8.0 ± 1.8	8.1 ± 2.0[b]				
	Δ	−0.3 ± 1.8*[d,e]	−0.1 ± 1.8[d]	0.1 ± 1.9[e]				
TV-viewing time, h/d	Baseline	5.2 ± 1.8	5.2 ± 1.7	5.2 ± 1.8	0.048	1.000	0.058	0.234
	1 year	5.0 ± 1.6	5.0 ± 1.7	5.1 ± 1.8				
	Δ	−0.3 ± 1.5*[e]	−0.2 ± 1.6*	−0.1 ± 1.6*[e]				
Sleeping time, h/d	Baseline	7.0 ± 1.2	7.0 ± 1.2	7.1 ± 1.2	0.706	1.000	1.000	1.000
	1 year	7.1 ± 2.5	7.1 ± 2.5	7.1 ± 1.3				
	Δ	0.1 ± 2.4	0.1 ± 2.4	0.0 ± 1.1				
Total LTPA, MET,·min/d	Baseline	345.2 ± 275.3[b]	346.4 ± 265.8	366.0 ± 285.3[b]	<0.001	<0.001	<0.001	0.048
	1 year	497.3 ± 364.5[a,b]	432.1 ± 380.6[a]	418.7 ± 338.1[b]				
	Δ	152.1 ± 343.9*[d,e]	85.7 ± 367.3*[d,f]	52.7 ± 310.6*[e,f]				
Light LTPA, MET,·min/d	Baseline	115.3 ± 134.3	111.5 ± 124.8	120.3 ± 144.2	0.358	0.659	0.906	1.000
	1 year	125.3 ± 138.5	119.0 ± 134.5	122.4 ± 133.3				
	Δ	10.1 ± 160.1*	7.5 ± 149.7	2.1 ± 155.4				
Moderate LTPA, MET, min/d	Baseline	130.1 ± 190.6	131.9 ± 191.1	137.2 ± 195.0	<0.001	<0.001	<0.001	0.369
	1 year	211.4 ± 251.9[a,b]	169.9 ± 225.2[a]	163.9 ± 239.2[b]				
	Δ	81.2 ± 238.1*[d,e]	37.9 ± 213.8*[d]	26.8 ± 219.5*[e]				
Vigorous LTPA, MET,·min/d	Baseline	99.8 ± 164.9	102.9 ± 169.0	108.5 ± 181.3	<0.001	0.176	0.001	0.225
	1 year	160.6 ± 248.9[b]	143.3 ± 294.8	132.4 ± 225.1[b]				
	Δ	60.8 ± 227.9*[e]	40.3 ± 292.7*	23.8 ± 213.5*[e]				
30-s chair stand test, n	Baseline	13.5 ± 4.9	13.3 ± 4.8	13.4 ± 4.9	<0.001	<0.001	0.001	1.000
	1 year	14.9 ± 5.8[a,b]	13.9 ± 5.9[a]	14.1 ± 6.2[b]				
	Δ	1.4 ± 5.2*[d,e]	0.5 ± 5.4*[d]	0.7 ± 5.5*[e]				

Abbreviations: IQR: interquartile range; LTPA: leisure-time physical activity; s: second; SD: standard deviation. Different letters in rows show significant difference between groups (a, b, and c), between time (*), and between time*group interaction (d, e, and f) by the Bonferroni post-hoc test ($P < 0.05$). ‡Data analyzed by repeated-measures two-factor ANCOVA ($P < 0.05$) and adjusted for sex and age.. §Data analyzed by ANCOVA ($P < 0.05$) and adjusted for sex, age, and baseline measurement.

(ANOVA), using the Bonferroni post-hoc correction. Changes in all outcomes were assessed using the general linear model (GLM) of repeated-measures analysis of covariance for the two factors: tertiles of 1-year change in MetSSS (T1, T2, and T3) and time (baseline and 1-year), adjusted for sex and age (Tables 1–3) plus total LTPA and energy (Tables 4 and 5) as possible confounders, and their interaction, using the Bonferroni post-hoc correction. In addition, ANCOVAwas used to determine the effects of tertiles of change in MetSSS (fixed factors) and all outcomes after 1 year (dependent variables), using the baseline measurements as covariates, sex, and age (Tables 1–3) plus total LTPA and energy (Tables 4 and 5) as additional covariates. In addition, GLM analysis of covariance adjusting for baseline measurements and age, total LTPA, or energy as additional covariates, was used for sex-stratified analysis to determine the effects of tertiles of change in MetSSS and all outcomes after 1 year. Results were considered statistically significant if *p*-value (two-tailed) <0.05.

Results

After 1-year follow-up, both T1 and T2 participants decreased their MetSSS (Δ = −1.7 ± 0.8 and Δ = −0.4 ± 0.2, respectively), whereas T3 participants increased their MetSSS (Δ = 0.8 ± 0.8).

Table 1 shows baseline characteristics of participants according to tertiles of 1-year change in MetSSS. There were significant differences in the percentage of women, age, prevalence of obesity, and medication across tertiles. The use of lipid-lowering, insulin, and oral hypoglycemic agents was more common in participants in higher tertiles of MetSSS. No significant changes were found in education level, smoking habit, married and employment status, antihypertensive agents, aspirin, or antiplatelet drugs and MetS components (hypertension, hyperglycemia, low HDL-c, and abdominal obesity), except for hypertriglyceridemia.

Changes in cardiovascular risk factors and BDI-II according to tertiles of 1-year change in MetSSS are shown in Table 2. After 1-year follow-up, the main changes resulted in significant reduction in all variables for participants who lowered MetSSS (T1 and T2), except for total cholesterol, with larger decreases in T1 participants. Conversely, HDL-c was increased significantly as the MetSSS decreased, with larger changes in T1 participants. Furthermore, WC, glucose, HbA1c, TG, SBP, VAI, and T&G index increased in T3 participants. No significant changes were found in LDL-c.

Table 3 shows 1-year changes in PA parameters and sedentary behavior according to tertiles of 1-year change in MetSSS. After 1 year, total, moderate, and vigorous LTPA and 30-s chair stand test increased in the three

Table 4 Nutrient intake according to tertiles of 1-year change in MetSSS.

		Tertile 1 Δ = −1.7 ± 0.8 (n = 1453)	Tertile 2 Δ = −0.4 ± 0.2 (n = 1453)	Tertile 3Δ = 0.8 ± 0.8 (n = 1453)	Repeated measures ANCOVA‡	*P* value for differences§		
		Mean ± SD	Mean ± SD	Mean ± SD	Time*Group	T1 vs. T2	T1 vs. T3	T2 vs. T3
Macronutrients								
Total energy, kcal/d	Baseline	2405.3 ± 535.6	2357.8 ± 554.6	2361.6 ± 556.7	<0.001	0.012	<0.001	0.026
	1 year	2223.6 ± 451.9[b]	2239.8 ± 470.6	2288.5 ± 489.9[b]				
	Δ	−181.7 ± 533.9*[d,e]	−118.0 ± 532.5*[d,f]	−73.0 ± 528.2*[e,f]				
Total fat intake, % total energy	Baseline	39.5 ± 6.4	39.9 ± 6.4	39.6 ± 6.6	0.702	0.501	1.000	0.124
	1 year	42.4 ± 5.6	42.8 ± 5.8C	42.2 ± 5.8C				
	Δ	2.9 ± 6.7*	2.9 ± 7.0*	2.7 ± 7.0*				
MUFA, % total energy	Baseline	20.5 ± 4.5	20.7 ± 4.6	20.5 ± 4.6	0.289	1.000	0.481	0.347
	1 year	24.3 ± 4.6	24.3 ± 4.5	24.0 ± 4.5				
	Δ	3.8 ± 5.3*	3.6 ± 5.5*	3.5 ± 5.4*				
PUFA, % total energy	Baseline	6.4 ± 1.8	6.5 ± 1.8	6.4 ± 1.8	0.002	0.764	<0.001	0.001
	1 year	7.6 ± 1.6[b]	7.5 ± 1.8[c]	7.3 ± 1.7[b,c]				
	Δ	1.2 ± 2.2*[e]	1.1 ± 2.2*	0.9 ± 2.1*[e]				
SFA, % total energy	Baseline	9.9 ± 2.0	10.1 ± 2.1	10.0 ± 2.1	0.027	<0.001	<0.001	1.000
	1 year	9.0 ± 1.6[a,b]	9.3 ± 1.7[a]	9.3 ± 1.8[b]				
	Δ	−0.9 ± 1.9*[e]	−0.8 ± 2.1*	−0.7 ± 2.0*[e]				
TFA, g/d	Baseline	0.60 ± 0.38	0.61 ± 0.41[c]	0.59 ± 0.36[c]	<0.001	<0.001	<0.001	0.681
	1 year	0.35 ± 0.25[a,b]	0.40 ± 0.28[a]	0.42 ± 0.29[b]				
	Δ	−0.25 ± 0.37*[e]	−0.22 ± 0.40*[f]	−0.17 ± 0.36*[e,f]				
Linoleic acid, g/d	Baseline	13.81 ± 5.55	13.74 ± 5.58	13.50 ± 5.67	0.973	1.000	0.031	0.015
	1 year	14.59 ± 4.22[b]	14.73 ± 4.69[c]	14.58 ± 4.76[b,c]				
	Δ	0.77 ± 5.94*	1.00 ± 6.17*	1.09 ± 6.11*				
ω−3 FA, g/d	Baseline	2.4 ± 0.9	2.4 ± 0.9	2.3 ± 0.9	<0.001	0.060	<0.001	<0.001
	1 year	2.8 ± 0.9[b]	2.7 ± 0.9[c]	2.6 ± 0.9[b,c]				
	Δ	1.9 ± 0.9*[e]	1.8 ± 0.9*[f]	1.7 ± 0.9*[e,f]				
Carbohydrate intake, % total energy	Baseline	40.6 ± 6.7	40.2 ± 6.7	40.5 ± 6.9	0.015	1.000	0.005	0.010
	1 year	36.9 ± 5.9[b]	37.1 ± 5.9[c]	37.8 ± 6.0[b,c]				
	Δ	−3.6 ± 6.5*[e]	−3.1 ± 7.1*	−2.7 ± 6.8*[e]				
Glycemic index	Baseline	54.2 ± 5.1[a]	53.7 ± 5.1[a]	53.9 ± 5.3	<0.001	1.000	<0.001	<0.001
	1 year	52.0 ± 4.6[b]	52.1 ± 4.4[c]	52.8 ± 4.8[b,c]				
	Δ	−2.1 ± 5.6*[e]	−1.6 ± 5.6*[f]	−1.0 ± 5.6*[e,f]				
Protein intake, % total energy	Baseline	16.6 ± 2.8[b]	16.8 ± 2.8	16.9 ± 3.0[b]	<0.001	<0.001	<0.001	0.264
	1 year	17.6 ± 2.7[a,b]	17.3 ± 2.7[a]	17.1 ± 2.7[b]				
	Δ	1.0 ± 2.9*[d,e]	0.5 ± 2.8*[d,f]	0.2 ± 2.9*[e,f]				
Cholesterol, mg/d	Baseline	383.2 ± 114.9	385.3 ± 119.4	382.3 ± 109.7	0.219	0.875	0.878	1.000
	1 year	348.9 ± 93.1	354.3 ± 97.0	357.7 ± 105.7				
	Δ	−34.3 ± 109.4*	−31.0 ± 118.0*	−24.6 ± 117.9*				
Fibre intake, g/d	Baseline	26.1 ± 8.5	26.0 ± 8.8	26.3 ± 8.9	<0.001	<0.001	<0.001	0.008
	1 year	31.0 ± 8.6[a,b]	29.9 ± 8.4[a,c]	29.4 ± 8.4[b,c]				
	Δ	4.9 ± 9.5*[d,e]	3.9 ± 9.3*[d,f]	3.2 ± 9.3*[e,f]				
Alcohol intake, g/d	Baseline	12.1 ± 15.9	10.8 ± 14.8	10.8 ± 14.4	0.056	0.506	0.289	1.000
	1 year	10.1 ± 13.8	9.6 ± 13.7	10.0 ± 14.1				
	Δ	−2.0 ± 11.5*	−1.2 ± 10.3*	−0.7 ± 11.0*				
Vitamins								
Vitamin A, μg/d	Baseline	1100.1 ± 656.3	1106.3 ± 630.9	1128.5 ± 643.7	0.342	1.000	1.000	0.514
	1 year	1039.0 ± 488.2	1063.9 ± 537.4	1048.8 ± 664.1				
	Δ	−61.1 ± 656.6*	−42.3 ± 652.7*	−79.8 ± 748.1*				
Vitamin B1, mg/d	Baseline	1.64 ± 0.41	1.63 ± 0.41	1.64 ± 0.41	0.009	<0.001	<0.001	0.436
	1 year	1.68 ± 0.38[a,b]	1.65 ± 0.38[a]	1.65 ± 0.39[b]				
	Δ	0.04 ± 0.43*[e]	0.01 ± 0.41	0.01 ± 0.42[e]				
Vitamin B2, mg/d	Baseline	1.99 ± 0.59	2.02 ± 0.66	2.03 ± 0.64	0.033	0.144	0.026	1.000
	1 year	2.01 ± 0.59	2.00 ± 0.63	2.01 ± 0.62				
	Δ	0.02 ± 0.61[e]	−0.01 ± 0.62	−0.02 ± 0.63[e]				
Vitamin B3, mg/d	Baseline	41.0 ± 9.6	40.8 ± 10.1	41.0 ± 9.9	0.088	0.002	<0.001	1.000
	1 year	41.5 ± 9.1[a,b]	40.9 ± 9.3[a]	41.1 ± 9.3[b]				
	Δ	0.5 ± 9.8*	0.1 ± 9.8	0.1 ± 9.6				
Vitamin B6, mg/d	Baseline	2.34 ± 0.57	2.34 ± 0.59	2.35 ± 0.58	<0.001	0.002	<0.001	0.006
	1 year	2.51 ± 0.55[a,b]	2.47 ± 0.56[a,c]	2.45 ± 0.55[b,c]				
	Δ	0.17 ± 0.59*[e]	0.13 ± 0.58*	0.09 ± 0.57*[e]				
Vitamin B9, μg/d	Baseline	351.3 ± 98.6	350.2 ± 103.4	353.4 ± 103.7	<0.001	0.005	<0.001	0.014
	1 year	383.5 ± 95.7[a,b]	377.0 ± 99.9[a]	372.2 ± 95.7[b]				
	Δ	32.3 ± 104.9*[e]	26.8 ± 105.6*[f]	18.8 ± 105.9*[e,f]				

(*continued on next page*)

Table 4 (*continued*)

		Tertile 1 Δ = −1.7 ± 0.8 (n = 1453)	Tertile 2 Δ = −0.4 ± 0.2 (n = 1453)	Tertile 3Δ = 0.8 ± 0.8 (n = 1453)	Repeated measures ANCOVA‡	*P* value for differences§		
		Mean ± SD	Mean ± SD	Mean ± SD	Time*Group	T1 vs. T2	T1 vs. T3	T2 vs. T3
Vitamin B12, μg/d	Baseline	10.1 ± 4.5	10.1 ± 4.5	10.1 ± 4.6	0.240	0.172	0.072	1.000
	1 year	10.1 ± 4.0	9.9 ± 4.0	10.0 ± 4.9				
	Δ	0.1 ± 4.6	−0.2 ± 4.6	−0.1 ± 5.2				
Vitamin C, mg/d	Baseline	200.2 ± 83.7	199.9 ± 83.7	201.1 ± 85.1	0.002	0.689	<0.001	0.005
	1 year	216.4 ± 78.4[b]	215.0 ± 83.7[c]	208.6 ± 77.1[b,c]				
	Δ	16.2 ± 85.4[*e]	15.1 ± 88.8[*f]	7.5 ± 81.6[*e,f]				
Vitamin D, μg/d	Baseline	6.3 ± 3.5	6.4 ± 3.5	6.1 ± 3.4	0.037	0.114	<0.001	0.130
	1 year	7.3 ± 3.6[b]	7.0 ± 3.5[c]	6.8 ± 3.5[b,c]				
	Δ	1.0 ± 4.2[*e]	0.7 ± 4.0[*]	0.6 ± 4.0[*e]				
Vitamin E, mg/d	Baseline	10.6 ± 3.8	10.7 ± 4.1	10.7 ± 4.1	0.126	1.000	0.005	0.011
	1 year	12.1 ± 3.3[b]	12.1 ± 3.7[c]	12.0 ± 3.6[b,c]				
	Δ	1.4 ± 4.3[*]	1.4 ± 4.6[*]	1.3 ± 4.4[*]				
Minerals								
Calcium, mg/d	Baseline	1027.9 ± 334.8	1044.3 ± 357.5	1035.5 ± 350.5	0.155	0.522	0.003	0.166
	1 year	998.9 ± 301.3[b]	1006.9 ± 319.6	995.2 ± 316.8[b]				
	Δ	−29.0 ± 324.2[*]	−37.4 ± 335.0[*]	−40.3 ± 331.9[*]				
Phosphorus, mg/d	Baseline	1761.2 ± 405.0	1762.9 ± 426.9	1768.4 ± 424.4	<0.001	<0.001	<0.001	0.059
	1 year	1818.3 ± 393.4[a,b]	1791.3 ± 414.1[a]	1784.8 ± 410.4[b]				
	Δ	57.1 ± 413.8[*d,e]	28.4 ± 410.1[*d]	16.5 ± 416.0[e]				
Magnesium, mg/d	Baseline	419.6 ± 103.8	419.4 ± 109.5	423.1 ± 111.5	<0.001	<0.001	<0.001	0.012
	1 year	466.1 ± 104.8[a,b]	456.0 ± 107.8[a,c]	453.5 ± 107.4[b,c]				
	Δ	46.5 ± 116.3[*d,e]	36.7 ± 115.1[*d]	30.4 ± 115.3[*e]				
Iron, mg/d	Baseline	16.6 ± 3.8	16.4 ± 4.0	16.5 ± 4.0	0.101	0.002	<0.001	0.101
	1 year	16.9 ± 3.7[a,b]	16.7 ± 3.8[a]	16.7 ± 3.8[b]				
	Δ	0.3 ± 4.0[*]	0.3 ± 4.1[*]	0.2 ± 4.1				
Iodine, μg/d	Baseline	283.0 ± 151.4	278.7 ± 162.3	285.7 ± 160.5	0.035	0.440	0.004	0.223
	1 year	280.1 ± 143.9[b]	275.9 ± 151.8	272.0 ± 147.3[b]				
	Δ	−2.9 ± 143.1[e]	−2.9 ± 154.4	−13.7 ± 149.8[*e]				
Potassium, mg/d	Baseline	4465.3 ± 1051.4	4447.0 ± 1086.5	4504.5 ± 1100.2	<0.001	0.006	<0.001	0.001
	1 year	4751.2 ± 1007.1[a,b]	4700.6 ± 1047.2[a,c]	4654.8 ± 1039.0[b,c]				
	Δ	285.8 ± 1092.8[*e]	253.6 ± 1081.9[*f]	150.3 ± 1095.1[*e,f]				
Selenium, μg/d	Baseline	119.1 ± 33.2[a]	116.1 ± 31.9[a]	117.5 ± 33.2	0.730	<0.001	0.001	1.000
	1 year	115.1 ± 29.8[a,b]	112.3 ± 28.8[a]	114.6 ± 30.9[b]				
	Δ	−3.9 ± 36.1[*]	−3.7 ± 33.5[*]	−3.0 ± 35.3[*]				
Zinc, mg/d	Baseline	13.30 ± 3.20	13.17 ± 3.24	13.24 ± 3.27	0.258	<0.001	<0.001	1.000
	1 year	12.92 ± 2.90[a,b]	12.73 ± 2.95[a]	12.91 ± 3.00[b]				
	Δ	−0.37 ± 3.36[*]	−0.44 ± 3.35[*]	−0.33 ± 3.34[*]				

Abbreviations: IQR: interquartile range; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid; SD: standard deviation; SFA: saturated fatty acid; TFA: trans fatty acid; ω-3 FA: omega-3 fatty acid. Different letters in rows show significant difference between groups (a, b, and c), between time (*) and between time*group interaction (d, e, and f) by the Bonferroni post-hoc test ($P < 0.05$). ‡Data analyzed by repeated-measures two-factor ANCOVA ($P < 0.05$) and adjusted for sex, age, total LTPA, and energy intake. §Data analyzed by ANCOVA ($P < 0.05$) and adjusted for sex, age, total LTPA, energy intake, and baseline measurement.

groups, with larger increases in T1 participants. As MetSSS decreased, total LTPA increased. Conversely, sedentary time and TV-viewing time significantly decreased in T1 participants, compared with T3 participants. No significant changes were found in sleeping time (around 7 h/day in all groups) and light LTPA among tertiles of MetSSS.

Changes in nutrient intake characteristics according to tertiles of 1-year change in MetSSS are shown in Table 4. After 1 year, the main changes in the three groups were a significant reduction in total energy, saturated fatty acids (SFAs), trans fatty acids (TFAs), carbohydrate, and glycemic index intake, with larger decreases in T1 participants compared with T3. In addition, iodine intake was significantly decreased in T3 participants. Contrarily, polyunsaturated fatty acid (PUFA), omega-3 fatty acid (ω-3 FA), protein, fiber, vitamins B6, B9, C, and D, magnesium, and potassium intake increased in the three groups, with larger increases in T1 compared with T3 participants. In addition, phosphorus and vitamin B1 intake significantly increased in T1 participants compared with T3. No significant changes between groups were found in total fat, monounsaturated fatty acid (MUFA), cholesterol, alcohol, other vitamins, and minerals intake.

MD adherence, DII, and dietary characteristics according to tertiles of 1-year change in MetSSS are shown in Table 5. The three groups significantly increased the intake of vegetables, legumes, fruits, nuts, whole grain cereals, total fish, white fish, and bluefish, resulting in increasing MD adherence, with larger increases in T1 participants compared with T3. Refined grain cereals, red and

Table 5 Adherence to MD, DII, and dietary characteristics according to tertiles of 1-year change in MetSSS.

		Tertile 1 Δ = −1.7 ± 0.8 (n = 1453)	Tertile 2 Δ = −0.4 ± 0.2 (n = 1453)	Tertile 3 Δ = 0.8 ± 0.8 (n = 1453)	Repeated measures ANCOVA‡	*P*-value for differences§		
		Mean ± SD	Mean ± SD	Mean ± SD	Time*Group	T1 vs. T2	T1 vs. T3	T2 vs. T3
Food groups								
Vegetables, g/d	Baseline	325.4 ± 135.0	324.0 ± 135.0	329.3 ± 138.9	<0.001	0.901	<0.001	0.001
	1 year	373.5 ± 140.2[b]	368.1 ± 147.3[c]	352.0 ± 136.6[b,c]				
	Δ	48.1 ± 152.1*[e]	44.1 ± 153.7*[f]	22.7 ± 147.7*[e,f]				
Potatoes, g/d	Baseline	66.6 ± 42.2	65.8 ± 42.6	67.1 ± 44.1	0.508	1.000	0.947	1.000
	1 year	63.1 ± 38.7	64.1 ± 38.8	66.2 ± 44.5				
	Δ	−3.5 ± 48.0*	−1.7 ± 47.2	−0.9 ± 48.4				
Legumes, g/d	Baseline	20.8 ± 10.6	20.2 ± 10.6	20.9 ± 11.6	0.001	0.087	<0.001	0.037
	1 year	26.0 ± 11.1[a,b]	24.9 ± 10.9[a]	24.1 ± 11.0[b]				
	Δ	5.2 ± 13.3*[e]	4.7 ± 13.0*[f]	3.3 ± 13.8*[e,f]				
Fruits, g/d	Baseline	356.3 ± 202.1	352.2 ± 200.0	359.7 ± 215.7	0.002	0.318	<0.001	0.027
	1 year	405.6 ± 192.5[b]	398.6 ± 182.4	386.8 ± 188.8[b]				
	Δ	49.3 ± 223.5*[e]	46.4 ± 214.3*[f]	27.2 ± 226.5*[e,f]				
Nuts, g/d	Baseline	14.9 ± 16.1	15.5 ± 17.6	15.2 ± 18.2	<0.001	0.137	<0.001	0.003
	1 year	31.0 ± 17.2[b]	30.0 ± 19.3[c]	28.1 ± 18.1[b,c]				
	Δ	16.1 ± 21.1*[e]	14.5 ± 22.6*	13.0 ± 22.1*[e]				
Cereals, g/d	Baseline	155.3 ± 77.7[a]	145.0 ± 71.8[a]	151.2 ± 80.3	0.083	0.025	0.683	<0.001
	1 year	127.9 ± 60.6[a]	123.3 ± 60.6[a,c]	134.9 ± 66.1[c]				
	Δ	−27.4 ± 84.8*	−21.7 ± 79.7*	−16.3 ± 84.8*				
Whole cereals	Baseline	39.2 ± 63.1	42.3 ± 62.9	41.3 ± 62.3	<0.001	<0.001	<0.001	1.000
	1 year	71.1 ± 64.3[a,b]	60.8 ± 59.5[a]	59.6 ± 63.7[b]				
	Δ	31.9 ± 76.1*[d,e]	18.5 ± 72.5*[d]	18.3 ± 71.2*[e]				
Refined cereals	Baseline	116.0 ± 87.9[a]	102.8 ± 80.7[a]	109.9 ± 91.2	<0.001	0.010	<0.001	0.010
	1 year	56.8 ± 66.3[b]	62.5 ± 67.2[c]	75.3 ± 76.4[b,c]				
	Δ	−59.2 ± 94.9*[d,e]	−40.2 ± 84.1*[d]	−34.5 ± 92.0*[e]				
Fish and seafood, g/d	Baseline	102.8 ± 47.3	102.9 ± 46.7	102.0 ± 47.3	<0.001	0.030	<0.001	0.016
	1 year	117.3 ± 47.8[a,b]	113.4 ± 45.6[a,c]	109.1 ± 47.5[b,c]				
	Δ	14.5 ± 52.3*[e]	10.5 ± 50.4*	7.1 ± 50.3*[e]				
White fish	Baseline	40.6 ± 26.9	39.3 ± 25.0	40.2 ± 25.9	0.001	0.004	<0.001	0.192
	1 year	47.4 ± 26.1[a,b]	44.1 ± 24.8[a]	42.6 ± 24.5[b]				
	Δ	6.7 ± 30.8*[e]	4.8 ± 29.5*	2.5 ± 28.4*[e]				
Bluefish	Baseline	34.9 ± 22.8	35.1 ± 22.7	34.2 ± 22.4	0.008	0.050	<0.001	0.087
	1 year	43.0 ± 24.3[b]	41.2 ± 23.0[c]	39.3 ± 22.9[b,c]				
	Δ	8.1 ± 27.8*[e]	6.0 ± 26.1*	5.1 ± 26.4*[e]				
Seafood	Baseline	27.3 ± 20.2	28.4 ± 21.3	27.7 ± 21.7	0.923	1.000	1.000	0.595
	1 year	26.9 ± 21.2	28.1 ± 21.3	27.2 ± 22.4				
	Δ	−0.4 ± 22.9	−0.3 ± 23.9	−0.5 ± 24.4				
Total meat, g/d	Baseline	151.2 ± 57.8	147.7 ± 57.6	149.8 ± 59.8	0.096	1.000	0.305	0.054
	1 year	131.3 ± 46.2	130.0 ± 48.0	135.8 ± 50.6				
	Δ	−19.9 ± 54.6*	−17.7 ± 57.3*	−14.0 ± 56.3*				
Red meat	Baseline	50.0 ± 34.1	49.5 ± 33.7	49.9 ± 35.6	0.028	0.262	0.003	0.354
	1 year	32.8 ± 26.8[b]	34.7 ± 28.5	37.3 ± 29.9[b]				
	Δ	−17.2 ± 34.2*[e]	−14.8 ± 34.7*	−12.7 ± 35.7*[e]				

(*continued on next page*)

Table 5 (*continued*)

		Tertile 1 Δ = −1.7 ± 0.8 (n = 1453)	Tertile 2 Δ = −0.4 ± 0.2 (n = 1453)	Tertile 3 Δ = 0.8 ± 0.8 (n = 1453)	Repeated measures ANCOVA‡	*P*-value for differences§		
		Mean ± SD	Mean ± SD	Mean ± SD	Time*Group	T1 vs. T2	T1 vs. T3	T2 vs. T3
White meat	Baseline	63.4 ± 33.0[a]	61.1 ± 35.6[a]	62.9 ± 33.6	0.339	0.015	0.040	1.000
	1 year	71.0 ± 31.2[a,b]	67.2 ± 32.2[a]	68.5 ± 30.9[b]				
	Δ	7.5 ± 34.7*	6.1 ± 36.1*	5.6 ± 34.4*				
Processed meat	Baseline	35.6 ± 24.1	34.9 ± 23.3	34.7 ± 22.4	0.022	1.000	0.024	0.155
	1 year	26.4 ± 16.5	26.8 ± 15.4	28.3 ± 17.5				
	Δ	−9.2 ± 24.9*[e]	−8.1 ± 23.7*	−6.4 ± 22.3*[e]				
Visceral	Baseline	2.1 ± 5.1	2.1 ± 5.4	2.3 ± 5.1	0.134	1.000	0.003	0.041
	1 year	0.3 ± 1.9[b]	0.4 ± 1.9[c]	0.7 ± 4.3[b,c]				
	Δ	−0.9 ± 5.1*	−0.8 ± 5.5*	−0.5 ± 6.9*				
Eggs, g/d	Baseline	23.8 ± 11.7	24.3 ± 12.0	23.8 ± 11.2	0.962	1.000	1.000	0.501
	1 year	24.8 ± 10.2	25.1 ± 11.6	24.6 ± 10.3				
	Δ	0.9 ± 11.5*	0.8 ± 13.1*	0.8 ± 11.8*				
Dairy products, g/d	Baseline	338.4 ± 193.7	342.3 ± 203.8	346.3 ± 203.8	0.037	0.188	0.006	0.628
	1 year	330.2 ± 185.7[b]	327.9 ± 195.9	323.4 ± 194.6[b]				
	Δ	−8.2 ± 184.9[e]	−14.4 ± 195.2*	−23.0 ± 186.1*[e]				
Whole-fat dairy	Baseline	43.1 ± 84.5	45.6 ± 103.4	42.4 ± 93.6	0.168	0.292	0.094	1.000
	1 year	22.1 ± 59.8	27.0 ± 70.1[a]	28.7 ± 80.0				
	Δ	−21.0 ± 84.9*	−18.6 ± 104.2*	−13.6 ± 96.8*				
Skimmed dairy	Baseline	151.2 ± 166.7	148.5 ± 159.3	156.1 ± 174.5	0.024	0.259	0.008	0.578
	1 year	163.1 ± 164.5[b]	156.2 ± 159.4	153.1 ± 164.6[b]				
	Δ	12.0 ± 167.1*[e]	7.7 ± 157.7	−3.0 ± 168.4[e]				
Cheese	Baseline	29.6 ± 23.7[a]	32.5 ± 27.3[a]	30.8 ± 24.0	0.447	1.000	1.000	1.000
	1 year	26.4 ± 22.2	28.5 ± 22.0	27.7 ± 21.5				
	Δ	−3.2 ± 25.5*	−4.0 ± 27.7*	−3.1 ± 24.7*				
Dairy desserts	Baseline	14.6 ± 26.8	15.2 ± 28.3	15.1 ± 30.4	0.595	0.074	1.000	0.454
	1 year	8.0 ± 20.9	10.0 ± 21.0	9.4 ± 20.0				
	Δ	−6.6 ± 28.2*	−5.2 ± 29.4*	−5.7 ± 30.7*				
Cookies and sweets, g/d	Baseline	27.9 ± 29.9[b]	26.0 ± 29.2	25.4 ± 26.1[b]	<0.001	0.199	<0.001	0.036
	1 year	12.9 ± 17.9[b]	14.6 ± 19.1	16.6 ± 21.1[b]				
	Δ	−15.0 ± 29.3*[d,e]	−11.4 ± 29.0*[d,f]	−8.8 ± 27.2*[e,f]				
Olive oil, g/d	Baseline	40.9 ± 16.7[b]	39.8 ± 16.9	39.2 ± 17.1[b]	0.431	1.000	1.000	1.000
	1 year	46.3 ± 14.8	46.2 ± 14.9	46.1 ± 15.3				
	Δ	5.4 ± 19.3*	6.4 ± 19.1*	6.9 ± 19.3*				
Other oils and fats, g/d	Baseline	2.9 ± 6.3	2.9 ± 6.3	3.1 ± 7.1	0.310	0.080	0.001	0.412
	1 year	0.7 ± 2.8[b]	1.1 ± 3.6	1.3 ± 4.3[b]				
	Δ	−2.2 ± 6.3*	−1.9 ± 6.5*	−1.8 ± 7.1*				
Ready-to-eat-meals/ Snacks, g/d	Baseline	11.5 ± 15.6[b]	10.6 ± 13.0	10.3 ± 13.5[b]	<0.001	0.175	0.004	0.584
	1 year	6.3 ± 9.6	6.7 ± 9.7	7.3 ± 10.5				
	Δ	−5.2 ± 14.5*[e]	−3.9 ± 12.1*	−2.9 ± 13.1*[e]				
Alcoholic drinks, g/d								
Wine	Baseline	66.1 ± 109.8	57.4 ± 99.3	55.9 ± 93.5	0.627	1.000	1.000	1.000
	1 year	64.4 ± 100.0	59.1 ± 97.8	58.5 ± 94.1				
	Δ	−1.7 ± 85.9	1.7 ± 76.1	2.5 ± 77.2				

Beer	Baseline	117.9 ± 230.3	107.6 ± 216.3	115.6 ± 222.2	0.051	0.116	0.005	0.873
	1 year	75.2 ± 169.4[b]	79.5 ± 175.1	93.5 ± 205.7[b]				
	Δ	−42.8 ± 179.7*	−28.1 ± 167.9*	−22.1 ± 205.8*				
Spirits	Baseline	3.7 ± 11.5	3.7 ± 11.4	3.3 ± 9.5	0.250	1.000	1.000	1.000
	1 year	2.5 ± 9.0	2.5 ± 10.8	2.7 ± 10.5				
	Δ	−1.3 ± 10.7*	−1.2 ± 11.6*	−0.6 ± 10.0*				
Dietary Inflammatory Index	Baseline	0.002 ± 1.990	−0.005 ± 2.022	−0.012 ± 2.028	<0.001	<0.001	<0.001	<0.001
	1 year	−0.238 ± 1.964[a,b]	0.003 ± 2.031[a,c]	0.181 ± 1.989[b,c]				
	Δ	−0.240 ± 2.102*[d,e]	0.008 ± 2.036[d,f]	0.194 ± 2.025*[e,f]				
MD Adherence	Baseline	8.3 ± 2.6[b]	8.4 ± 2.7[c]	8.6 ± 2.7[b,c]	<0.001	<0.001	<0.001	<0.001
	1 year	12.5 ± 2.8[a,b]	11.6 ± 2.8[a,c]	11.2 ± 2.9[b,c]				
	Δ	4.2 ± 3.3*[d,e]	3.3 ± 3.2*[d,f]	2.6 ± 3.1*[e,f]				

Abbreviations: IQR: interquartile range; SD: standard deviation; MD: Mediterranean diet. Different letters in rows show significant difference between groups (a, b, and c), between time (*) and between time*group interaction (d, e, and f) by the Bonferroni post-hoc test ($P < 0.05$). [†]Data analyzed by repeated-measures two-factor ANCOVA ($P < 0.05$) and adjusted for sex, age, total LTPA, and energy intake. [§§]Data analyzed by ANCOVA ($P < 0.05$) and adjusted for sex, age, total LTPA, energy intake, and baseline measurement.

processed meat, cookies/sweets, and ready-to-eat-meals/snacks significantly decreased in the three groups, with larger decreases in participants with the highest MetSSS reduction (T1). Dairy products intake largely decreased in T3 participants compared with T1. DII significantly lowered in T1, resulting in an anti-inflammatory dietary pattern, whereas it significantly increased in T3, resulting in a pro-inflammatory dietary pattern. No significant changes between groups were found in potatoes, seafood, eggs, total meat, whole-fat dairy, cheese, dairy desserts, olive oil, and wine and alcoholic drinks intake.

Finally, GLM sex-stratified analysis showed that women did not present statistically significant differences according to tertiles of 1-year change in MetSSS in terms of changes of total blood cholesterol ($p = 0.158$), sedentary lifestyle ($p = 0.350$), and vigorous LTPA ($p = 0.217$), as well as the consumption of red meat ($p = 0.065$), processed meat ($p = 0.753$) and skimmed dairy ($p = 0.788$), and the intake of vitamin B2 ($p = 0.224$) and iodine ($p = 0.544$), whereas MUFA ($p = 0.026$) intake and egg ($p = 0.034$) consumption significantly increased in them, with larger increases in T1 participants compared with T3. In men, there were no differences in terms of fruit ($p = 0.122$) and cookies consumption ($p = 0.182$), but either carbohydrate intake ($p = 0.108$; data not shown).

Discussion

To our knowledge, this is the first study that has assessed longitudinal changes in lifestyle factors as LTPA, sedentary behavior, and dietary characteristics in older adults with MetS according to changes on the severity of MetS. The most relevant observation was that increased MetSSS (T3) was associated with a pro-inflammatory dietary pattern, decreased LTPA and MD adherence, and increased sedentary time and depression risk, which is associated with high risk of several major chronic diseases [4–13].

Cardiovascular risk factors

Higher decreases in cardiovascular risk factors as weight, BMI, WC, glucose, HbA1c, total cholesterol, TG, SBP, DBP, HR, VAI, and T&G index, and higher increases in HDL-c in those participants who lowered their MetSSS, as well as increases in WC, glucose, HbA1c, TG, SBP, VAI, and T&G index in those participants who increased their MetSSS, were in accordance with previous observations in which MetSSS predicted the risk of diabetes and CHD [14]. HR is a simple indicator of the autonomous nervous system, strongly associated with insulin resistance, and the evidence showed that the risk of MetS may be increased with elevated HR [29], which is strongly associated with our results in which HR decreased as MetSSS did. VAI is considered as a reliable indicator of adipose tissue dysfunction and cardiometabolic disease risk [19], which is in accordance with our results in which VAI decreased in participants who decreased their MetSSS, but increased in participants who increased their MetSSS. Likewise, T&G index is a simple measure of insulin resistance [20],

indicating that insulin sensitivity was inversely associated with MetSSS.

Depressive symptoms

Depression in older people is associated with more cognitive and functional impairment than in younger adults, with an increased risk of death, disability, and dementia [30]. Depression risk lowered in participants reducing more their MetSSS, which is in accordance with previous findings in which depression and MetS were significantly correlated. Evidence found a bidirectional association between MetS and depression, probably due to depression has been associated with central obesity, chronic inflammation, and insulin resistance [13]. Comparing our results with a previous study [12] in which the depression score of MetS individuals were higher than those without MetS, our participants showed higher depression score at baseline and lower after 1-year follow-up, with the lowest score in T1 participants.

Sedentary behavior and physical activity

Evidence shows that PA has an important impact on cardiometabolic risk, reducing the risk of MetS. Regular exercise reduced weight, BP, insulin resistance, and improved lipid disorders, including raising HDL-c and lowering TG [3,5]. Such results are correlated with our findings in which as MetSSS was reduced, total LTPA increased. Indeed, previous evidence found a negative linear association between LTPA and incident MetS, with a significant reduction in MetS risk when LTPA increased, independently of BMI [31]. Participants with higher moderate-to-vigorous LTPA showed a decrease in MetSSS, which is in accordance with previous findings in which moderate exercise was associated with a substantial reduction in CHD, and vigorous activity was associated with a significantly lower prevalence of two or more of the following risk factors: high BMI, HR, DBP and SBP, and low HDL-c [32]. Nevertheless, no significant changes were found in light LTPA between groups, enhancing the important role of PA programs on MetS persons based on moderate and vigorous intensity.

Evidence shows that sedentary behavior and physical inactivity (PI) are major modifiable CVD risk factors, with an association between sedentary behavior and CVD morbidity and mortality [4]. It was estimated that 6% of CHD, 7% of T2DM, 10% of breast cancer, and 10% of colon cancer cases are caused by PI, and by avoiding PI, it is estimated that life expectancy of the world's population would increase by 0.68 years [33]. Previous evidence shows that moderate-to-vigorous PA is inversely associated with CVD mortality and appears to attenuate the negative CVD consequences of sedentary behavior, whereas sitting and TV-viewing time are important CVD risk factors, particularly in population with lower PA level [4]. Such results are strongly correlated with our findings in which participants who increased their MetSSS showed higher sedentary and TV-viewing time.

The 30-s chair stand test assesses lower body strength because of its role in common everyday activities [24], providing information on declines in mobility and a measure to identify frail individuals [34]. Number of repetitions in the 30-s chair stand test substantially increased in participants who reduced their MetSSS, resulting in higher body strength, which is a strong protective factor against MetS [35]. Comparing our results with previous findings, our participants showed fewer repetitions than non-institutionalized Spanish elderly [36].

Dietary characteristics

The caloric restriction has beneficial effects on cardiac health and in prevention of CVD [37], which is in accordance with our results in which total energy was reduced as MetSSS decreased. Moreover, MD is characterized by high consumption of fruits and vegetables, legumes, nuts and whole cereals, high intake of olive oil, but low-to-moderate consumption of dairy products, low intake of meat and poultry and regular, but moderate intake of wine [38]. MD is recognized as one of the healthiest dietary patterns, with proven benefits in patients with CVD [39] and in the prevention and treatment of several diseases such as diabetes, hypertension and MetS. MD can reduce the prevalence of MetS and reversion of this condition [7], which is in accordance with our results in which high MD adherence is associated with reducing MetSSS.

Inflammation is believed to be involved in the development and progression of several non-communicable diseases, including CVD, T2DM, MetS, obesity, and cancer. Dietary intake is one of the modifiable factors involved in the development of inflammation and inflammatory-related diseases [11]. In this way, DII increased as MetSSS did, resulting in an anti-inflammatory dietary pattern for participants who reduced their MetSSS, and a pro-inflammatory dietary pattern for participants who increased their MetSSS. These results are strongly related to previous findings in which a pro-inflammatory diet was associated with CVD [11].

The SFA and TFA intakes were high in participants with increasing MetSSS, perhaps due to the high intake of red and processed meat, snacks/ready-to-eat products and cookies/sweets in high MetSSS participants. This is consistent with previous findings in which red and processed meat intake was positively associated with MetS [40]. A high intake of red and processed meat could increase the risk of chronic diseases, including T2DM, CVD, and several types of cancer. Moreover, previous evidence showed a small, but potentially important reduction in cardiovascular risk when SFA intake was lowered [41], which is in accordance with our results in which those participants reducing more their MetSSS, also reduced SFA intake.

TFA intake influences the regulation of lipid metabolism, inflammation, and oxidative stress, and it is positively associated with the risk of coronary artery disease [42]. Previous results showed that a reduction of TFA lowered the incidence of myocardial infarction and CVD

mortality [42], which is in accordance with our findings in which those participants reducing more their MetSSS showed higher TFA reduction. The evidence shows that greater adherence to a Western dietary pattern is associated with increased risk of MetS [43]. Our results showed that the intake of cookies/sweets and ready-to-eat-meals/snacks was largely reduced in participants who most reduce their MetSSS, which is in accordance with previous findings in which higher dietary contribution of ultra-processed foods is associated with higher prevalence of MetS [44].

The intake of PUFA, specifically ω-3 FA, increased in participants with larger decreases in MetSSS, perhaps due to higher intake of nuts and total fish. Fish intake contains beneficial nutrients, such as ω-3 FA, proteins, vitamin D, iodine, selenium, and taurine that are preventive of CVD [45]. As previously described, MetS is characterized for a "low-grade" chronic inflammation and ω-3 FAs have been shown to decrease the production of inflammatory mediators and the appearance of CVD risk factors, having a positive effect in obesity and T2DM [46]. Such results are related to our findings in which ω-3 FA and vitamin D intakes were high in participants who decreased their MetSSS, whereas iodine intake significantly decreased in participants who increased their MetSSS after 1-year follow-up.

Nut consumption reduces the risk of CVD and may be beneficial in the prevention of MetS and obesity, showing that for every 1-serving/week increase in nut intake, the risk of MetS is reduced by 4% [47]. This is consistent with our results in which nut intake was significantly higher in participants who most reduced their MetSSS.

Vegetables and fruits have many health benefits, since they are rich in fiber, minerals, vitamins, and phytochemicals. Strong evidence indicates that fruits and vegetables decrease the risk of several cancers, depression, hypertension, T2DM, and all-cause mortality, as well as their antioxidants and anti-inflammatory components play an important role in MetS [48] and might lower BP and improve endothelial function [49]. Potassium and magnesium are also inversely associated with BP [50]. Previous evidence shows that higher intake of vitamins B1, B2, niacin, B6, and B9 were all associated with reduced risk of MetS [51], which is strongly correlated with our results in which the intake of vitamins B1, B6, and B9 increased in those participants with higher decrease in MetSSS after 1-year follow-up. Fruit or/and vegetable intake is inversely associated with MetS risk [48], which is in accordance with our results in which fruit, vegetables, vitamin C, fiber, magnesium, phosphorus, and potassium intake increased in those participants with higher decrease in MetSSS after 1-year follow-up.

Legumes are rich in protein, fiber, carbohydrate, micronutrients, and bioactive compounds such as phytochemicals [52], and evidence shows that legume consumption reduced BP, total cholesterol, LDL, and TG, and it has been associated with reduced total mortality [49]. This is in accordance with our findings in which those participants who most decreased their MetSSS after 1-year follow-up were those who more increased legume intake, even though other previous studies concluded no association between legume consumption and MetS [52].

Total protein intake increased in participants who more decreased their MetSSS (T1), possibly because of an increased intake of legumes, fish, and seafood, which is in accordance with a previous study in which higher protein intake reduced MetS by managing body composition [53].

Strong evidence shows that whole grain intake is associated with reduced risk of CHD, CVD, cancer, mortality from all causes, respiratory diseases, infectious diseases, diabetes, and all non-cardiovascular and non-cancer causes [54]. Furthermore, diets high in insoluble dietary fiber and whole grains might significantly reduce diabetes risk [55]. This is consistent with our results in which whole grain cereals consumption increased in T1 participants, whereas that of refined grain cereals consumption decreased. Contrary to our results, other authors found that refined cereals are not associated with the risks of CVD, CHD, stroke, or cancer [56]. Finally, carbohydrate intake and glycemic index decreased in T1 participants, which is in accordance with previous results in which diets low in carbohydrates and comprising foods with low glycemic index are postulated to improve insulin resistance and MetS, preventing the development of T2DM [57].

Strengths and limitations

The main strength of this study was that, to our knowledge, this is the first study that has examined 1-year changes in lifestyle factors as LTPA, sedentary behavior, and dietary characteristics in older adults with MetS according to changes on the severity of MetS. Another strength of our study is the large sample of older adults living in the Mediterranean area with MetS that has been assessed. The FFQ used to collect information on nutrients intake, takes into consideration nutritional supplements, such as multivitamins and minerals as a contribution to micronutrient intake. Furthermore, it has been used validated scores and questionnaires. However, the study has several limitations too. First, the use of self-reported data to evaluate PA has inherent limitations as questionnaires overestimate the engagement in PA. Second, although the FFQ is a validated tool, it could overestimate the intake of certain food groups as well as micronutrient (intake of vitamins and minerals). Finally, the MetSSS was validated in a Caucasian or European sample; generalization to other racial and ethnic groups requires further validation.

Conclusions

Increasing MetSSS was associated with pro-inflammatory dietary pattern, low LTPA and low MD adherence, and high sedentary time and high depression risk. This approach provides new and useful information for prevention and treatment plans for MetS patients according to the severity

of the disease, focused on modification of lifestyles to reduce obesity, to increase moderate/vigorous PA and body strength, to increase MD adherence, and follow an anti-inflammatory dietary pattern.

Authors' contributions

LGAB, MMB, and JAT made substantial contributions to the conception and design of the work. All authors contributed substantially to the acquisition of data. LGA, MMB, and JAT conducted the statistical analyses and drafted the article. All authors revised the article critically for important intellectual content. All authors approved the final version to be published. All authors agreed all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Ethical approval and consent to participate

All participants provided written informed consent, and the study protocol and procedures were approved according to the ethical standards of the Declaration of Helsinki.

Availability of data and material

There are restrictions on the availability of data for the PREDIMED-Plus trial, due to the signed consent agreements around data sharing, which only allow access to external researchers for studies following the project purposes. Requestors wishing to access the PREDIMED-Plus trial data used in this study can make a request to the PREDIMED-Plus trial Steering Committee chair: jordi.salas@urv.cat. The request will then be passed to members of the PREDIMED-Plus Steering Committee for deliberation.

Declaration of competing interest

J.S.-S. reports serving on the board of and receiving grant support through his institution from the International Nut and Dried Fruit Council, and Eroski Foundation. Reports serving in the Executive Committee of the Instituto Danone Spain and on the Scientific Committee of the Danone International Institute. He has received research support from Patrimonio Comunal Olivarero, Spain; and Borges SA, Spain. Reports receiving consulting fees or travel expenses from Danone; Eroski Foundation, Instituto Danone—Spain, and Abbot Laboratories.

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References

[1] Alberti KGMM, Eckel RH, Grundy SM, Zimmet PZ, Clleman JI, Donato KA, et al. Harmonizing the metabolic syndrome: a joint interim statement of the international diabetes federation task force on epidemiology and prevention; National heart, lung, and blood institute; American heart association; World heart federation; International atherosclerosis society; and international association for the study of obesity. Circulation 2009;120(16):1640−5.

[2] Moreira GC, Cipullo JP, Ciorlia LAS, Cesarino CB, Vilela-Martin JF. Prevalence of metabolic syndrome: association with risk factors and cardiovascular complications in an urban population. PloS One 2014;9(9):e105056.
[3] Myers J, Kokkinos P, Nyelin E. Physical activity, cardiorespiratory fitness, and the metabolic syndrome. Nutrients 2019;11(7):1652.
[4] Lavie CJ, Ozemek C, Carbone S, Katzmarzyk PT, Blair SN. Sedentary behavior, exercise, and cardiovascular health. Circ Res 2019;124(5):799–815.
[5] Westheim A, Os I. Physical activity and the metabolic cardiovascular syndrome. J Cardiovasc Pharmacol 1992;20(Suppl 8):S49–53.
[6] Grundy SM. Metabolic syndrome update. Trends Cardiovasc Med 2016;26:364–73.
[7] Babio N, Toledo E, Estruch R, Ros E, Martínez-González MA, Castañer O, et al. Mediterranean diets and metabolic syndrome status in the PREDIMED randomized trial. CMAJ (Can Med Assoc J) 2014;186(17):E649–57.
[8] Di Daniele N, Noce A, Vidiri MF, Moriconi E, Marrone G, Annicchiarico-Petruzzelli M, et al. Impact of Mediterranean diet on metabolic syndrome, cancer and longevity. Oncotarget 2017;8(5):8947–79.
[9] Grosso G, Marventano S, Yang J, Micek A, Pajak A, Scalfi L, et al. A comprehensive meta-analysis on evidence of Mediterranean diet and cardiovascular disease: are individual components equal? Crit Rev Food Sci Nutr 2017;57(15):3218–32.
[10] Garcia-Arellano A, Martínez-González MA, Ramallal R, Salas-Salvadó J, Hébert JR, Corella D, et al. Dietary inflammatory index and all-cause mortality in large cohorts: the SUN and PREDIMED studies. Clin Nutr 2019;38(3):1221–31.
[11] Namazi N, Larijani B, Azadbakht L. Dietary inflammatory index and its association with the risk of cardiovascular diseases, metabolic syndrome, and mortality: a systematic review and meta-analysis. Horm Metab Res 2018;50(5):345–58.
[12] Kazaz İ, Angin E, Kabaran S, İyigün G, Kirmizigil B, Malkoç M. Evaluation of the physical activity level, nutrition quality, and depression in patients with metabolic syndrome: comparative study. Medicine (Baltim) 2018;97(18):e0485.
[13] Pan A, Keum N, Okereke OI, Sun Q, Kivimaki M, Rubin RR, et al. Bidirectional association between depression and metabolic syndrome. Diabetes Care 2012;35(5):1171–80.
[14] DeBoer MD, Gurka MJ, Woo JG, Morrison JA. Severity of the metabolic syndrome as a predictor of type 2 diabetes between childhood and adulthood: the Princeton Lipid Research Cohort Study. Diabetologia 2015;58(12):2745–52.
[15] Wiley JF, Carrington MJ. A metabolic syndrome severity score: a tool to quantify cardio-metabolic risk factors. Prev Med 2016;88:189–95.
[16] Gallardo-Alfaro L, BibiloniMM, Mascaró CM, Montemayor S, Ruiz-Canela M, Salas-Salvadó J, et al. Leisure-time physical activity, sedentary behaviour and diet quality are associated with metabolic syndrome severity: the PREDIMED-plus study. Nutrients 2020;12(4):1013.
[17] Martínez-González MA, Buil-Cosiales P, Corella D, Bulló M, Fitó M, Vioque J, et al. Cohort Profile: design and methods of the PREDIMED-Plus randomized trial. Int J Epidemiol 2019;48(2):387–388o.
[18] Sanz J, Navarro ME, Vázquez C. Adaptación española para el Inventario de Depresión de Beck-II (BDI-II). Propiedades psicométricas en estudiantes universitarios. Análisis y Modificación de Conducta. Universidad de Huelva. 2003;124(29):239–88.
[19] Amato MC, Giordano C. Visceral adiposity index: an indicator of adipose tissue dysfunction. *Int J Endocrinol.* Hindawi Publishing Corporation. 2014:730827.
[20] Guerrero-Romero F, Simental-Mendía LE, González-Ortiz M, Martínez-Abundis E, Ramos-Zavala MG, Hernández-González SO, et al. The product of triglycerides and glucose, a simple measure of insulin sensitivity. Comparison with the euglycemic-hyperinsulinemic clamp. J Clin Endocrinol Metab 2010;95(7):3347–51.
[21] Topolski TD, LoGerfo J, Patrick DL, Williams B, Walwick J, Patrick MB. The Rapid assessment of physical activity (RAPA) among older adults. Prev Chronic Dis 2006;3(4):A118.
[22] Molina L, Sarmiento M, Peñafiel J, Donaire D, Garcia-Aymerich J, Gomez M, et al. Validation of the REGICOR short physical activity questionnaire for the adult population. PloS One 2017;12(1):E0168148.
[23] Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett Jr DR, Tudor-Lock C, et al. Compendium of physical activities: a second update of codes and MET values. Med Sci Sports Exerc 2011;43(8):1575–81. 2011.
[24] Jones CJ, Rikli RE, Beam WC. A 30-s chair-stand test as a measure of lower body strength in community-residing older adults. Res Q Exerc Sport 1999;70(2):113–9.
[25] Martínez-González MA, López-Fontana C, Varo JJ, Sánchez-Villegas A, Martinez JA. Validation of the Spanish version of the physical activity questionnaire used in the Nurses' health study and the health professionals' follow-up study. Publ Health Nutr 2005;8(7):920–7.
[26] Fernández-Ballart JD, Piñol JL, Zazpe I, Corella D, Carrasco P, Toledo E, et al. Relative validity of a semi-quantitative food-frequency questionnaire in an elderly Mediterranean population of Spain. Br J Nutr 2010;103(12):1808–16.
[27] Moreiras O, Carbajal A, Cabrera L, Cuadrado C. Tablas de composición de alimentos [Food composition tables. 17th ed. Madrid (Spain): Piramide; 2015.
[28] Shivappa N, Steck SE, Hurley TG, Hussey JR, Hébert JR. Designing and developing a literature-derived, population-based dietary inflammatory index. Publ Health Nutr 2014;17(8):1689–96.
[29] Liu X, Luo X, Liu Y, Sun X, Han C, Zhang L, et al. Resting heart rate and risk of metabolic syndrome in adults: a dose–response meta-analysis of observational studies. Acta Diabetol 2017;54(3):223–35.
[30] Rodda J, Walker Z, Carter J. Depression in older adults. BMJ 2011;343:d5219.
[31] Zhang D, Liu X, Liu Y, Sun X, Wang B, Ren Y, et al. Leisure-time physical activity and incident metabolic syndrome: a systematic review and dose-response meta-analysis of cohort studies. Metabolism 2017;75:36–44.
[32] Rennie KL, McCarthy N, Yazdgerdi S, Marmot M, Brunner E. Association of the metabolic syndrome with both vigorous and moderate physical activity. Int J Epidemiol 2003;32(4):600–6.
[33] Lee I-M, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT, et al. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 2012;380(9838):219–29.
[34] Mehmet H, Yang AWH, Robinson SR. What is the optimal chair stand test protocol for older adults? A systematic review. Disabil Rehabil 2019;24:1–8.
[35] Atlantis E, Martin SA, Haren MT, Taylor AW, Wittert GA, Members of the Florey Adelaide Male Ageing Study. Inverse associations between muscle mass, strength, and the metabolic syndrome. Metabolism 2009;58(7):1013–22.
[36] Pedrero-Chamizo R, Gómez-Cabello A, Delgado S, Rodríguez-Llarena S, Rodríguez-Marroyo JA, Cabanillas E, et al. Physical fitness levels among independent non-institutionalized Spanish elderly: the elderly EXERNET multi-center study. Arch Gerontol Geriatr 2012;55(2):406–16.
[37] Brandhorst S, Longo VD. Dietary restrictions and nutrition in the prevention and treatment of cardiovascular disease. Circ Res 2019;124(6):952–65.
[38] Esposito K, Maiorino MI, Bellastella G, Panagiotakos DB, Giugliano D. Mediterranean diet for type 2 diabetes: cardiometabolic benefits. Endocrine 2017;56(1):27–32.
[39] Estruch R, Ros E, Salas-Salvadó J, Covas MI, Corella D, Arós F, et al. Primary prevention of cardiovascular disease with a Mediterranean diet supplemented with extra-virgin olive oil or nuts. N Engl J Med 2018;378(25).
[40] Kim Y, Je Y. Meat consumption and risk of metabolic syndrome: results from the Korean population and a meta-analysis of observational studies. Nutrients 2018;10(4).
[41] Hooper L, Martin N, Abdelhamid A, Smith GD. Reduction in saturated fat intake for cardiovascular disease. Cochrane Database Syst Rev 2015;6:CD011737.
[42] Oteng A-B, Kersten S. Mechanisms of action of trans fatty acids. Adv Nutr 2019:nmz125.
[43] Agodi A, Maugeri A, Kunzova S, Sochor O, Bauerova H, Kiacova N, et al. Association of dietary patterns with metabolic syndrome: results from the Kardiovize Brno 2030 Study. Nutrients 2018;10(7):E898.

[44] Martínez Steele E, Juul F, Neri D, Rauber F, Monteiro CA. Dietary share of ultra-processed foods and metabolic syndrome in the US adult population. Prev Med 2019;125:40–8.
[45] Tørris C, Småstuen MC, Molin M. Nutrients in fish and possible associations with cardiovascular disease risk factors in metabolic syndrome. Nutrients 2018;10(7):E952.
[46] Tortosa-Caparrós E, Navas-Carrillo D, Marín F, Orenes-Piñero E. Anti-inflammatory effects of omega 3 and omega 6 polyunsaturated fatty acids in cardiovascular disease and metabolic syndrome. Crit Rev Food Sci Nutr 2017;57(16):3421–9.
[47] Li H, Li X, Yuan S, Jin Y, Lu J. Nut consumption and risk of metabolic syndrome and overweight/obesity: a meta-analysis of prospective cohort studies and randomized trials. Nutr Metab (Lond) 2018;15:46.
[48] Tian Y, Su L, Wang J, Duan X, Jiang X. Fruit and vegetable consumption and risk of the metabolic syndrome: a meta-analysis. Publ Health Nutr 2018;21(4):756–65.
[49] Miller V, Mente A, Dehghan M, Rangarajan S, Zhang X, Swaminathan S, et al. Fruit, vegetable, and legume intake, and cardiovascular disease and deaths in 18 countries (PURE): a prospective cohort study. Lancet 2017;390(10107):2037–49.
[50] Sacks FM, Willett WC, Smith A, Brown LE, Rosner B, Moore TJ. Effect on blood pressure of potassium, calcium, and magnesium in women with low habitual intake. Hypertension 1998;31(1):131–8.
[51] Wu Y, Li S, Wang W, Zhang D. Associations of dietary vitamin B1, vitamin B2, niacin, vitamin B6, vitamin B12 and folate equivalent intakes with metabolic syndrome. Int J Food Sci Nutr 2020:1–12.
[52] Jiang Y-T, Zhang J-Y, Liu Y-S, Chang Q, Zhao YH, Wu QJ. Relationship between legume consumption and metabolic syndrome: a systematic review and meta-analysis of observational studies. NutrMetab Cardiovasc Dis 2019;30(3):384–92.
[53] Oh C, No JK. Appropriate protein intake is one strategy in the management of metabolic syndrome in Korean elderly to mitigate changes in body composition. Nutr Res 2018;51:21–8.
[54] Aune D, Keum N, Giovannucci E, Fadnes LT, Boffetta P, Greenwood DC, et al. Whole grain consumption and risk of cardiovascular disease, cancer, and all cause and cause specific mortality: systematic review and dose-response meta-analysis of prospective studies. BMJ 2016;353:i2716.
[55] Martin O Weickert, Pfeiffer Andreas FH. Impact of dietary fiber consumption on insulin resistance and the prevention of type 2 diabetes. J Nutr 2018;148(1):7–12.
[56] Gaesser GA. Perspective: refined grains and health: genuine risk, or guilt by association? Adv Nutr 2019;10(3):361–71.
[57] Wood RJ, Fernandez ML. Carbohydrate-restricted versus low-glycemic-index diets for the treatment of insulin resistance and metabolic syndrome. Nutr Rev 2009;67(3):179–83.