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Effects of a multicomponent training followed by a detraining period on metabolic syndrome profile of older adults

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ABSTRACT

Aims: The present study sought to analyze the effects of 6-month multicomponent training (MCT) combined with a 4-month detraining on metabolic syndrome (MetS) profile among older adults with decreased functional capacity.

Methods: This quasi-experimental study included a total of 104 older adults (80.5 ± 6.0 years) and the sample was divided into a training (TRAIN, $n = 55$) or control group (CON). Harmonized definition was used to diagnose the MetS. Functional capacity, blood biochemical parameters, blood pressure, body composition and anthropometric measurements were assessed 3 times. Analysis of variance for repeated measures and Wilcoxon signed-rank test were used to check the differences within groups.

Results: TRAIN decreased diastolic blood pressure (DBP), high-density lipoprotein cholesterol (HDL—C) and total fat mass during training period, whereas CON did not show any significant changes. During detraining, TRAIN increased HDL—C, systolic blood pressure (SBP), waist circumference (WC) and total fat mass; and decreased glucose and fat free mass, whereas CON increased the concentration of glucose and HDL—C. From baseline to post-detraining assessment, CON increased the concentration of triglycerides and the WC, while TRAIN only increased the WC (all $p < 0.05$).

Conclusions: Exercise can be a key component in the treatment of the MetS, since MCT seems to be effective to decrease DBP and total fat mass. Nevertheless, 4-months of detraining could cause a drop of total fat mass, but no in DBP. To avoid reversibility of the benefits obtained, it could be beneficial to promote continuing exercise programs.

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1. Introduction

Current lifestyles and health policies in industrialized countries have led to substantial increase of lifespan, but simultaneously there has also been a marked decrease of physical activity (PA). This has promoted the progressive rise, already among middle-aged adults and even more in older adults, of metabolic diseases that expose these patients to increased cardiovascular morbidity (Bruseghini et al., 2015).

Metabolic syndrome (MetS) is defined as a cluster of conditions that includes central obesity, high blood pressure (BP), dyslipidemia, and hyperglycemia or insulin resistance (IR) (Tan et al., 2013). It is often associated with several health disorders such as type 2 diabetes mellitus (T2DM), cardiovascular disease (CVD), prothrombotic state, cancer, and a low level of physical fitness (Finley et al., 2006; "Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III) Final Report,", 2002; Uzunlulu et al., 2016). People with MetS have a 2-fold increased risk of developing CVD and a 5-fold increased risk of developing T2DM than those without MetS (Isomaa et al., 2001; Wilson et al., 2005), placing a huge economic burden on public health services. For instance, in Spain, the projected burden was €1900 million by 2020 (Scholze et al., 2010).

MetS affects from 20 % to 25 % of the world's adult population (Moreira et al., 2014). However, it seems that the prevalence of people with MetS changes depending on the criteria (Amirfaiz and Shahril, 2019; Subías-Perié et al., 2022a), sex (Amirfaiz and Shahril, 2019; World Health Organization., 2015), age (Bull et al., 2020; Myers et al., 2019) and ethnicity of the population used (Alberti et al., 2009; Ervin, 2009). Related to the criteria, the National Cholesterol Education Program-Third Adult Treatment Panel III (NCEP-ATP III) and Harmonized definitions are the recommended definitions to evaluate the prevalence of MetS (Amirfaiz and Shahril, 2019).

One of the major current discussions in relation to the MetS is the pathophysiology, the underlying cause of the MetS continues to challenge the experts but it seems that IR is the most significant factor (Swarup et al., 2022). IR causes microvascular damage, which predisposes a patient to a dysfunction and a wall inflammation of the endothelium. Endothelial dysfunction plus low-density lipoprotein cholesterol (LDL-C) can cause atherosclerotic disease and hypertension. Moreover, hypertension increases vascular resistance, and causes peripheral vascular disease, left ventricular hypertrophy, cardiomyopathy, and renal impairment. So, hypertension and endothelial dysfunction can further result in ischemic heart disease (Ravaglia et al., 2006; Swarup et al., 2022). Furthermore, genetics, physical inactivity, aging, oxidative stress and proinflammatory state may also have a causal effect, but their role can vary depending on different factors as ethnicity, sex, and age group, among others (Golbidi et al., 2012; International Diabetes Federation., 2006). Taking into account that IR and central obesity are important factors in the development of MetS, it is necessary changing of lifestyles of the population to reduce obesity prevalence and to increase PA (Alberti et al., 2009; International Diabetes Federation., 2006).

Moving on now to consider the effects of exercise on MetS profile, there are several meta-analyses that show the key role of exercise on MetS. A meta-analysis among adult population concluded that aerobic exercise significantly improved waist circumference (WC; average reduction = 3.4 cm); fasting plasma glucose (FPG; average reduction = 0.15 mmol/L); high-density lipoprotein cholesterol (HDL—C; average increase = 0.05 mmol/L); triglycerides (TGs; average reduction = 0.29 mmol/L); and diastolic blood pressure (DBP; average reduction = 1.6 mmHg) among other cardiovascular risk factors. Moreover, sub-analyses suggested that aerobic exercise with vigorous intensity and conducted 3 days/week for ≥12 weeks, offered larger and more widespread improvements. However, no significant effects were determined following resistance training possibly due to limited data (Wewege et al., 2018). Previously, Naci et al. (Naci and John, 2013) reported that exercise and many drug interventions were often potentially similar in terms of their mortality benefits in the secondary prevention of coronary heart disease, rehabilitation after stroke, treatment of heart failure and prevention of T2DM. Another meta-analysis compared the effects of exercise intervention and sedentary controls in subjects with a clinical diagnosis of MetS at baseline, observing that exercise group had a greater reduction in body mass index (BMI), WC, DBP, systolic blood pressure (SBP), FPG, TGs and LDL-C. Also, they described similar changes in combined aerobic and resistance exercise (Ostman et al., 2017).

The main benefits of exercise on MetS are the increase in antioxidant capacity and the induction of anti-inflammatory effects (Ravaglia et al., 2006; Swarup et al., 2022). Moreover, exercise regulates fat and glucose metabolism which increases the action of insulin, reduces BP and improves BP control in overweight adult subjects (Golbidi et al., 2012). Specifically, multicomponent training (MCT) is recommended by the World Health Organization (WHO) (Bull et al., 2020), because it is one of the most effective exercise programs to improve metabolic outcomes, functional capacity, cardiorespiratory fitness and quality of life of older adults (Bouaziz et al., 2016; Cadore et al., 2013). The MCT includes a combination of aerobic, strength, power, gait and balance training programs, and/or flexibility, and they should add gradual increases in the volume, intensity, and complexity of the individual exercises; being the most commonly used in older adults (Bouaziz et al., 2017, 2016; Subías-Perié et al., 2022b). Despite the above, the effects of MCT on MetS should be studied more deeply, particularly in older adults. Furthermore, admitting that periods of detraining have been shown to have a negative effects on functional capacity and frailty of older adults (Fernández-García et al., 2022), to the best of our knowledge there are not studies analyzing the impact of a detraining period on MetS risk factors in this population.

We hypothesized that, in older adults, 6-month MCT improve the MetS profile, but 4-month detraining could reduce the improvements on MetS and even return to the baseline values. Therefore, the main objectives of this study were to analyze the effects of a 6-month MCT and 4-month detraining period on MetS profile among older adults with decreased functional capacity, and to analyze the influence of exercise intervention in the risk of developing MetS in this population.

2. Materials and methods

2.1. Study design and participants

This quasi-experimental study was carried out between 2018 and 2020 within the framework of the EXERNET-Elder 3.0 project (Fernández-García et al., 2020). Participants were recruited from 3 nursing homes and 4 healthcare centres from Zaragoza, Spain. In order to be included, participants had to fulfil the following criteria: (a) being older than 65 years; (b) having a decreased functional capacity (4–9 points) according to the cut-off points of the Short Physical Performance Battery (SPPB) (Guralnik et al., 2000; Treacy and Hassett, 2018); (c) not suffering dementia and/or cancer. In total, 169 older adults were initially derived from the centers mentioned above, but only 104 people met the inclusion criteria and were enrolled in the study. A total of 99 participants (training group [TRAIN], $n = 54$) performed the first 6-month of the study protocol; and finally, 97 participants (TRAIN, n = 54) completed the whole study protocol (Fig. 1).

Participants were designed by convenience into the control group (CON) or TRAIN to magnify training attendance according to participant's preferences and availability. Both participants and researchers were aware of the allocation, so no blinding was performed. The TRAIN performed a supervised 6-month MCT followed by a 4-month detraining period, in which they continued with their routine activities, whereas the CON followed their usual lifestyle during the whole course of the project but underwent identical testing to the TRAIN at baseline and follow-ups. Both groups were evaluated 3 times: at the baseline assessment (T0), at the post-training assessment (T1), and at the post-detraining assessment (T2). Moreover, during the full project,

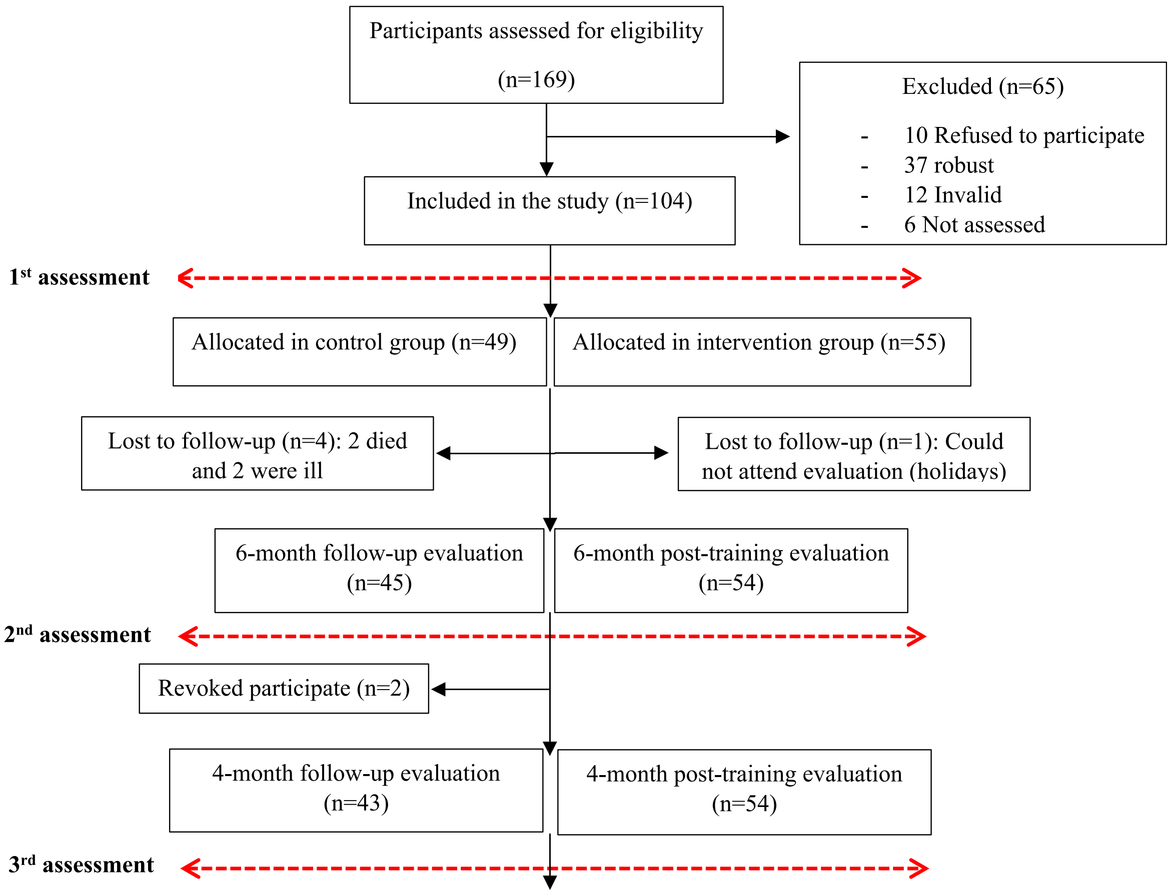

Fig. 1. Flow chart of participant recruitment and follow-up.

participants of both groups received 3 talks related to healthy habits in order to engage CON participants along the study, reducing the possible drop off caused by multiple evaluation periods. The topics of these talks were the following: "Functional capacity and frailty", "Nutritional recommendations for older people", and "Physical exercise to improve health in older people". These talks were delivered by a certified sport scientist, nurse and nutritionist.

The health outcomes were compiled with personal interviews using a structured questionnaire and the pharmacological treatment was collected from the electronic prescription of the National Health System, followed by physical analysis to evaluate functional capacity, body composition and anthropometric measurements according to standardized and objective protocols. Furthermore, a biochemical analysis was performed to analyze glucose, TGs, HDL—C, LDL-C and total cholesterol (TC). Moreover, BP was measured to learn the SBP and DBP. This study was registered in the electronic repository clinicaltrials.gov (reference number: NCT03831841).

2.2 Ethics statement

All potential participants received oral and written information about the aims, possible benefits and risks derived from participation in this study. Afterwards, written informed consent was obtained from all the included participants. The study was performed in accordance with the Ethical Guidelines of the Declaration of Helsinki of 1961, revised in Fortaleza, Brazil (World Medical Association, 2013) and the current legislation of human clinical research of Spain (Law 14/2007). The study protocol was approved by the Hospital Universitario Fundación de Alcorcón Ethics Committee (16/50).

2.2. *Multicomponent training program*

The MCT was carried out between January and June 2019 and consisted of a 6-month period. All training sessions were supervised by four specialized exercise professionals. Each session had a maximum of 16 participants and an instructor-to-participant ratio of 1:12. All of them always trained in the same group of participants and, to reduce inter-professional variability during the exercise program, the exercise professionals were trained to standardize the training protocol.

Summarizing, this exercise program consisted of a 6-month MCT of three supervised sessions per week of 1-h duration. The first and third weekly sessions, called "Strength and Functional sessions", were used to improve strength, power and static balance through exercises and tasks that simulated activities of daily living. On the second weekly session, named "Endurance sessions", participants carried out aerobic basic exercises such as walking, steps and stationary cycle in addition to agility, coordination and motor skill tasks. To avoid excessive muscle fatigue, sessions were separated by 48 h. All sessions included 10 min of warm-up (joint mobility and cardiorespiratory exercises), 35–40 min of main part exercises and 10–15 min of cool down, involving flexibility, breathing control and a cognitive task.

During the whole intervention period, to assure that stimulus was appropriate to cause body adaptations there was a progression of the training. Moreover, each session was adapted to different levels to individualize exercises depending on participant's characteristics and functional capacity status. The attendance of TRAIN participants was recorded by the exercise professionals.

2.3. Functional capacity

The SPPB measures functional status according to level of balance, usual gait speed and lower limb strength. In order to assess performance, each task was scored from 0 to 4 with a total battery score of 12 points (Guralnik et al., 1994; Treacy and Hassett, 2018) and three main functional stages: invalid (0–3 points), decreased functional capacity (4–9 points) and maintained functional capacity (10–12 points). Invalid and maintained functional capacity participants were not included in the sample of this report.

2.4. Metabolic syndrome

Harmonized definition (Alberti et al., 2009) was the criteria to diagnose MetS in this report, because it is one of the most commonly used (Amirfaiz and Shahril, 2019) and also because its superior agreement (k index = 1.000) (Subías-Perié et al., 2022a) with International Diabetes Federation (IDF) definition (International Diabetes Federation., 2006). Sex and population specific thresholds were used to measure the total of MetS conditions as proposed by the Harmonized definition (glucose ≥100 mg/dL or drug treatment; WC > 80 for women and > 94 cm for men; SBP ≥ 130 and/or DBP ≥ 85 mmHg or drug treatment; TGs ≥ 150 mg/dL or drug treatment; and HDL-C < 40 for men and < 50 mg/dL for women or drug treatment). Participants were categorized as having MetS if they have three or more of those five conditions.

2.5. Biochemical parameters

All participants were fasting during the blood test, and it was performed through venous puncture in the antecubital fossa (cephalic, basilic or median cubital veins), using a 21-gauge butterfly needle (BD Vacutainer Safety-Lok., BD Biosciences, North Ryde, NSW 2113, Australia) with four different 4 mL Vacutainer® tubes (BD Biosciences, Australia), one containing citrate and three containing ethylenediaminetetraacetic acid (EDTA). Blood samples for biochemical analysis were obtained from all participants between 8:00 and 10:00 a.m., were centrifuged at 3500 rpm for 10 min, and were clotted at room temperature. Serum analysis was performed within 24 h after collection.

2.6. Blood pressure

The measurement protocol of the European Society of Cardiology (ESC) and the European Society of Hypertension (ESH) has been followed to measure the BP (Williams et al., 2018). It was measured at the sitting comfortable position in a quiet environment, using a digital and calibrated sphygmomanometer Omron Automatic BP Monitor (OMRON M6 COMFORT IT [HEM-7322U-E] Kyoto, Japan), with an appropriate cuff size for the arm circumference. BP initially was measured in both upper arms, and the arm with the higher BP values was used for all subsequent measurements. Three BP measurements were recorded, 1–2 min apart, and additional measurements were taken only if the first two readings differ by >10 mmHg. BP was recorded as the average of the last two BP readings. BP measurements were taken by experienced nurses.

2.7. Body composition and anthropometric measurements

A body composition analyser based on Bio-Electrical Impedance Analysis with 200 kg maximum capacity and 50 g error margin (TANITA BC-418MA, Tanita Corp., Tokyo, Japan) was used to measure the body weight (kg), body fat percentage (%), total fat mass (kg) and fat free mass (kg). Participants removed their shoes and heavy clothes before weighing. All measurements were performed at same hour, with empty bladder and same conditions for all participants and evaluations.

Anthropometric measurements were registered according to the International Society for the Advancement of Kinanthropometry (ISAK) protocol (Marfell-Jones et al., 2012) by two researchers accredited as ISAK level 1 anthropometrists. A portable stadiometer with 2.10 m maximum capacity and 1 mm error margin (Seca, Hamburg, Germany) was used to measure height. WC and hip circumferences were taken using a flexible non-elastic measuring tape Rosscraft Anthrotape (Rosscraft Innovations Inc., Vancouver, BC, Canada). Measures were performed twice, and the mean was calculated. If there were incongruences between the first two evaluations, a third measure was done, and the median was calculated. The waist-to-hip ratio (WHR) is an indicative of regional fat distribution, and it was determined using the formula as WC divided by hip circumference.

2.8. Statistical analysis

Statistical Package for the Social Sciences v. 25.0 for Windows (IBM SPSS, Inc., Chicago, IL, USA) was used for all statistical analyses. Continuous variables are presented as mean and standard deviation for normally distributed variables. Median (interquartile range) for those showing no normal distribution. The statistical significance level was set at $p < 0.05$ in all tests. Shapiro–Wilk test was used to analyze the distribution of the variables. Glucose and HDL-C did not show normal distribution.

Sample size was calculated for a power of 80 % and 5 % alpha level and reject the null hypothesis H0: $\mu 1 = \mu 2$. Assuming a medium-large effect size (f = 0.30) and a correlation among repeated measures 0.5, a total sample size of 68 (34 per group) would be needed. However, the sample was incremented a 30 % to contemplate possible losses during follow-up. Thus, the total final sample needed was 90 participants.

Independent t-test was used to examine differences between groups in descriptive characteristics. Mann-Whitney U test was used for those that did not show a normal distribution. Crosstabs were used to calculate the Odds Ratios (ORs) of each group individually and the total sample to develop MetS for the three different assessments with a 95 % confidence interval. Analysis of variance (ANOVA) for repeated measures was used to check differences within and between TRAIN and CON groups, for normally distributed variables. Wilcoxon signed-rank test was performed for those that did not show a normal distribution. Group by time interactions could only be applied for normally distributed variables.

Effect size statistics using Cohen's d were calculated for the independent t-test, partial eta square (η^2p) for repeated measures analyses, and effect size r for Mann-Whitney U and Wilcoxon signed-rank tests. The effect size for Cohen's d can be large (>0.8), medium (0.8–0.5) or small (<0.5–0.2); η^2p can be large (>0.14), medium (0.14–0.06) or small (<0.06–0.01); and r can be large (>0.5), medium (0.5–0.3) or small (<0.3–0.1).

3. Results

Descriptive characteristics of the included participants are shown in Table 1. Weight, height and WHR showed significant differences between TRAIN and CON groups at the T0 (Cohen's d ranged from 0.47 to 0.67; $p < 0.05$). Regarding attendance, the average rate collected by TRAIN participants was 83.2 ± 10.6 %.

The effects of 6-month MCT on MetS parameters of TRAIN and CON groups are shown in Table 2. There were no differences between groups in the evaluated variables for this period (Cohen's ranged from 0.01 to 0.32 and r ranged from 0.02 to 0.15; $p > 0.05$). TRAIN decreased the DBP and the concentration of HDL-C (η^2p was 0.00 and r was 0.36, respectively; p < 0.05) from the T0 to the T1. However, CON did not show significant changes for this period. No group by time interactions were found for the first 6-month of exercise intervention.

Moreover, the effect of 6-month MCT on body composition measurements of both groups are detailed in Table 3 (Supplementary material). There were no differences between groups in the evaluated variables for this period (Cohen's ranged from 0.01 to 0.30; p > 0.05). TRAIN decreased the body fat percentage and total fat mass (η^2p were 0.084 and 0.077, respectively; p < 0.05) from the T0 to the T1. No group

Table 1
Socio-demographic, anthropometrics, body composition, and serum biochemical characteristics of the subjects.

Characteristics	TRAIN (n = 55)	CON (n = 49)	p-Value	Effect size d or r
Socio-demographic				
Age (y.)	81.2 ± 6.2	79.8 ± 5.7	0.694	0.10
Anthropometrics and body composition				
Weight (kg)	76.6 ± 14.6	69.8 ± 14.3	0.022#	0.47
Height (cm)	159.6 ± 9.0	155.2 ± 7.7	0.016#	0.53
BMI (kg/m^2)	30.3 ± 5.1	29.2 ± 6.1	0.379	0.20
Body fat (%)	37.3 ± 6.6	37.2 ± 8.0	0.999	0.01
FFM (kg)	44.8 ± 8.0	41.6 ± 7.6	0.122	0.41
Hip circumference (cm)	104.5 ± 8.7	105.1 ± 11.7	0.791	0.06
WHR	0.91 ± 0.08	0.86 ± 0.07	0.010#	0.67
Serum Biochemical				
LDL-C (mg/dL)	99.0 ± 34.0	99.0 ± 31.3	0.998	0.00
TC (mg/dL)	172.6 ± 32.8	174.2 ± 41.1	0.833	0.04

Data are presented as mean ± standard deviation.
Abbreviations: BMI, Body mass index; CON, Control group; d, Cohen's d; FFM, Fat free mass; LDL-C: Low-density lipoprotein cholesterol; n, Number of participants of the sample; r, effect size r; TC, Total cholesterol; TRAIN, Training group; WHR, Waist-to-hip ratio.
[#] Significant differences when compared training and control groups at the baseline assessment. Significant level was set at 0.05.

by time interactions were found for the first 6-month of exercise intervention.

The effects of 4-month detraining period on MetS parameters of TRAIN and CON groups are shown in Table 4. TRAIN demonstrated a higher SBP and lower WC than CON at the T1 and T2 (Cohen's d ranged from 0.02 to 0.49, respectively; $p < 0.05$). There were no differences between groups for the other evaluated variables (Cohen's d ranged from 0.07 to 0.36 and r ranged from 0.02 to 0.10; $p > 0.05$). TRAIN decreased the concentration of glucose level (r was 0.42; p < 0.05), whereas CON increased this variable (r was 0.50; p < 0.05). Moreover, both groups increased concentration of HDL-C levels (CON: r was 0.37, $p = 0.017$; TRAIN: r was 0.43, $p = 0.002$). Additionally, TRAIN increased the SBP (η^2p was 0.04; $p = 0.046$), and the WC (η^2p was 0.05; $p = 0.045$). No group by time interactions were found for the last 4-month of detraining.

Furthermore, the effects of 4-month detraining period on body composition measurements of both groups are detailed in Table 5 (Supplementary material). TRAIN decreased the fat free mass (η2p was 0.172; p < 0.05), and both groups increased the body fat percentage and total fat mass (TRAIN: η2p were 0.276 and 0.236, respectively; CON: η2p were 0.121 in these variables; all $p < 0.05$) from the T1 to the T2.

The effects of 6-month MCT followed by a 4-month detraining period on MetS profile of both groups are presented in Table 6. CON increased the concentration of TGs (η^2p was 0.051; $p = 0.040$) and the WC (η^2p was 0.019; p < 0.001) from T0 to T2, while TRAIN only increased the WC (η^2p was 0.022; $p < 0.001$). Group by time interactions were found for WC (η^2p was 0.410; $p = 0.009$). This interaction demonstrated that the increase in WC was higher in CON than TRAIN.

Table 7 shows the ORs of each group individually and the total sample to develop MetS for the three different assessments. TRAIN decreased the percentage of people with the MetS a 22.6 %, and the ORs from 1.01 (0.72–1.40) to 0.83 (0.65–1.08) during training period, but during detraining period this percentage increased a 19.7 % and the ORs until 1.03 (0.73–1.44). Nevertheless, CON decreased the percentage of people with MetS an 8.8 % and the ORs increased from 0.99 (0.62–1.57) to 1.69 (0.83–3.45) during intervention period, but during detraining this percentage increased a 5.0 % and the ORs decreased until 0.96 (0.55–1.69).

4. Discussion

The main findings of this study are that a 6-month MCT seems to improve the risk factors of MetS and reduce the risk of suffering MetS in older adults with decreased functional capacity, improving

Table 2
Effects of exercise intervention on metabolic syndrome parameters of the subjects.

				Within		Group by time interaction
				TRAIN	CON	η^2p
Variables	TRAIN	CON	Effect size d or r	p-Value (η^2p or r)	p-Value (η^2p or r)	p-Value (η^2p or r)
Glucose (mg/dL)[a]						
T0 (n = 55/46)	97.0 (90.0–108.0)	99.5 (89.0–124.0)	0.15			
T1 (n = 52/42)	96.5 (87.5–108.7)	92.5 (83.7–103.2)	0.10	0.490 (0.090)	0.066 (0.270)	–
HDL-C (mg/dL)[a]						
T0 (n = 55/46)	53.0 (43.0–60.0)	47.0 (39.0–62.5)	0.08			
T1 (n = 52/42)	48.5 (37.2–59.7)	46 (40.7–61.0)	0.02	0.007 * (0.360)	0.518 (0.100)	–
TGs (mg/dL)	(n = 52)	(n = 39)				
T0	127.6 ± 50.0	129.8 ± 55.0	0.04	0.941 (0.000)	0.312 (0.011)	0.474 (0.006)
T1	127.1 ± 50.6	123.1 ± 58.0	0.07			
SBP (mmHg)	(n = 54)	(n = 44)				
T0	138.6 ± 14.9	137.3 ± 16.9	0.08	0.289 (0.008)	0.081 (0.031)	0.466 (0.006)
T1	136.6 ± 15.8	132.7 ± 17.0	0.24			
DBP (mmHg)	(n = 54)	(n = 44)				
T0	76.1 ± 11.6	72.4 ± 7.7	0.32	0.048* (0.000)	0.339 (0.010)	0.924 (0.000)
T1	74.0 ± 10.2	71.2 ± 8.9	0.29			
WC (cm)	(n = 52)	(n = 37)				
T0	96.8 ± 12.0	94.1 ± 13.8	0.21	0.578 (0.004)	0.415 (0.008)	0.327 (0.011)
T1	98.5 ± 10.6	98.4 ± 14.5	0.01			

Data are presented as mean ± standard deviation for normally distributed variables, and median (interquartile range) for those showing no normal distribution.
Abbreviations: CON, Control group; d, Cohen's d; DBP, Diastolic blood pressure; HDL—C, High-density lipoprotein cholesterol; n, Number of participants of the sample; η^2p, partial eta square; r, effect size r; SBP, Systolic blood pressure; T0, Baseline assessment; T1, Post-training assessment; TGs, Triglycerides; TRAIN, Training group; WC, Waist circumference.
[a] These variables were not normally distributed.
[*] Significant differences within groups between the baseline and the post-training assessments. Significant level was set at 0.05.

Table 4
Effects of detraining on metabolic syndrome parameters of the subjects.

				Within		Group by time interaction
				TRAIN	CON	η^2p
Variables	TRAIN	CON	Effect Size d or r	p-Value (η^2p or r)	p-Value (η^2p or r)	p-Value (η^2p or r)
Glucose (mg/dL)[a]						
T1 (n = 52/42)	96.5 (87.5–108.7)	92.5 (83.7–103.2)	0.10	0.002 * (0.420)	0.050* (0.300)	
T2 (n = 54/34)	96.0 (88.7–113.2)	97.5 (92.7–121.0)	0.10			–
HDL-C (mg/dL)[a]						
T1 (n = 52/42)	48.5 (37.2–59.7)	46.0 (40.7–61.0)	0.02			
T2 (n = 54/32)	53.5 (42.0–62.2)	49.0 (41.7–58.7)	0.04	0.002 * (0.430)	0.017* (0.370)	–
TGs (mg/dL)	(n = 52)	(*n* = 27)				
T1	127.1 ± 50.6	120.1 ± 58.2	0.13	0.260 (0.016)	0.214 (0.020)	
T2	132.1 ± 53.4	128.3 ± 57.3	0.07			0.725 (0.002)
SBP (mmHg)	(n = 54)	(n = 39)				
T1	136.8 ± 15.9[#]	132.7 ± 18.1	0.24	0.046 * (0.043)	0.687 (0.002)	
T2	142.3 ± 16.8[#]	134.0 ± 17.1	0.49			0.316 (0.011)
DBP (mmHg)	(n = 54)	(n = 39)				
T1	74.4 ± 9.9	71.0 ± 8.8	0.36	0.239 (0.015)	0.126 (0.026)	
T2	76.1 ± 8.9	73.6 ± 8.3	0.29			0.689 (0.002)
WC (cm)	(*n* = 50)	(*n* = 24)				
T1	98.1 ± 10.4[#]	98.5 ± 14.2	0.03	0.045 * (0.055)	0.289 (0.016)	
T2	99.5 ± 10.8[#]	99.7 ± 13.5	0.02			0.776 (0.001)

Data are presented as mean ± standard deviation for normally distributed variables, and median (interquartile range) for those showing no normal distribution. Abbreviations: CON, Control group; d, Cohen's d; DBP, Diastolic blood pressure; HDL—C, High-Density Lipoprotein cholesterol; n, Number of participants of the sample; η^2p, partial eta square; r, effect size r; SBP, Systolic blood pressure; T1, Post-training assessment; T2, Post-detraining assessment; TGs, Triglycerides; TRAIN, Training group; WC, Waist circumference.

[a] These variables were not normally distributed.

[#] Significant differences when compared training and control groups.

[*] Significant differences within groups between the post-training and the post-detraining assessments. Significant level was set at 0.05.

Table 6
Effects of exercise training followed by a detraining period on metabolic syndrome parameters of the subjects.

				Within		Group by time interaction
				TRAIN	CON	η^2p
Variables	TRAIN	CON	Effect Size d or r	p-Value (η^2p or r)	p-Value (η^2p or r)	p-Value (η^2p or r)
Glucose (mg/dL)[a]						
T0 (*n* = 55/46)	97.0 (90.0–108.0)	99.5 (89.0–124.0)	0,14	0.157 (0.190)	0.137 (0.270)	
T2 (n = 54/34)	96.0 (88.7–113.2)	97.5 (92.7–121.0)	0,10			–
HDL-C (mg/dL)[a]						
T0 (n = 55/46)	53.0 (43.0–60.0)	47.0 (39.0–62.5)	0.08			
T2 (n = 54/32)	53.5 (42.0–62.2)	49.0 (41.7–58.7)	0.04	0.370 (0.120)	0.909 (0.170)	–
TGs (mg/dL)	(n = 54)	(*n* = 29)				
T0	126.7 ± 49.3	120.8 ± 53.1	0.12	0.454 (0.007)	0.040* (0.051)	
T2	130.8 ± 52.9	136.4 ± 58.3	0.10			0.218 (0.019)
SBP (mmHg)	(n = 54)	(*n* = 42)				
T0	138.8 ± 14.8	135.5 ± 18.1	0.20	0.240 (0.015)	0.364 (0.009)	
T2	141.9 ± 16.8	132.9 ± 17.9	0.52			0.146 (0.022)
DBP (mmHg)	(n = 54)	(n = 42)				
T0	76.0 ± 11.6	71.3 ± 7.7	0.48	0.805 (0.001)	0.361 (0.009)	
T2	76.4 ± 9.9	72.8 ± 8.8	0.38			0.601 (0.003)
WC (cm)	(*n* = 51)	(n = 24)				
T0	96.0 ± 11.3	94.9 ± 13.2	0.09	<0.001* (0.224)	<0.001* (0.191)	
T2	99.6 ± 10.7	99.6 ± 13.5	0.00			0.009 (0.410)*

Data are presented as mean ± standard deviation for normally distributed variables, and median (interquartile range) for those showing no normal distribution. Abbreviations: CON, Control group; d, Cohen's d; DBP, Diastolic blood pressure; HDL—C, High-Density Lipoprotein cholesterol; n, Number of participants of the sample; η^2p, partial eta square; r, effect size r; SBP, Systolic blood pressure; T0, Baseline assessment; T2, Post-detraining assessment; TGs, Triglycerides; TRAIN, Training group; WC, Waist circumference.

[a] These variables were not normally distributed.

[*] Significant differences within groups between the baseline and the post-detraining assessments. Significant level was set at 0.05.

cardiovascular health. On the other hand, a 4-month detraining period seems to cause a worsening of their cardiovascular health, but it seems that the detraining period affects cardiometabolic risk factors in different ways. Moreover, this exercise program seems to get protective effects or decrease the risk of cardiometabolic factors, even though it is accompanied by a detraining period. To the best of our knowledge, the present study provides the first information about the effect of a MCT followed by a detraining period on MetS in older adults with decreased functional capacity.

Table 7
Odds ratios of individual groups and total sample to develop MetS for the three different assessments.

Assessments	TRAIN	CON	Odds Ratio (95 % CI)	Kappa Index
T0	(n = 54)	(n = 46)		
MetS	23 (41.8 %)	19 (41.3 %)	TRAIN: 1.01 (0.72–1.40)	0.005
Non-MetS	32 (58.2 %)	27 (58.7 %)	CON: 0.99 (0.62–1.57) TOTAL: 1.02 (0.46–2.26)	
T1	(n = 52)	(n = 40)		
MetS	10 (19.2 %)	13 (32.5 %)	TRAIN: 0.83 (0.65–1.08)	0.122
Non-MetS	42 (80.8 %)	27 (67.5 %)	CON: 1.69 (0.83–3.45) TOTAL: 0.49 (0.19–1.29)	
T2	(n = 54)	(n = 32)		
MetS	21 (38.9 %)	12 (37.5 %)	TRAIN: 1.03 (0.73–1.44)	0.012
Non-MetS	33 (61.1 %)	20 (62.5 %)	CON: 0.96 (0.55–1.69) TOTAL: 1.06 (0.43–2.61)	

Data are presented as frequencies (%). Abbreviations: CI, Confidence interval; CON, Control group; MetS, Metabolic syndrome; n, Number of participants of the sample; T0, Baseline assessment; T1, Po st-training assessment; T2, post-detraining assessment; TOTAL, Training and control groups; TRAIN, Training group.

4.1. Training effects on metabolic syndrome parameters

The MCT has been shown to be effective in reducing the DBP (−2.1 mmHg) in older adults with decreased functional capacity. These results are in line with a meta-analysis performed by Ostman et al. (2017). They reported that aerobic exercise (DBP: −2.27 mmHg; SBP: −2.54 mmHg) and combined aerobic and resistance exercise (DBP: −0.23 mmHg; SBP -3.79 mmHg) could significantly decrease the BP in adults with MetS. Moreover, Wewege et al. (2018) observed that aerobic exercise reduced DBP (−1.6 mmHg) but not SBP, and the resistance exercise did not show significant effects in adults with MetS. Furthermore, a meta-analysis performed by Pattyn et al. (2013) concluded that a dynamic endurance training could get a mean DBP decrease of 5.15 mmHg and 7.11 mmHg of SBP in adults with MetS. In our study, there was a little improvement in DBP and it could be related to the fact that 70 (TRAIN: 33 (22 women); CON: 37 (30 women)) of 104 participants were treated with antihypertensive drugs and began the study with a lower baseline BP (Wright et al., 2018). The type and intensity of exercise could influence in the BP. For example, aerobic exercise seems to show a greater reduction in DBP and SBP than strength or combined training (Ostman et al., 2017; Wewege et al., 2018), and high intensity exercise seems to be more effective than moderate intensity exercise in BP improvement (Leal et al., 2020; Wewege et al., 2018).

The relationship between exercise-induced fat mass reduction and HDL-C level is complex, particularly in older adults. While some studies have reported that aerobic exercise can increase HDL-C levels (Kelley et al., 2005; Pattyn et al., 2013; Wewege et al., 2018), others, including Ostman et al. (2017), have found no significant effects. Resistance and combined exercise have also shown mixed results, with some studies indicating a positive effect on HDL-C (Marques et al., 2009; Ostman et al., 2017), while others have observed no significant change (Wewege et al., 2018). Siu et al. (2021) noted that exercise may attenuate the decrease in HDL-C with aging but may not necessarily increase it, especially in older population where enhancing HDL-C through exercise intervention seems challenging.

Our study observed a modest reduction in fat mass (average reduction = 0.9 kg) and body fat percentage (average reduction = 1 %) in the TRAIN group, which could be linked to a decline in HDL-C concentration. Berglund et al. (2021) found that changes in Vo_2peak, rather than body weight or fat mass, were associated with changes in HDL-C in older individuals. This suggests that the intensity, volume and nature of exercise may play a more critical role than mere changes in body composition. Furthermore, the attenuated response of older women to exercise regarding HDL-C level, as noted by Wilmore (2001) is relevant considering our study's sample composition (75 of 104 participants were women). In addition, Kodama et al. (2007) and Durstine et al. (2001) highlighted that exercise volume and intensity significantly influenced HDL-C levels. It seems that the minimal weekly exercise volume for increasing HDL-C level was estimated to be 900 kcal of energy expenditure per week or 120 min of exercise per week (Kodama et al., 2007), however, better results can be obtained by increasing the energy expenditures to 1200–2200 kcal per week (Durstine et al., 2001). In addition, some researchers reported that vigorous exercise is more effective for improving HDL-C level than moderate exercise (Wewege et al., 2018; Wood et al., 2019). Our MCT was designed to be adaptable to individual functional capacities and was not conducted at vigorous intensity, which may explain its less pronounced effect on HDL-C levels. Lastly, external factors, such as diet, sleep cycles, stress, and alcohol consumption, which were not controlled in our study, can also affect the metabolic response to exercise and thus affect HDL-C concentration (García-Cardona et al., 2015). Moreover, the use of cholesterol-lowering drugs by nearly half of our participants (TRAIN: 25 participants; CON: 24 participants) may have influenced the final HDL-C results.

In summary, the observed decline in HDL-C in our study could be attributed to a combination of factors, including the modest reduction in fat mass and body fat percentage, the nature, volume and intensity of the exercise program, the demographic composition of our sample, uncontrolled external factors, and the use of cholesterol-lowering drugs.

Currently, the role of HDL-C on CVD is uncertain, although HDL-C levels have historically been inversely associated with a higher risk of CVD. However, recent large-scale cohort studies and Mendelian randomization trials have failed to confirm that higher HDL-C levels are associated with improved CVD (Güleç and Erol, 2020; Liu et al., 2022). Indeed, current ESC and European Atherosclerosis Society dyslipidemia guidelines emphasize that the risk of cardiovascular event and increased mortality appears to increase when HDL-C is above 90 mg/dL, so, the association between HDL-C concentration and all-cause mortality is U-shaped, and both extremely high and low HDL-C concentrations are associated with an increase in mortality (Madsen et al., 2017). Furthermore, pharmaceutical intervention studies aimed at increasing HDL-C levels did not result in amelioration of cardiovascular outcomes (Mach et al., 2020). Although the impact of exercise on HDL-C levels of older adults appears to be modest, with variations not definitively linked to altered cardiovascular risk, this parameter remains a critical component of our analysis. HDL-C is a vital component in the constellation of MetS definition, and its evaluation is essential for a comprehensive understanding of the dynamics of the syndrome. Recent literature, as discussed in the third paragraph, also presents an evolving perspective on the association between HDL-C level and cardiovascular risk, warranting its inclusion in our study. Furthermore, we hypothesize that exercise regimens with higher aerobic exercise time, intensity or volume might be necessary to induce significant alterations in HDL-C levels, potentially impacting cardiovascular risk profiles.

Our MCT did not show improvements on glucose, TGs, SBP and WC. Previous studies reported similar results, showing that resistance and combined training did not improve glucose and TGs level, although aerobic exercise could decrease glucose, TGs and WC (Ostman et al., 2017; Wewege et al., 2018). Furthermore, Pattyn et al. (2013) described that the dynamic endurance training remained statistically unaltered the levels of TGs and glucose. In these parameters, the type of training seems to be an important factor, since aerobic training shows improvements, but not the resistance or combined training. Therefore, as strength training has been shown to be effective in improving several health parameters (Fragala et al., 2019; Lovell et al., 2010), it would be interest to calculate how much time of aerobic exercise should be included in

MCT to reduce glucose, TGs, SBP and WC.

Considering the results obtained in our study and bibliography consulted, exercise interventions are a key component in the management of patients with the MetS and in the prevention of CVD. Our results are in line with previous evidence that analyzed the effect of exercise on MetS factors (Kelley and Kelley, 2006; Ostman et al., 2017; Pattyn et al., 2013; Wewege et al., 2018). Although exercise is an important part of the treatment of MetS in older adults, the role of dietary pattern is also key (Julibert et al., 2019). So, the management of MetS always could base on healthy lifestyle choices, but has not infrequently to be supported by pharmacological treatment (Nilsson et al., 2019), which could obtains good results (Grundy et al., 2019; Nilsson et al., 2019) even in older adults with decreased functional capacity.

4.2. Detraining effects on Metabolic syndrome parameters

It is very common for older adults to have to stop exercise programs due to pain, a cold, a surgical operation, or holiday periods among others. In this line, there are not studies that assessing the impact of a detraining period on MetS risk factors in this population. Nonetheless, a few reports have previously analyzed the consequences of detraining period on individual cardiometabolic risk factors in adult population (Damirchi et al., 2014; Moker et al., 2014; Mora-Rodriguez et al., 2014; Nikseresht et al., 2016; Nolan et al., 2018). However, in this study, we have analyzed the effects of detraining on MetS and individual cardiometabolic risk factors in older adults with decreased functional capacity.

After the 4-month detraining period, TRAIN showed higher SBP and lower WC than CON, at the post-training and detraining assessment. Moreover, during this period, TRAIN returned to the initial values of HDL-C and total fat mass, increased the SBP, and decreased the concentration of glucose. However, WC continued increasing during the three different assessments. Whereas CON returned to the baseline values of glucose and HDL—C. Previous studies found that the obtained improvements on concentration of HDL-C returned to baseline values when the detraining period is between 1 and 4 months, independently of changes produced during training period (Mora-Rodriguez et al., 2014; Nikseresht et al., 2016; Nolan et al., 2018). Moreover, we attended that WC increased after 4-month detraining period. In this line, Damirchi et al. (2014) observed that after 6 weeks of detraining, the obtained improvements on WC were declined. Nevertheless, other studies concluded that the WC training-induced improvements were unchanged after a detraining period of 1 month (Mora-Rodriguez et al., 2014; Nikseresht et al., 2016; Nolan et al., 2018). It seems that WC needs more time to return to initial values than others cardiometabolic risk factors. Furthermore, we have described that SBP restored to the initial values after 4-month detraining period. In this line, other studies attended that the values of BP returned to initial values after a detraining period (Damirchi et al., 2014; Moker et al., 2014; Mora-Rodriguez et al., 2014). However, Nolan et al. (2018) observed that an exercise program with 1-month detraining period did not obtain changes in this variable. Related to plasma glucose, we noticed that TRAIN decreased the plasma glucose level after detraining period. Similar results were obtained in other studies (Nikseresht et al., 2016; Nolan et al., 2018), in which they observed that the training-induced improvements in glucose were maintained after different detraining periods. Nevertheless, other studies establishing a longer detraining period observed that changes in glucose produced by exercise, returned to baseline values (Damirchi et al., 2014; Mora-Rodriguez et al., 2014). Finally, the effects of detraining on TGs are not clear, since there are few reports published, presenting results in opposite directions; authors report that benefits are maintained (Nikseresht et al., 2016) while others conclude that benefits return to the baseline (Nolan et al., 2018) even in a similar detraining period of one month.

Considering the results obtained in our study and other reports, it seems that WC is the most maintained cardiometabolic risk factor during detraining period. On the other hand, HDL—C, BP and glucose seem to return to initial values after a detraining period. In this way, it could be beneficial to set shorter break periods or include an unsupervised training prescription during vacation periods (Mañas et al., 2021).

4.3. Final effect after training and detraining period on Metabolic syndrome parameters

The MCT performed for 6 months seems to get protective effects on MetS profile or decrease the risk of cardiometabolic factors, even though it is followed by a 4-month detraining period. After 10 months of training and detraining periods, CON increased the concentration of TGs and WC, while TRAIN only increased WC. Furthermore, the increment in WC is greater in CON than TRAIN. In the same line, Damirchi et al. (2014) observed that after 6 weeks of detraining the exercise group restored to the initial values of BP, WC and glucose, but control group showed a higher MetS-Z score than exercise group at the end of detraining. Moreover, Nikseresht et al. (2016) attended that resistance and aerobic training could keep the training-induced improvements in WC after a detraining period of one month. In addition, they detected that the concentration of TGs continued decreasing after a detraining period in control and exercise groups. Furthermore, Nolan et al. (2018) observed that a detraining period increased the MetS-Z score in exercise group, but this risk was less or equal than at the baseline. Thus, it seems that MCT decreases the progression of cardiovascular risk factors during aging, reducing the increase of TGs and WC. However, further research with greater samples and reports with control and intervention group are needed to identify the specific effects of training on MetS profile during aging.

4.4. Risk of developing metabolic syndrome for the three different assessments

The implementation of our MCT seems to reduce the risk of developing MetS in older adults. Previous studies observed similar results, reporting that regular exercise could decrease the risk of developing MetS (Pattyn et al., 2013; Wewege et al., 2018). Specially, aerobic exercise seems to play a main role in reducing the risk of MetS (Wewege et al., 2018). Nevertheless, Liang et al. (2021) examined the effects of aerobic, resistance, and combined exercise on MetS parameters and cardiovascular risk factors, to identify the most effective way of improving MetS and preventing CVD. They concluded that combined exercise was the best exercise scheme for improving WC, DBP, glucose, and TGs; resistance exercise was the most effective at ameliorating LDL-C levels and SBP; and aerobic exercise was the optimal way of improving HDL—C. Therefore, combined exercise may be the most effective choice in improving the MetS and cardiovascular risk factors.

4.5. Strengths and limitations

This study has some limitations. First, there was no randomization of the sample because of pragmatic (to maximize training attendance) and ethical reasons, since not prescribing exercise to older adults may be considered unethical (Izquierdo et al., 2016). In addition, this condition simulated real-life conditions, where motivated people do exercise and unmotivated people do not. Second, the role of diet, sleep cycles, stress, alcohol consumption and pharmacological treatment have not been controlled. Therefore, the results obtained come mainly from the interaction of exercise, diet, drugs treatment and others uncontrolled points of each participant. Finally, participant attrition in CON is another critical factor. The loss of 8 participants during detraining period in CON could have disproportionately affected the prevalence of MetS or Non-MetS cases, potentially altering the final results of CON in the Table 7.

On the contrary, this report has several strengths. First, this is the first study to assess the effects of detraining on MetS in older adults with decreased functional capacity. Second, a rigorous and systematic methodology was used to assess health outcomes through a structured questionnaire, biochemical analysis and physical examination. Third, the exercise program was individualized according to the functional capacity and individual abilities of the participants, which could help to develop individualized protocols for this population. Fourth, the pharmacological treatment of the sample was registered. Fifth, this report highlights the relevance of exercise interventions in the treatment of patients with the MetS and in the prevention of CVD in older adults. Finally, this study underlines the importance of not making or reducing gaps in exercise programs, since the training-induced improvements are lost in few weeks and the cardiometabolic risk factors increase again.

4.6. Theoretical and practical implications

This report has some theoretical implications for scientists, theorists and colleagues. First, MCT is effective to improve cardiometabolic risk factors of MetS in older adults, but perhaps better results could have been obtained if the exercise program had had a greater aerobic component and volume. However, strength component allows to obtain improvements in several and transversal health parameters such as quality of life, functional capacity, body composition and frailty, promoting a true healthy aging. Second, maybe performing a MCT at vigorous intensity would have made it possible to obtain better results, but in a sample of older individuals (80.5 $\pm$ 6.0 years), safety and injury prevention aspects are critical to promote adherence and avoid detraining periods. Third, a detraining period seems to reverse the improvements obtained during the training period, thus avoiding injuries, generating adherence and promoting continuous exercise programs are of special importance. Finally, exercise programs should be considered as an effective tool for the treatment of MetS in this population and it would be recommended in nursing homes and healthcare centers, but greater health benefits can be obtained if it is combined with a healthy diet and pharmacological treatment, if necessary to control any component of cardiovascular risk.

Furthermore, this exercise program has some practical implications for improving the quality of life of older populations. It has been seen that MCT is able to improve the MetS profile, but it also improves other aspects of health that help to have a better quality of life. Fernández-García et al. (2022) showed positive effects of MCT on functional capacity and frailty levels, improving overall health and reducing activity limitations and physical health problems. Moreover, these exercise programs are developed in groups of several people, and new personal relationships and friendships are established, which can help to improve physical and mental well-being, social functioning, level of vitality and emotional health problems (Dorgo et al., 2009). Finally, MCT has been associated with a lower risk of cognitive decline and dementia (Bouaziz et al., 2016). Thus, MCT has been well established as a preventive and therapeutic strategy to counteract the detrimental changes of aging, and improving the quality of life of older adults.

In light of the broader context of aging and lifestyle, it is vital to understand how exercise can evolve into an influential habit, particularly considering the role of sociocultural factors. The environment and conviviality within PA significantly promote a healthy lifestyle, improving older people's quality of life during aging (Parra-Rizo et al., 2022a). Our study's high adherence rates to MCT reflect this, incorporating elements such as recreational and functional activities aligned with individual functional skills. This approach, aligned with insights from other studies (Parra-Rizo et al., 2022b), highlights the necessity of ongoing PA for quality aging and emphasizes its importance in MetS management and overall well-being in the elderly.

4.7. Future perspectives

It would be interesting to implement the MCT program as a health primary prevention tool (to avoid the development of MetS) and/or secondary prevention (as part of the treatment of people diagnosed with MetS) within the National Health System. The recommendation would be given by physicians or nurses from primary care centers and nursing homes, and the exercise programs would be prescribed and monitored by sports professionals. Thus, the future line derived from this study is implement the MCT in Spanish National Health System and to evaluate its efficacy and its cost-effectiveness as a health tool. In addition, in future research, it could be interesting to investigate what kind of exercise, intensity and volume should be prescribed based on the altered cardiometabolic risk factor of MetS, to improve the effectiveness of exercise as a health tool. Specifically, it would be interesting to know how exercise influences in HDL-C subclass distribution, since it seems that plasma HDL-C levels do not adequately reflect protective functions of HDL-C and a greater protective potential is attributed to the smaller and denser HDL-C particles (Stadler and Marsche, 2020). In this line, it would be interesting to analyze how HDL-C functionality changes after an exercise intervention, since it has been observed that in patients with obesity, T2DM or other inflammatory diseases, HDL-C is completely dysfunctional (Stadler and Marsche, 2020). Finally, it could be interesting to assess how much detraining period could be allowed, to avoid the reversibility of the benefits obtained during the exercise program.

5. Conclusion

In conclusion, 6-month of a MCT has demonstrated to be achievable and beneficial in older adults with decreased functional capacity, showing positive effects on the cardiometabolic risk factors like DBP and total fat mass, but also reducing the concentration of HDL—C. Nevertheless, 4-month of detraining period cause a return to initial values of HDL-C and fat mass, but not in DBP. Even though WC is maintained for the first 6-month and it increases from T0 to T2 in both groups of our report, it suggests that the improvement of WC stays longer. Furthermore, it seems that TRAIN decreases the risk of development MetS during training period, but risk returns during detraining period. However, it should be highlighting that CON increases or maintains the risk of developing MetS during all study. Moreover, MCT seems to diminish the increase of TGs and WC, and the decrease of HDL-C during aging. To avoid reversibility of the benefits obtained with exercise interventions, it could be beneficial to promote continuing PA programs, encouraging shorter break periods or implementing them with an unsupervised exercise program.

CRediT authorship contribution statement

Jorge Subías-Perié: Writing – review & editing, Writing – original draft, Visualization, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **David Navarrete-Villanueva:** Writing – review & editing, Validation, Supervision, Investigation, Formal analysis, Data curation. **Ángel Iván Fernández-García:** Writing – review & editing, Validation, Supervision, Investigation, Formal analysis, Data curation. **Ana Moradell:** Writing – review & editing, Validation, Supervision, Investigation, Formal analysis, Data curation. **Gabriel Lozano-Berges:** Writing – review & editing, Validation, Investigation, Formal analysis, Data curation. **Eva Gesteiro:** Writing – review & editing, Methodology. **Jorge Pérez-Gómez:** Writing – review & editing, Methodology. **Ignacio Ara:** Writing – review & editing, Resources, Methodology. **Alba Gómez-Cabello:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Germán Vicente-Rodríguez:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization. **José Antonio Casajús:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

None.

Data availability

Data will be made available on request.

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Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Hospital Universitario Fundación Alcorcón Ethics Committee (Spain) (16/50).

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.exger.2024.112363.

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