EFFECTS OF A TRAINING PROGRAM ON OLDER ADULTS. ASSOCIATION BETWEEN PHYSICAL ABILITIES, BODY COMPOSITION AND MOCA RESULTS ACCORDING TO GENDER

EFECTOS DE UN PROGRAMA DE ENTRENAMIENTO EN ADULTOS MAYORES. ASOCIACIÓN ENTRE CAPACIDADES FÍSICAS, COMPOSICIÓN CORPORAL Y RESULTADOS EN MOCA SEGÚN GÉNERO

***Montserrat Monserrat Hernández*[1]**
***Juan Carlos Checa Olmos*[1]**
***Ángeles Arjona Garrido*[1]**
***José Manuel Ávalos Colomina*[2]**

[1] Geography, History, and Humanities, Faculty of Humanities, University of Almería, Spain
[2] Education, Faculty of Education, University of Almería, Spain

Correspondence:
Montserrat Monserrat Hernández, mmh548@ual.es

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Abstract

The presence of diseases related to cognitive impairment is a growing problem today. The aim of this study is to establish a relation between sports practice, body parameters and cognitive impairment.

The experimental group (EG) consisted of a total of 29 individuals, with a mean age of 66.14 years (SD 4.55), sixteen women and 13 men; and the control group (CG) consisted of 30 participants, fifteen women and 15 men, with a mean age of 68.52 (SD 5.52). Body parameters were measured by bioimpedance (BIA); trained physical abilities were measured by walking speed and handgrip strength; and the Montreal Cognitive Assessment Test (MoCa) was administered for cognitive evaluation. The results show that the training program improved physical abilities, BIA and MoCa scores of the EG (time $p < .001$, group < .05, time*group < .001) and that there are significant differences with respect to the CG. Furthermore, muscle mass is the trained anthropometric parameter that has the greatest influence on the results of cognitive impairment (in both men (sig = .040) and women (sig = .020)), with right hand grip strength being the physical ability that has the greatest influence on this parameter (T1 sig = .015, T2 sig = .004). This research demonstrated the importance of strength work within an adapted training program for the prevention of cognitive impairment, resulting in improved MoCa test scores in the group that had practiced it. This illustrates the way forward for further work on exercise as a means of preventing cognitive decline.

Keywords: Cognitive impairment, healthy aging, exercise program, elderly, prevention.

Resumen

La presencia de enfermedades relacionadas con el deterioro cognitivo es un problema creciente en la actualidad. El objetivo de este estudio es establecer una relación entre la práctica deportiva, los parámetros corporales y el deterioro cognitivo. El grupo experimental (GE) estuvo formado por un total de 29 individuos, con una edad media de 66.14 años (*DE* 4.55), dieciséis mujeres y 13 hombres; y el grupo control (GC) estuvo formado por 30 participantes, 15 mujeres y 15 hombres, con una edad media de 68.52 (*DE* 5.52). Los parámetros corporales se midieron mediante bioimpedancia (BIA); las habilidades físicas entrenadas se midieron mediante la velocidad al caminar y la fuerza de prensión manual; y se administró la Prueba de Evaluación Cognitiva de Montreal (MoCa) para la evaluación cognitiva. Los resultados muestran que el programa de entrenamiento mejoró las capacidades físicas, las puntuaciones BIA y MoCa del GE (tiempo $p < .001$, grupo < .05, tiempo*grupo < .001) y que existen diferencias significativas con respecto al GC. Además, la masa muscular es el parámetro antropométrico entrenado que mayor influencia tiene en los resultados del deterioro cognitivo (tanto en hombres (*sig* = .040) como en mujeres (*sig* = .020)), siendo la fuerza de agarre de la mano derecha la capacidad física que tiene mayor influencia. mayor influencia en este parámetro (T1 *sig* = .015, T2 *sig* = .004). Esta investigación demostró la importancia del trabajo de fuerza dentro de un programa de entrenamiento adaptado para la prevención del deterioro cognitivo, lo que resultó en mejores puntuaciones en las pruebas MoCa en el grupo que lo había practicado. Esto ilustra el camino a seguir para seguir trabajando sobre el ejercicio como medio para prevenir el deterioro cognitivo.

Palabras clave: Deterioro cognitivo, envejecimiento saludable, programa de ejercicio, anciano, prevención.

Introduction

During the aging process, there is a gradual and cumulative decrease in physiological reserve influenced by genetic and environmental factors (DeJaeger, 2016). This situation is currently referred to as frailty (Clegg, et al., 2013; Morley, et al., 2013), which corresponds to a clinical state in which greater vulnerability can be observed in those who suffer from it. Fragility manifests as a reduced ability of the body to adequately respond to adverse events, which can increase the risk of functional decline. In current discussions about the incidence of fragility, the inclusion of the concept of cognitive decline has emerged, as its occurrence is proportional to advancing age (Legdeur et al., 2019; Lu et al., 2018; Perrote et al., 2017). Thus, physiological processes produced by the passing of time, such as changes in insulin signaling pathways, growth factor, mitochondrial dysfunction, cellular senescence, stem cell depletion, inflammation of some hormone systems, etc. (Rodríguez, 2015), can lead to hormonal and inflammatory dysregulation, leading, in addition to physiological deterioration, to the appearance of cognitive impairment (Tay et al., 2016) and, therefore, studying both processes together will allow detection and treatment and a direct impact on the health outcomes of the individuals (Rosado et al., 2017). Therefore, more and more research are linking both perspectives (Auyeung et al., 2017; Gale et al., 2017), even coining the term cognitive frailty for those cases in which physical frailty and mild cognitive impairment are present in the absence of dementia (Facal et al., 2018).

Cognitive performance encompasses varying degrees of underlying mental processes. It includes selective attention, judgment, anticipation, planning and problem solving, selective inhibition, etc. (Diamante, 2013; Tam, 2013). Previous studies have shown that physical exercise improves cognitive performance, either by increasing brain-derived neurotrophic factors (Fernández & Santi, 2022; Pintilie, 2021) increased blood flow in the prefrontal cortex of the brain (Curtelin et al., 2016; Whitake et al., 2020) or others (Jiménez, 2017; Urquidi et al., 2022).

Focusing on strength exercises, studies have shown benefits in cognitive function in relation to physical function and muscle strength with the application of 12-week and 16-week programs (Tsai et al., 2018; Yoon et al., 2016); others have observed more positive values in neuroprotective growth factor levels in a group of older adults with cognitive impairment when applying a training program that included strength and aerobic exercises than when only performed aerobic exercises (Marcos-Pardo et al., 2021; Romero-Arenas et al., 2011; Tsai et al., 2018). Moreover, these benefits can be extended when strength exercises were performed in conjunction with cognitive training (Fritz-Silva, 2021; Suo et al., 2018). However, the environment and the type of physical activity carried out will depend on the capabilities of users, therefore, initial studies are currently being carried out on the benefits of working the physical qualities cited in the aquatic environment with people with reduced autonomy (Ayán et al., 2017; Faíl et al., 2022; Pérez & Hurtado, 2021; Tarragüel et al., 2023). In addition, to the muscle strength-cognition and/or physical exercise-cognition relation, other less widespread studies relate anthropometric changes, such as percentage of fat mass, lean mass and/or hydration with cognitive impairment. New research (Alcaraz et al., 2015; Mero & Pérez, 2022) relate Body Mass Index (BMI) values to scores on attention and memory tests. Similarly, Rivera Villaseñor (2018), in addition to BMI, measures biochemical levels related to the presence of insulin and adiponectin count. García et al. (2014) link excess fat mass with low-grade inflammation associated with dementia. Other studies (Białecka & Pietruszka, 2019; Simmons et al., 2021; Suhr et al., 2021) showed the influence of hydration levels with cognitive performance, especially with respect to reaction speed. Behrman and Ebmeier (2014) associate sarcopenia with cognitive decline in old age, stating that the loss of muscle mass can reduce physical activity, which in turn affects cerebral blood flow and may accelerate cognitive function decline. Additionally, the decrease in certain growth factors and the metabolic alterations associated with sarcopenia may negatively impact neuronal health and brain plasticity. Moreover, the study by Cova et al. (2017)

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showed differences in the set of values in fat mass, lean mass and hydration using electrical impedance markers, with differences observed between men and women. Gender, therefore, is considered as a determinant sociodemographic variable in research of this type (Auyeung et al., 2017; Kilgour et al., 2013) arguing that body composition is and is measured differently between men and women at different stages of life; however, this is not taken into account in most research in this regard.

For all these reasons, the present research has been stimulated by the search of the possible relation between sports practice, anthropometric parameters and cognitive impairment, establishing a relation between the three parameters not analyzed in previous studies observed and taking the gender variable into account. All this is done in order to continue providing valid information on the relation between physical exercise and cognitive impairment, providing ideas that support the concept of cognitive frailty.

To sum up, the hypotheses that guide our proposal are the following: 1) application of a 16-week exercise program (2 days per week) produces changes in the fat mass, muscle mass and hydration of the participants; 2) there are relations between the practice of physical exercise program and improvement of the analytical parameters that measure cognitive deterioration, being the anthropometric modification (less fat mass, more lean mass and more hydration) a determining factor; 3) there are differences in the results according to gender.

Materials and Methods

Design & Participants

We used a repeated measures design comparing between two groups (control and experimental).

The study began with 60 participants (90% confidence level; 10% margin error) (INE, 2023). Distribution between the groups was carried out using a computer program (Rakko.tools).

The experimental group started with 30 participants, but one of them could not continue due to the impossibility of attending the training sessions, so in the end this group consisted of twenty-nine participants, with a mean age of 66.14 years (*SD* 4.55), sixteen women and 13 men. They were recruited on a voluntary basis from among those attending the University of Almeria's University for Older Adults (UAL-Mayores) in person by the teaching staff there. The inclusion criteria were: be older than 65, good physical health without diagnosis of cognitive impairment by their doctor and mini mental tests (Llamas et al., 2015) and attendance two years to the course of the University of Seniors with a minimum attendance at 80% of sessions and confirming that in the previous year they had begun strength training. In this way, it was controlled that all participants performed the same tasks of cognitive stimulation and developed a similar lifestyle. Exclusion criteria included presenting any musculoskeletal injury or medication consumption in the last six months and during the study, or any other health problem that could interfere both in the safety of the physical exercise practice and in the quality of the results obtained.

The control group was composed of thirty participants, fifteen women and 15 men, with a mean age of 68.52 (*SD* 5.52), with the same inclusion and exclusion criteria as those referred to the experimental group.

Instruments

Bioimpedance measurements (BIA) were performed with a Tanita BC-601 scale, manufacturer/brand TANITA EAN-4904785811508. Individuals were fasting for 8 hours beforehand, but they were being hydrated. Accuracy was checked with a recognized impedance calibration circuit (R:383 Ohm, Xc:45 Ohm, 1% error). Standard external and internal electrode positions were on both hands and feet (Withers et al., 1999). The results for the variables of corporal composition that are shown show different depending on gender and age.

The MoCa Test (Kalafatis et al., 2021) is a brief cognitive assessment test that measures the performance of various abilities. This test has a high accuracy that allows it to be applied to different cultural and age groups and a variety of academic backgrounds (Delgado et al., 2019; Malek et al. 2015). In addition, it has proven to be a reliable instrument for detecting early cognitive changes in a wide range of disorders (Delgado et al., 2019). It is a 30-item scale, with items including six for orientation, five for memory, six for language, six for attention, three for visuospatial, and four for executive skills. Regarding the cut-off score for detecting dementia, there are several points of view (Maust, et al., 2012; Pedraza et al., 2016), there are those who recommend using 26 as the threshold and those who prefer to do so from 23 points onwards. We opted for 26 because the participants are cognitively active (by attending university, UAL-Mayores) and, thus, we would also be more demanding with respect to the improvements observed.

The physical abilities analyzed followed the line of the recent literature (Griebler et al., 2022; Yoon et al., 2016; Yoon et al., 2018) with the objective of obtaining more detailed information on each one of them, for this reason we measured manual strength-pressure, walking speed and maximum oxygen volume (VO_2max).

The TKK-5401 (Takei) manual dynamometer was used to analyze manual strength-pressure. The results of this measurement are provided according to gender and age groups. In this case, for people between 65 and 70 years the values range from “risk of dependence” (18.56 kg in women and 34.20 kg in men) to “autovalent without risk” (20.14 kg in women and 35.83 kg in men) (Maust et al., 2012).

The walking speed study was carried out using Witty-Gate photocells (Microgate Srl, Italia) (Doyle et al., 2020, Franca et al., 2021). For gait evaluation, a distance of 10 meters was used. Participants started from a static position (without acceleration), but there was a deceleration zone to prevent them from slowing down before reaching the designated distance and for safety purposes. Photocells were placed at 2, 4, and 10 meters to measure acceleration over the first 2 meters, the 4-meter speed for the SPPB, and the 10-meter test in a single walk. Establishing results between values of < 0.6 m/s (high probability of poor health and physical function) up to 1.2 m/s (exceptional health expectations) (Inzitari et al., 2017).

VO_2max was estimated by testing 6 minutes of walking with a Polar V800 pulsometer (Polar Electro Oy, FI-90440 KEMPELE, Finland) and through the formula VO_2max (mL-kg(-1)-min(-1)) = 70.161 + (0.023 × 6MWT [m]) - (0.276 × weight [kg]) - (6.79 × sex, where m = 0, f = 1) - (0.193 × resting HR [beats per minute]) - (0.191 × age [y]) (Burr et al., 2011; Lloret et al., 2014; Passler et al., 2018; Toledo et al., 2017). The results are also estimated according to gender and age, therefore for the age group between 65 and 70 years are considered “excellent” score from 45.7 ml/kg/min for men and 37.8 ml/kg/min for women and “deficient” values at < 32.3 ml/kg/min for men and < 27.5 ml/kg/min for women [53-55]. The same group of researchers always collected the data.

Procedure

During 16 weeks one group participated in the proposed training program, while the other did not. The Montreal Cognitive Assessment Test (the MoCa test) and bioelectrical impedance were measured before and after the intervention in both control and experimental groups. The volunteers completed a health questionnaire/report to confirm that they met the criteria proposed in the previous section. All research procedures were performed in accordance with the 1975 Declaration of Helsinki, and the consent form, the questionnaire applied, and the study were approved by the Bioethics Committee of the University of Almeria (Reference: UALBIO2022/049).

The intervention took place during 16 weeks after a process of familiarization of the users with the trainers and the techniques for performing the exercises. One-hour outdoor training sessions were always conducted by the same personal trainer with a degree in Sports Science and specialized in working with people over 65 years of age, in groups of five to seven people, twice a week in Monday-Wednesday or Tuesday-Thursday morning groups. The sessions were mainly composed of basic movement patterns with exercises such as squats or deadlift for the lower body and dumbbell pushes from the floor or dumbbell rowing for the upper body. They were performed with different implements and applying a progression in intensity and volume during the weeks, measured and adjusted according to the Omni-Res Scale (Lagally & Robertson, 2006) to control that the intensity was always between six and nine Perceived Effort Rating Scale (RPE). The main exercises were worked with three sets of 8-12 repetitions or Repetitions in Reserve (RIR) of 3-4 (Lovegrove et al., 2022). With 1-2-minute breaks between each series. At the end of each session, High Intensity Interval Training (HIIT) adapted to their age was performed with different auditory and visual stimuli to get up from a bench and walk fast, among others, adjusting the intensity between six and nine according to the Rate of Perceived Exertion (RPE) scale, aiming to achieve cardiorespiratory improvements and thus promote a more comprehensive and beneficial program. All aerobic training was controlled by means of the perceived exertion scale or RPE trying to reach between six and eight RPE. In addition, they were given recommendations to walk an average of 8,000 steps per day, which were monitored using a mobile app (Google Fit) and was enhanced by all participants.

Statistical Analysis

Statistical analysis was performed with SPSS for Windows (version 27.0). The Levene’s test and the Kolmogorov-Smirnov test justified the application of parametric analysis.

Initially, to evaluate the effects of the intervention program, dependent sample (within-group) and independent sample (between-group) comparisons were conducted between Time 1 (T1) and Time 2 (T2) using t-tests for related and independent samples on the following variables: MoCa score, BIA parameters (body fat mass, visceral fat, lean mass, hydration), hand grip strength, gait speed, and VO_2max. In addition to the t-tests, effect size was calculated (using partial

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eta squared) for each comparison, allowing for identification of the magnitude of changes in each variable following the intervention.

To explore the relationship between variables, a Pearson correlation analysis was performed between MoCa and the BIA variables, hand grip strength, gait speed, and VO_2max, with the aim of identifying significant associations that would guide subsequent analyses, as well as results in the BIA parameters that could be considered repetitive (insert reference).

To further explore the effect of the intervention (experimental and control groups) and gender on MoCa results, a Analysis of variance (2 x 2 ANOVA) was conducted. This analysis allowed for the evaluation of the combined influence and main effects of the independent variables on the MoCa outcome. For the significance analysis, partial eta squared (ηp^2) was reported as a measure of the effect size, and since the interaction was significant, the differences between conditions were examined.

To check the assumptions of the ANOVA, the Levene's test for homoscedasticity and the Kolmogorov-Smirnov test for normality were performed. Likewise, for the repeated measures, Mauchly's test of sphericity was performed.

We performed a Linear Regression Analysis (stepwise introduction) to analyze whether there was an influence of BIA parameters (fat mass, lean mass and hydration) on cognitive outcomes (main variable). Prior to this, and to obtain more accurate information regarding gender, a reduction of dimensions was carried out by means of an Exploratory Factor Analysis (EFA) for men and for women (extraction of principal components with Varimax rotation) discarding values that saturated less than .4 in each factor (Lloret et al., 2014) in which, to avoid collinearity, and supported by theoretical data on analysis of anthropometric parameters with BIA (Norman et al., 2014; Withers et al., 1999), a correlation analysis was previously performed to confirm the appropriateness of the choice.

Finally, to check the type and degree of influence of the training parameters on the muscle mass variable, we performed another linear regression (stepwise introduction) where the dependent variable is the muscle mass parameter and, as independent variables, right hand grip strength, left hand grip strength, walking speed and VO_2max (the latter recoded according to gender).

Results

Analyzed variables and differences according to group (control or experimental) and time of data collection (T1 and T2).

Multiple inter-subject comparisons (Bonferroni correction) show that the control and experimental groups had equivalent levels for all variables before the intervention, with significant differences appearing between both groups after the intervention.

The data show (see table 1) that the experimental and control groups started the program under equal conditions. In addition, there were statistically significant differences between the control and experimental groups in the anthropometric parameters observed through BIA, the results of the MoCa test and the physical abilities trained after the exercise program in the experimental sample.

The effect size tests show a medium effect size on the variables lean mass, body hydration, walking speed and VO_2max; while a large effect size on MoCa, fat mass, visceral fat, manual strength right and left.

Influence of Anthropometric Parameters on Cognitive Change According to Gender

To facilitate the interpretation of the results in the linear regression, an EFA was previously performed and, prior to this, a correlation analysis was carried out between the anthropometric variables to observe, as supported by the literature, that the conventional BIA scale uses specific equations for the estimation of body composition, so that the as assumptions of a constant hydration of lean mass inversely proportional to fat mass could lead to estimation errors and duplication of results (Norman et al., 2012; Withers et al., 1999). For this reason, we chose to eliminate the body fat parameter (and not hydration) in order to have reference of three different parameters (fat, muscle and hydration) (see table 2).

Table 1
Multiple Inter-Subject Comparisons: Experimental and Control, T1 and T2 Statistics After Experimental Intervention. MoCa and BIA Values

			Mean	SD	*LS* (sig)	T-Students (sig)	Eta squared
MoCa	T1	Experimental group	24.68	3.252	6.560 (.113)	0.093 (.762)	
		Control group	24.93	2.887			
	T2	Experimental group	28.55	1.761	1.099 (.299)	39.253 (< .001)	.431
		Control group	24.53	2.885			
Fat mass	T1	Experimental group	34.93	8.251	1.051 (.310)	.275 (.602)	
		Control group	33.81	8.026			
	T2	Experimental group	32.49	8.715	0.357 (.552)	1.939 (.033)	.191
		Control group	35.60	8.631			
Visceral fat	T1	Experimental group	12.90	3.559	5.579 (.22)	1.297 (.805)	
		Control group	12.60	5.405			
	T2	Experimental group	11.86	3.512	5.249 (.260)	3.755 (.003)	.157
		Control group	12.36	5.268			
Lean mass	T1	Experimental group	44.53	8.616	0.97 (.327)	39.933 (.524)	
		Control group	46.17	10.92			
	T2	Experimental group	45.87	8.608	1.578 (.214)	15.785 (< .001)	.130
		Control group	48.88	9.873			
Body hydration	T1	Experimental *group*	46.66	5.455	5.834 (.191)	26.527 (.293)	
		Control group	48.00	4.201			
	T2	Experimental group	48.48	5.684	6.123 (.160)	3.825 (.049)	.127
		Control group	47.97	4.253			
Manual strength pressure I	T1	Experimental group	26.54	8.68	8.124 (.170)	4.352 (.965)	
		Control group	25.56	7.22			
	T2	Experimental group	29.09	10.21	4.235 (.253)	7.244 (.033)	.227
		Control group	26.06	8.21			
Manual strength pressure D	T1	Experimental group	26.35	8.91	7.132 (.324)	8.743 (.954)	
		Control group	25.98	7.95			
	T2	Experimental group	27.34	8.77	8.344 (.228)	4.437 (.042)	.347
		Control group	26.31	7.88			
Walking speed	T1	Experimental group	0.57	0.77	7.143 (.127)	3.754 (.122)	
		Control group	0.55	0.74			
	T2	Experimental group	0.92	0.61	6.518 (.233)	2.568 (.002)	.127
		Control group	0.59	0.55			
VO_2max	T1	Experimental group	22.86	4.40	3.658 (.145)	4.322 (.354)	
		Control group	23.07	3.87			
	T2	Experimental group	27.76	4.76	4.428 (.244)	3.875 (.001)	.115
		Control group	23.09	3.98			

Note. SD = Standard deviation.

LS = Levene's statistics (significance).

sig = significance.

Table 2
Correlations Between Anthropometric Parameters Measured With BIA and MoCa

	Fat mass	Visceral fat	Lean mass	Body hydration	MoCa	MSP I	MSPD	Walking speed	VO_2max
Fat mass	1								
Visceral fat	-.126	1							
Lean mass	-.515**	.694**	1						
Body hydration	-.968**	.126	.590**	1					
MoCa	.028	-.394*	.324*	.563	1				
MSP I	-.643**	.469**	.843**	.635**	.213	1			
MSPD	-.640**	.567**	.854**	.640**	.115	.921**	1		
Walking speed	.114	-.367*	-.434**	.174	.197	-.562**	-.513**	1	
VO_2max	-.017	.068	.073	.090	.109	-.105	-.089	.350**	1

Note. **Significance < .001.

*Significance < .05.

MSP I: Manual strength pressure I.

MSPD = Manual strength pressure D.

Además, se observaron correlaciones significativas entre los resultados en MoCa y grasa visceral de forma significativa y negativa ($p < .05$) y, MoCa y Lean mass de forma significativa y positiva ($p < .05$). No se observaron relaciones significativas entre los resultados en MoCa y fuerza manual, velocidad de la marcha ni Vo_2max.

The ANOVA test shows that both group membership and gender are significant ($p < .001$) with a considerable effect size, indicating that both variables affect the MoCa results. The groupgender interaction is not significant ($p = .190$), suggesting that the effect of the program is similar between men and women in terms of improvement in MoCa (see table 3).

Tabla 3
Mean Square of MoCa Results. Comparison Between Groups (Pre-Test and Post-Test) and by Gender

Effect	Dependent variable	Mean square	*F*	Partial Eta square
Group	MoCa	177.347	10.272*	.248
Gender	MoCa	85.67	15.92*	.172
Group^{x}Gender	MoCa	9,45	1.76	.0.24

Note. *Significance < .05.

Considering scientific studies on gender differences in body composition (Pekkarinen et al., 2012) and, especially, after menopause, in visceral fat in women (Greendale et al., 2019), we found it necessary to perform the EFA distinguishing according to gender.

The results shown below explain how the factors extracted in the EFA are different for each group in terms of factor 1 (in which visceral fat is taken into account).

Females

The EFA shows the existence of two strongly differentiated factors with a Total Explained Variance of 96.968% and Kaiser-Meyer-Olkin measure (*KMO* = .451; *sig* < .001).

Factor 1. Denominated “unhealthy fat and hydration”, which strongly saturate positive visceral fat and negative body hydration. Composed of visceral fat in positive (.907) and negative body hydration (-.979).

Factor 2. Denominated “healthy muscle mass”, it saturates only and strongly the positive lean mass. Composed solely of muscle mass (.982).

Males

The EFA shows the existence of two strongly differentiated factors with a Total Explained Variance of 96.702% and Kaiser-Meyer-Olkin measure (*KMO* = .390; *sig* < .001).

Factor 1. Denominated "healthy fat and hydration", strongly saturate visceral fat negatively and body hydration positively. Composed of negative visceral fat (-.979) and positive Body Hydration (.920).

Factor 2. Denominated "healthy muscle mass", strongly and exclusively saturates the positive muscle mass composed solely of muscle mass (.991).

Next, as shown in the results of the linear regression (table 4), differentiated by gender, we can see how factor 2 "healthy muscle mass" is the accepted model for both groups with respect to its influence on the results of the MoCa test. However, a slightly greater influence of this variable is observed in the group of women compared to that of men.

Table 4
Linear Regression Divided by Gender. MoCa Dependent Variable

Model		Not standardized coefficient	Standardized coefficient	t-Student	sig	Durbin Watson	ANOVA	R
		B (dev)	Beta					
Females	Constant	30.818 (3.753)		8.213	< .001	2.099	8.125*	.713
	Factor 2	0.041 (0.092)	-0.124	0.451	.020			
Males	Constant	29.514 (5.480)		5.386	< .001	1.305	9.207*	.519
	Factor 2	0.032 (0.103)	-0.097	0.309	.040			

Note. *Significance < .001.

Influence of Training-Derived Fitness Parameters on Muscle Mass

As already observed in previous analyses, muscle mass is an influential factor in cognitive values. In the training program we trained both upper body strength (measured through the manual strength-grip variables) and lower body strength (measured with the walking speed variable) and oxygen capacity (VO_2max), so we performed a linear regression analysis with the main objective of finding out which trained ability had the greatest influence on the anthropometric parameter of muscle mass.

The results of the analysis showed that the manual strength-grip of the right hand (both in T1 and T2) is the only parameter analyzed in the experimental group that influences the muscle mass determinant in the cognitive variability. Likewise, the strength of the variable (the model) is observed to increase at T2 with respect to T1 (see table 5).

Table 5
Linear Regression T1 and T2. Lean Mass as a Dependent Variable

Model		Not standardized coefficient	Standardized coefficient	t Student	Sig	Durbin Watson
		B (dev)	Beta			
T1	Constant	1.576 (0.395)		3.988	< .001	1.743
	Manual grip force (Right)*	0.525 (0.196)	0.533	2.675	.015	
T2	Constant	1.500 (0.458)		3.768	.001	2.247
	Manual grip force (Right)**	0.519(0.160)	0.579	3.251	.004	

Note. *Summary of Model 1 (T1): *R* = .533; *R2* = .285; excluded variables= (F-P left = 0.718; *sig* = .483)

(test speed = -0.372; *sig* = .714) (VO_2max = -1.631; *sig* = .121).

**Summary of Model 1 (T2): *R* = .579; *R2* = .335; excluded variables= (F-P left = 1.049; *sig* = .307). (test speed = 0.155; *sig* = .878) (VO_2max = -1.015; sig = .323).

Discussion

The main objective of the present study is to observe if the physical abilities trained, in the proposed exercise program, manage to modify the results of the MoCa Test and taking the gender variable into account. In this respect, the effectiveness of the training program in which strength and resistance are combined is proven, as other research shows (García et al., 2013). More specifically, the program improved all the BIA parameters of the participants, especially visceral fat and lean mass. These data are consistent with other studies in which these parameters are also modified through strength-resistance training (Griebler et al., 2022; Pekkarinen et al., 2012; Yoon et al., 2016). These results may be due to numerous factors that have not been the objective of the present study, but the scientific literature can give us information to relate them such as: 1) the beginning of a training program increases caloric expenditure, and this reduces the body fat percentage; 2) exercise can motivate the person to include other healthy habits including eating thus reducing caloric intake; etc. (Collado et al., 2021; Milanović et al., 2015).

However, we consider it interesting to note that although the participants started with some parameters at levels considered "danger" (fat mass, visceral fat, manual force-grip and walking speed), the practice of a 16-week training program failed to raise these to levels outside the "no danger" band; however, it positively improved all of them. Therefore, it is recommended to follow a training progression and remain constant (Pérez, 2020; Prado et al., 2017) and, even more, having observed the strong relationship between levels in MoCa, muscle mass and manual force-grip.

Analyzing the above parameters by gender has confirmed that the measurements should be made taking into account this variable (Beaudart et al., 2020; Ling et al., 2011), as well as that the training programs should suggest specificities according to group (García, 2022; González & Rivas, 2018). This is because the physical and physiological parameters and changes are not the same between men and women throughout life and, moreover, for women, nonexistence of menstruation produces physiological situations that must be taken into account in training design; for example, there are studies that relate visceral fat accumulation in women after menopause with variations in the proportion of insulin growth factor (IGF-1) and sarcopenia (Barclay et al., 2019; Nguyen et al., 2020) associated with cognition. But most of these studies are cross-sectional, so the present investigation may provide useful and necessary information for further research. In general, there are not enough studies related to prescription of physical activity in the elderly differentiated by gender for the prevention of cognitive decline.

In the present study it has been observed that for both men and women a muscle mass at healthy levels helps in the prevention of cognitive decline. This is consistent with other studies (Del Carmen et al., 2023; Zanchetta et al., 2021). It is true that there are recent studies that highlight this theory (Amaral et al., 2019; Ortega et al., 2012; Soriano et al., 2022), but in our case we provide new information about physical exercise and physical qualities that have a positive impact and the physical ability to improve the influential parameter.

In addition to the above, this study aimed to analyze the relationship training-cognitive impairment more accurately, establishing links between the physical abilities trained in the program, BIA variables modified thanks to this training and the results in MoCa. In this respect we can establish several ideas. The first is that there are modifications derived from training in both physical abilities and in anthropometric variables and, the second, that right hand force-grip is the ability as it has the greatest influence on the muscle mass variable which in turn is the most influential in the results of the MoCa test. In this sense, the importance of laterality with respect to the dominant limb and its greater relevance in activities of daily living, among others, seems to be related, where significant changes in this limb are more relevant to analyze the health condition (Zaccagni et al., 2020). The muscle mass is the most influential factor may be due to the fact that, as recent studies show, low lean mass causes dysfunction in the secretion of myokine (type III fibronectins containing 5/irisin and cathepsin B) which are related to muscle activity and which cross the blood-brain barrier producing the regulation of brain expressions derived from neurotrophic factor (BDNF) (Matthews et al., 2019; Rose, 2021).

There are also studies that relate low lean mass with deficiencies in the protein balance, which is reflected in deficient protein metabolism at the cerebral level (Domínguez et al., 2016; Poddar et al., 2019), even because low muscle mass produces dysfunctions at the mitochondrial level and more residues of reactive oxygen species reach the brain, generating situations of oxidative stress that promote senescence (Liguori et al., 2018; Limoge et al., 2017), or that the influence on insulin metabolism causes brain receptors to decrease along with their sensitivity and increases cerebrovascular damage Tau phosphorylation (González & Rivas, 2018).

Limitations

The study has several limitations to mention: first, the absence of a physical exercise program with adequate monitoring and progression of the load, as the 1-RM of the participants was not estimated prior to the start of the exercise program. In line with the above, it is also important to point out that the training sessions followed guidelines for the exercises to be performed, but it was the trainer in question who designed them without supervision during the session which, despite being fully trained to do so, the rest of the session was directed by the trainer according to his or her interests in each group. Another limitation to point out, with respect to aerobic exercise, is the absence of heart rate monitoring during the session, based only on a subjective effort scale, as well as the absence of a stress test that would calculate cardiorespiratory ability through a direct method.

Conclusions

In relation to all the above mentioned in this article, we believe that further research should be done on cognitive frailty and its prevention by combining a proposal of strength-resistance exercise to maximize the gains and adapt a more specific dose for each subject according to his or her characteristics. In this sense, it is proposed to replicate this same intervention with a more detailed program and/or tests of greater reliability in the measurements of cardiorespiratory ability, strength or body composition or to analyze biochemical values. Finally, it is also proposed to carry out an intervention such as the one presented for a longer period of time, in order to check whether the trend between both times of evaluation of muscle mass gain for longer training time is confirmed and whether this translates into greater cognitive gains.

This study highlights the interconnected role of muscle mass, grip strength, and body composition in cognitive test outcomes, advancing our understanding of cognitive frailty and the biological foundations that link physical and cognitive health. For researchers in geriatrics, neuroscience, and exercise sciences, these findings emphasize the need for a multidisciplinary approach to the study of aging, underscoring how physical factors such as muscle mass and strength can serve as predictors of cognitive health. Furthermore, this study advocates for integrating cognitive frailty into existing aging models, which could open new lines of research on the biochemical and physiological impacts of exercise on brain health.

Moreover, until now, few studies have provided such a nuanced exploration of how these factors vary by gender or have examined the predictive power of anthropometric variables, such as muscle mass, specifically for cognitive health. By detailing these factors, our research highlights the need for gender-specific approaches in exercise-based interventions and sheds light on unique physiological indicators relevant to cognitive frailty.

In general, our findings suggest that strength and endurance programs can improve physical and cognitive health in older adults, increasing their independence. Implementing these programs in geriatric and community care could reduce cognitive decline, healthcare costs, and benefit overall well-being in society.

Therefore, the main conclusions of this research are: 1) the practice of a training program that combines strength and endurance of 2 hours a week helps in the prevention of cognitive deterioration; 2) the manual force-grip is the variable that predicts in the state of muscle mass of the surveyed subjects; 3) muscle mass is the anthropometric variable that has the greatest relationship with cognitive deterioration; 4) although there are differences between men and women in terms of physical ability, type of measurement and BIA values in both sexes, muscle mass has the greatest influence on cognitive deterioration.

For all the above we believe that this research presents a very fine analysis in terms of influential factors and differences according to gender not previously performed.

Ethics Committee Statement

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee: University of Almería (Reference: UALBIO2022/049).

Conflict of Interest Statement

There is no conflict of interest.

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Authors' Contribution

Conceptualization M.M., J.CCH & A.A.; Methodology M.M &. JC CH; Software M.M.; Validation M.M., JC.CH. & A.A.; Formal Analysis A.A.; Investigation M.M. & J. M. A.; Resources M.M. & J.M A.; Data Curation M.M, JC,CH &A.A..; Writing – Original Draft M.M, JC,CH &A.A.; Project Administration M.M, JC,CH & A.A..; Funding Acquisition M.M, JC,CH &A.A. Todos los autores han leído y están de acuerdo con la versión publicada del manuscrito.

Data Availability Statement

Data available upon request from the corresponding author (mmh548@ual.es).

References

Alcaraz-Ortíz, M. R., Ramírez-Flores, D., & Palafox-López, G. I. (2015). El déficit cognitivo relacionado con el índice de masa corporal elevado. *Revista Especializada en Ciencias de la Salud, 18*(1), 33–38. https://www.revistas.unam.mx/index.php/vertientes/article/view/51742

Auyeung, T. W., Lee, J. S. W., Kwok, T., & Woo, J. (2011). Physical frailty predicts future cognitive decline - a four-year prospective study in 2737 cognitively normal older adults. *The Journal of Nutrition, Health & Aging*, *15*(8), 690–694. https://doi.org/10.1007/s12603-011-0110-9

Ayán, C., Carvalho, P., Varela, S., & Cancela, J. M. (2017). Effects of water-based exercise training on the cognitive function and quality of life of healthy adult women. *Journal of Physical Activity & Health*, *14*(11), 899–904. https://doi.org/10.1123/jpah.2017-0036

Barclay, R. D., Burd, N. A., Tyler, C., Tillin, N. A., & Mackenzie, R. W. (2019). The role of the IGF- 1signaling cascade in muscle protein synthesis and anabolic resistance in aging skeletal muscle. *Front Nutrition*, *6*. https://doi.org/10.3389/fnut.2019.00146

Beaudart, C., Bruyère, O., Geerinck, A., Hajaoui, M., Scafoglieri, A., Perkisas, S., Bautmans, I., Gielen, E., Reginster, J.-Y., Buckinx, F., & Belgian Aging Muscle Society (BAMS) (2020). Equation models developed with bioelectric impedance analysis tools to assess muscle mass: A systematic review. *Clinical Nutrition ESPEN*, *35*, 47–62. https://doi.org/10.1016/j.clnesp.2019.09.012

Behrman, S., & Ebmeier, K. P. (2014). Can exercise prevent cognitive decline? The Practitioner, 258(1767), 17–21. https://www.thepractitioner.co.uk/Symposium/Care-Of-The-Elderly/5290-/Can-exercise-prevent-cognitive-decline

Białecka, A. & Pietruszka, B. (2019). La asociación entre el estado de hidratación y la función cognitiva entre voluntarios ancianos de vida libre. *Investigación Clínica y Experimental*, 31:695-703. https://doi.org/10.1007/s40520-018-1019-5

Burr, J. F., Bredin, S. S. D., Faktor, M. D., & Warburton, D. E. R. (2011). The 6-minute walk test as a predictor of objectively measured aerobic fitness in healthy working-aged adults. *The Physician and Sportsmedicine*, *39*(2), 133–139. https://doi.org/10.3810/psm.2011.05.1904

Clegg, A., Young, J., Iliffe, S., Rikkert, M. O., & Rockwood, K. (2013). Frailty in elderly people. *Lancet*, *381*(9868), 752–762. https://doi.org/10.1016/S0140-6736(12)62167-9

Collado, D., Lavín, A. M., Peñacoba, C., Del Coso, J., Leyton, M., Luque, A., & Amado, D. (2021). Key factors associated with adherence to physical exercise in patients with chronic diseases and older adults: an umbrella review. *International Journal of Environmental Research and Public Health*, *18*(4). https://doi.org/10.3390/ijerph18042023

Cova, I., Pomati, S., Maggiore, L., Forcella, M., Cucumo, V., Ghiretti, R., Grande, G., Muzio, F., & Mariani, C. (2017). Nutritional status and body composition by bioelectrical impedance vector analysis: A cross sectional study in mild cognitive impairment and Alzheimer's disease. *PloS One*, *12*(2), e0171331. https://doi.org/10.1371/journal.pone.0171331

Curtelin, D., Pérez, M., Martín, M., Cherouveim, E.D., Torres, R., Calbet, J.A. & Morales, D. (2016). Flujo sanguíneo cerebral durante el ejercicio de esprint. *Kronos: Revista Universitaria de la Actividad Física y el Deporte*, *15*(2), 1-9. http://hdl.handle.net/11268/6145

de Araújo Amaral, C., Amaral, T. L. M., Monteiro, G. T. R., de Vasconcellos, M. T. L., & Portela, M. C. (2020). Factors associated with low handgrip strength in older people: data of the Study of Chronic Diseases (Edoc-I). *BMC Public Health*, *20*(1), 395. https://doi.org/10.1186/s12889-020-08504-z

de Jaeger, C. (2018). Fisiología del envejecimiento. *EMC - Kinesiterapia - Medicina Física*, *39*(2), 1–12. https://doi.org/10.1016/s1293-2965(18)89822-x

Del Carmen Cervera, M., López, J. J., García, V., Aguado, H. J., & De Luis Román, D. A. (2023). Prevalencia de sarcopenia en pacientes mayores de 75 años ingresados por fractura de cadera. *Endocrinología, Diabetes y Nutrición*, *70*, 396–407. https://doi.org/10.1016/j.endinu.2022.03.011

Delgado, C., Araneda, A., & Behrens, M. I. (2019). Validación del instrumento Montreal Cognitive Assessment en español en adultos mayores de 60 años. *Neurología (English Edition)*, *34*(6), 376–385. https://doi.org/10.1016/j.nrl.2017.01.013

Diamante, A. (2013). Funciones ejecutivas. *Annual Review Psychology*, *64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Domínguez, M., de Oliveira, E., Odena, M. A., Portero, M., Pamplona, R., & Ferrer, I. (2016). Redox proteomic profiling of neuroketal-adducted proteins in human brain: Regional vulnerability at middle age increases in the elderly. *Free Radical Biology & Medicine*, *95*, 1–15. https://doi.org/10.1016/j.freeradbiomed.2016.02.034

Doyle, B., Browne, D., & Horan, D. (2020). The relationship of aerobic endurance and linear speed on repeat sprint ability performance in female international footballers. *International Journal Human Movements Sports Science*, *8*, 147–153. https://doi.org/10.13189/saj.2020.080407

Facal, D., Maseda, A., Pereiro, A. X., Gandoy, M., Lorenzo-López, L., & Millán-Calenti, J. C. (2018). Fragilidad cognitiva: revisión de las definiciones empleadas en estudios empíricos. *Revista Espanola de Geriatria y Gerontologia*, *53*, 175. https://doi.org/10.1016/j.regg.2018.04.417

Faíl, L. B., Marinho, D. A., Marques, E. A., Costa, M. J., Santos, C. C., Marques, M. C., Izquierdo, M., & Neiva, H. P. (2022). Benefits of aquatic exercise in adults with and without chronic disease-A systematic review with meta-analysis. *Scandinavian Journal of Medicine & Science in Sports*, *32*(3), 465–486. https://doi.org/10.1111/sms.14112

Fernández, R.A. & Santi, M.E. (2022*). Ejercicio físico y factores neurotróficos derivados del cerebro, efectos sobre la función cognitiva en adultos sin deterioro cognitivo* [Tesis de grado], Universidad del Gran Rosario. https://hdl.handle.net/20.500.14125/319

França, C., Gouveia, E. R., Caldeira, R., Marques, A., & Martins, J. (2021). Predictors of explosive leg power in elite football players. *Journal Phycology Education Sport*, *21*, 3599–3605. http://dx.doi.org/10.7752/jpes.2021.06486

Fritz-Silva, N. (2021). Effects of high-intensity interval training in older adults: a systematic review. *Cultura Ciencia y Deporte*, *16*(48), 187–198. https://doi.org/10.12800/ccd.v16i48.1627

Gale, C. R., Ritchie, S. J., Cooper, C., Starr, J. M., & Deary, I. J. (2017). Cognitive ability in late life and onset of physical frailty: The Lothian Birth Cohort 1936. *Journal of the American Geriatrics Society*, *65*(6), 1289–1295. https://doi.org/10.1111/jgs.14787

García, E., López De Munain, M. L., & Santibáñez, M. (2013). Impacto del ejercicio físico en la función cognitiva tras el ictus: una revisión sistemática. *Revista Neurología*, *57*(535). https://doi.org/10.33588/rn.5712.2013292

García, S., Faxén, G., Čermáková, P., Eriksdotter, M., & Religa, D. (2014). Body mass index In dementia. *European Journal of Clinical Nutrition*, *68*(11), 1204–1209. https://doi.org/10.1038/ejcn.2014.199

García, V. (2021). *Diferencias individuales en deporte y creatividad* [Tesis de doctorado], Universidad de Murcia. http://hdl.handle.net/10201/115205

González, N. F., & Rivas, A. D. (2018). Actividad física y ejercicio en la mujer. *Revista Colombiana de Cardiologia*, *25*, 125–131. https://doi.org/10.1016/j.rccar.2017.12.008

Greendale, G. A., Sternfeld, B., Huang, M., Han, W., Karvonen-Gutierrez, C., Ruppert, K., Cauley, J. A., Finkelstein, J. S., Jiang, S.-F., & Karlamangla, A. S. (2019). Changes in body composition and weight during the menopause transition. *JCI Insight*, *4*(5). https://doi.org/10.1172/jci.insight.124865

Griebler, N., Schröder, N., Artifon, M., Frigotto, M., & Pietta-Dias, C. (2022). The effects of acute exercise on memory of cognitively healthy seniors: A systematic review. *Archives of Gerontology and Geriatrics*, *99*(104583), 104583. https://doi.org/10.1016/j.archger.2021.104583

Instituto Nacional de Estadística. (2023). *Estadísticas demográficas de España*. https://www.ine.es

Inzitari, M., Calle, A., Esteve, A., Casas, Á., Torrents, N., & Martínez, N. (2017). ¿Mides la velocidad de la marcha en tu práctica diaria? Una revisión. *Revista Española de Geriatría y Gerontología*, *52*(1), 35–43. https://doi.org/10.1016/j.regg.2015.12.010

Jiménez Roldán, M. J. (2017). *Efectos del entrenamiento de fuerza sobre las funciones ejecutivas en mayores sin deterioro cognitivo: una revisión sistemática de la literatura* [Tesis de Maestría], Universidad de Sevilla. https://hdl.handle.net/11441/70746

Kalafatis, Chris, Modarres, M. H., Apostolou, P., Marefat, H., Khanbagi, M., Karimi, H., Vahabi, Z., Aarsland, D., & Khaligh-Razavi, S.-M. (2021). Validity and cultural generalisability of a 5-minute AI-based, computerised cognitive assessment in mild cognitive impairment and Alzheimer's dementia. *Frontiers in Psychiatry*, *12*, 706695. https://doi.org/10.3389/fpsyt.2021.706695

Kilgour, A. H. M., Ferguson, K. J., Gray, C. D., Deary, I. J., Wardlaw, J. M., MacLullich, A. M. J., & Starr, J. M. (2013). Neck muscle cross-sectional area, brain volume and cognition in healthy older men: a cohort study. *BMC Geriatrics*, *13*(1), 20. https://doi.org/10.1186/1471-2318-13-20

Lagally, K. M., & Robertson, R. J. (2006). Construct validity of the Omni resistance exercise scale. *Journal of Strength and Conditioning Research*, *20*(2), 252–256. https://doi.org/10.1519/00124278-200605000-00003

Legdeur, N., Heymans, M. W., Comijs, H. C., Huisman, M., Maier, A. B., & Visser, P. J. (2018). Age dependency of risk factors for cognitive decline. *BMC Geriatrics*, *18*(1), 187. https://doi.org/10.1186/s12877-018-0876-2

Liguori, I., Russo, G., Curcio, F., Bulli, G., Aran, L., Della-Morte, D., Gargiulo, G., Testa, G., Cacciatore, F., Bonaduce, D., & Abete, P. (2018). Oxidative stress, aging, and diseases. *Clinical Interventions in Aging*, *13*, 757–772. https://doi.org/10.2147/cia.s158513

Limoge, M., Safina, A., Beattie, A., Kapus, L., Truskinovsky, A. M., & Bakin, A. V. (2017). Tumor-fibroblast interactions stimulate tumor vascularization by enhancing cytokine-driven production of MMP9 by tumor cells. *Oncotarget*, *8*(22), 35592–35608. https://doi.org/10.18632/oncotarget.16022

Ling, C. H. Y., de Craen, A. J. M., Slagboom, P. E., Gunn, D. A., Stokkel, M. P. M., Westendorp, R. G. J., & Maier, A. B. (2011). Accuracy of direct segmental multi-frequency bioimpedance analysis in the assessment of total body and segmental body composition in middle-aged adult population. *Clinical Nutrition*, *30*(5), 610–615. https://doi.org/10.1016/j.clnu.2011.04.001

Llamas, S., Llorente, L., Contador, I., & Bermejo, F. (2015). Spanish versions of the Minimental State Examination (MMSE). Questions for their use in clinical practice. *Revista de Neurología*, *61*(8), 363–371. https://doi.org/10.33588/rn.6108.2015107

Lloret, S., Ferreres, A., Hernández, A., & Tomás, I. (2014). El análisis factorial exploratorio de Los ítems: una guía práctica, revisada y actualizada. *Annals of Psychology*, *30*(3), 1151–1169. https://doi.org/10.6018/analesps.30.3.199361

Lovegrove, S., Hughes, L. J., Mansfield, S. K., Read, P. J., Price, P., & Patterson, S. D. (2022). Repetitions in reserve is a reliable tool for prescribing resistance training load. *Journal of Strength and Conditioning Research*, *36*(10), 2696–2700. https://doi.org/10.1519/JSC.0000000000003952

Lu, X., Li, W., Ma, Y., Chen, H., Zeng, Y., Yu, X., & Wang, H. (2019). Cognitive decline and Mortality among community-dwelling Chinese older people. *BMC Medicine*, *17*, 1–10. https://doi.org/10.1186/s12916-019-1295-8

Malek, M., Powell, J., Belden, C. M., Connor, K., Evans, L., Coon, D. W., & Nieri, W. (2015). Age-and education-adjusted normative data for the Montreal Cognitive Assessment (MoCA) in older adults age 70-99. *Aging, Neurological and Cognition*, *22*(6), 755–761. https://doi.org/10.1080/13825585.2015.1041449

Marcos-Pardo, P.J., González-Gálvez, N., Vaquero-Cristóbal, R., Sagarra- Romero, L., López-Vivancos, A., Velázquez-Díaz, D., Gea, G.M., Ponce- González, J.G., Esteban-Cornejo, I., Jiménez-Pavón, D., & Carbonell-Baeza, A. (2021). Programa de Intervención multidominio Healthy- Age. Recomendaciones para un envejecimiento saludable: por la red Healthy-Age. *Cultura, Ciencia y Deporte*, *16*(48), 311-320. http://dx.doi.org/10.12800/ccd.v16i48.1743

Matthews, V. B., Aström, M.-B., Chan, M. H. S., Bruce, C. R., Krabbe, K. S., Prelovsek, O., Akerström, T., Yfanti, C., Broholm, C., Mortensen, O. H., Penkowa, M., Hojman, P., Zankari, A., Watt, M. J., Bruunsgaard, H., Pedersen, B. K., & Febbraio, M. A. (2009). Brain-derived neurotrophic factor is produced by skeletal muscle cells in response to contraction and enhances fat oxidation via activation of AMP-activated protein kinase. *Diabetologia*, *52*(7), 1409–1418. https://doi.org/10.1007/s00125-009-1364-1

Maust, D., Cristancho, M., Gray, L., Rushing, S., Tjoa, C., & Thase, M. E. (2012). Psychiatric rating scales. *Handbook of Clinical Neurology*, *106*, 227–237. https://doi.org/10.1016/B978-0-444-52002-9.00013-9

Mero, S.M. & Pérez, J.D. (2022). *Déficit cognitivo relacionado con la obesidad*. PhD thesis. Universidad Estatal de Milagro, Ecuador. https://repositorioslatinoamericanos.uchile.cl/handle/2250/8211725

Milanović, Z., Sporiš, G., & Weston, M. (2015). Effectiveness of high-intensity interval training (HIT) and continuous endurance training for VO2max improvements: A systematic review and meta-analysis of controlled trials. *Sports Medicine*, *45*(10), 1469–1481. https://doi.org/10.1007/s40279-015-0365-0

Morley, J. E., Morris, J. C., Berg-Weger, M., Borson, S., Carpenter, B. D., del Campo, N., Dubois, B., Fargo, K., Fitten, L. J., Flaherty, J. H., Ganguli, M., Grossberg, G. T., Malmstrom, T. K., Petersen, R. D., Rodriguez, C., Saykin, A. J., Scheltens, P., Tangalos, E. G., Verghese, J., … Vellas, B. (2015). Brain health: The importance of recognizing cognitive impairment: An IAGG consensus conference. *Journal of the American Medical Directors Association*, *16*(9), 731–739. https://doi.org/10.1016/j.jamda.2015.06.017

Nguyen, T. T., Ta, Q. T. H., Nguyen, T. T. D., Le, T. T., & Vo, V. G. (2020). Role of insulin resistance in the Alzheimer's disease progression. *Neurochemical Research*, *45*(7), 1481–1491. https://doi.org/10.1007/s11064-020-03031-0

Norman, K., Stobäus, N., Pirlich, M., & Bosy, A. (2012). Bioelectrical phase angle and Impedance vector analysis-clinical relevance and applicability of impedance parameters. *Clinical Nutrition*, *31*, 854–861. https://doi.org/10.1016/j.clnu.2012.05.008

Ortega, F. B., Silventoinen, K., Tynelius, P., & Rasmussen, F. (2012). Muscular strength in male adolescents and premature death: cohort study of one million participants. *BMJ (Clinical Research Ed.)*, *345*, e7279. https://doi.org/10.1136/bmj.e7279

Passler, S., Bohrer, J., Blöchinger, L., & Senner, V. (2019). Validity of wrist-worn activity trackers for estimating VO2max and energy expenditure. *International Journal of Environmental Research and Public Health*, *16*(17), 3037. https://doi.org/10.3390/ijerph16173037

Pedraza, O. L., Sierra, F., Salazar, A. M., Hernández, A. M., Ariza, M. J., Montalvo, M. C., & Piñeros, C. (2016). Intra and interrater reliability of the Minimental State Exmination (MMSE) and Montréal Cognitive Assessment (MoCA test) applied by health personnel in training. *Acta Neurologica*, *32*(1), 35–40. https://doi.org/10.22379/2422402273

Pekkarinen, E., Vanninen, E., Länsimies, E., Kokkarinen, J., & Timonen, K. L. (2012). Relation between body composition, abdominal obesity, and lung function: Relation between body composition and lung function. *Clinical Physiology and Functional Imaging*, *32*(2), 83–88. https://doi.org/10.1111/j.1475-097X.2011.01064.x

Pérez Díaz, P. (2020). *Diseño de un programa de educación para la salud para el fomento de la actividad física en el anciano* [Tesis de Grado], Universidad de La Laguna. http://riull.ull.es/xmlui/handle/915/19865

EFFECTS OF A TRAINING PROGRAM ON OLDER ADULTS. ASSOCIATION BETWEEN PHYSICAL ABILITIES, BODY COMPOSITION AND MOCA RESULTS ACCORDING TO GENDER

Pérez Zambrano, J. A., & Hurtado Villegas, M. A. (2020). *Implementación de la terapia acuática en adulto mayor con deterioro cognitivo, Grupo de Confraternidad de Adultos y Adultos Mayores Lupita Nolivos, C.A.E* [Tesis de Grado], Universidad de Guayaquil. http://repositorio.ug.edu.ec/handle/redug/49099

Perrote, F. M., Brochero, N. N., Concari, I. A., García, I. E., Assante, M. L., & Lucero, C. B. (2017). Asociación entre pérdida subjetiva de memoria, deterioro cognitivo leve y demencia. *Neurología argentina*, *9*(3), 156–162. https://doi.org/10.1016/j.neuarg.2017.06.002

Pintilie, S. R., Condrat, A. D., Fodor, A., Sitar-Tăut, A.-V., Damian, M., Login, C., Lotrean, L., Cornean, R. E., Florea, M., Chiș, A., & Vulturar, R., (2021). Neuroprotective effects of physical exercise: Implications in health and disease. *Revista Medicală Română*, *68*(3), 383–389. https://doi.org/10.37897/rmj.2021.3.9

Poddar, J., Pradhan, M., Ganguly, G., & Chakrabarti, S. (2019). Biochemical deficits and cognitive decline in brain aging: Intervention by dietary supplements. *Journal of Chemical Neuroanatomy*, *95*, 70–80. https://doi.org/10.1016/j.jchemneu.2018.04.002

Prado, C., López, P. & Morales, G. (2017). *Efecto de ejercicios de fuerza resistencia equilibrio y flexibilidad en índices de marcha y equilibrio evaluados mediante el test de Tinetti en adultos mayores asistentes a un taller de ejercicio físico de la comuna de Talcahuano*. [Tesis de Grado], Universidad Católica de la Santísima Concepción, Chile. https://tesis.ucsc.cl/handle/25022009/3114

Rivera Villaseñor, N.A. (2018). *Deterioro cognitivo en pacientes con diabetes mellitus tipo 2 y su asociación con niveles de IL-1β y adiponectina*. [Tesis de doctorado], Universidad autónoma de Querétaro. http://ri-ng.uaq.mx/handle/123456789/1077

Rodríguez, L. M. (2015). Determinants of frailty and longevity: are they the same ones? *Nestle Nutrition Institute Workshop Ser*, *83*, 29–39. https://doi.org/10.1159/000382057

Romero-Arenas, S., Pérez-Gómez, J., & Alcaraz, P. E. (2011). Entrenamiento en circuito. ¿Una herramienta útil para prevenir los efectos del envejecimiento? (Circuit training. A useful tool for preventing the effects of aging?). *Cultura Ciencia Deporte*, *6*(18), 185–192. https://doi.org/10.12800/ccd.v6i18.45

Rosado, C., Carnicero, J. A., Losa, J., Guadalupe, A., Castillo, C., & Gutiérrez, G. (2017). Cognitive performance across 3 frailty phenotypes: Toledo study for healthy aging. *Journal of the American Medical Directors Association*, *8*(9), 785–790. https://doi.org/10.1016/j.jamda.2017.04.008

Rose-John, S. (2021). Therapeutic targeting of IL-6 trans-signaling. *Cytokine*, *144*(155577), 155577. https://doi.org/10.1016/j.cyto.2021.155577

Simmons, S. F., Alessi, C., & Schnelle, J. F. (2001). An intervention to increase fluid intake in nursing home residents: prompting and preference compliance. *Journal of the American Geriatrics Society*, *49*(7), 926–933. https://doi.org/10.1046/j.1532-5415.2001.49183.x

Soriano-Ursua, I. G., Piña-Ramírez, N. I., Albavera-Hernández, C., & Ávila-Jiménez, L. (2022). Deterioro cognitivo asociado a obesidad en adultos en un hospital general en Cuernavaca, Morelos. *Atención Familiar*, *30*(1), 61–67. https://doi.org/10.22201/fm.14058871p.2023.1.83866

Suhr, J. A., Hall, J., Patterson, S. M., & Niinistö, R. T. (2004). The relation of hydration status to cognitive performance in healthy older adults. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology*, *53*(2), 121–125. https://doi.org/10.1016/j.ijpsycho.2004.03.003

Suo, C., Singh, M. F., Gates, N., Wen, W., Sachdev, P., Brodaty, H., Saigal, N., Wilson, G. C., Meiklejohn, J., Singh, N., Baune, B. T., Baker, M., Foroughi, N., Wang, Y., Mavros, Y., Lampit, A., Leung, I., & Valenzuela, M. J. (2016). Therapeutically relevant structural and functional mechanisms triggered by physical and cognitive exercise. *Molecular Psychiatry*, *21*(11), 1633–1642. https://doi.org/10.1038/mp.2016.19

Tam, Nicoladie D. (2013). Improvement of processing speed in executive function immediately following an increase in cardiovascular activity. *Cardiovascular Psychiatry and Neurology*, 212767. https://doi.org/10.1155/2013/212767

Tarragüel, M. G., Peñarrocha, P. B., Moina, S., Peris, A. M., Cuevas, B. F., & Colás, E. C. (2023). Intervención de la terapia ocupacional en el medio acuático. *Revista Sanitaria de Investigación*, *4*(3). https://revistasanitariadeinvestigacion.com/intervencion-de-la-terapia-ocupacional-en-el-medio-acuatico/

Tay, L., Lim, W. S., Chan, M., Ye, R. J., & Chong, M. S. (2016). The independent role of inflammation in physical frailty among older adults with mild cognitive impairment and mild-to-moderate Alzheimer's disease. *The Journal of Nutrition, Health & Aging*, *20*(3), 288–299. https://doi.org/10.1007/s12603-015-0617-6

Toledo, E. R., Valdés, J. E., Soto, F. R., Salas, N. G., & Gómez, J. V. (2017). Prueba de escalón de Mcardle: una ecuación para estimar el VO2 máx. en estudiantes de educación física. *Revista Científica de la Actividad Física*, *18*(2), 1–7. https://doi.org/10.29035/rcaf.18.2.2

Tsai, C.-L., Ukropec, J., Ukropcová, B., & Pai, M.-C. (2018). An acute bout of aerobic or strength exercise specifically modifies circulating exerkine levels and neurocognitive functions in elderly individuals with mild cognitive impairment. *NeuroImage: Clinical*, *17*, 272–284. https://doi.org/10.1016/j.nicl.2017.10.028

Urquidi, V., Aguilar, E., de Ochoa, C., Valverde, J. & González, F. (2022). Efecto del entrenamiento físico sobre la capacidad cognitiva del adulto mayor. *Revista de Divulgación Científica FOD*, 1(1), 8-11.

Whitake, A.A., Alwatban, M., Freemyer, A., Perales, J. & Billinger, S.A. (2020). Efectos del ejercicio por intervalos de alta intensidad sobre la función cerebrovascular: una revisión sistemática. *Revista de Educación Física*, 160: 23-26.

Withers, R. T., Laforgia, J., & Heymsfield, S. B. (1999). Critical appraisal of the estimation of body composition via two-, three-, and four-compartment models. *American Journal of Human Biology: The Official Journal of the Human Biology Council*, *11*(2), 175–185. https://doi.org/10.1002/(sici)1520-6300(1999)11:2<175::aid-ajhb5>3.3.co;2-3

Yoon, D., Kang, D., Kim, H., Kim, J. S., Song, H. S., & Song, W. (2016). Effect of elastic band- Based high-speed power training on cognitive function, physical performance and muscle strength in older women with mild cognitive impairment. *Gerontolgy International*, *17*(5), 765–772. https://doi.org/10.1111/ggi.12784

Yoon, D. H., Lee, J.-Y., & Song, W. (2018). Effects of resistance exercise training on cognitive function and physical performance in cognitive frailty: A randomized controlled trial. *The Journal of Nutrition, Health & Aging*, *22*(8), 944–951. https://doi.org/10.1007/s12603-018-1090-9

Zaccagni, L., Toselli, S., Bramanti, B., Gualdi-Russo, E., Mongillo, J., & Rinaldo, N. (2020). Handgrip strength in young adults: Association with anthropometric variables and laterality. *International Journal of Environmental Research and Public Health*, *17*(12), 4273. https://doi.org/10.3390/ijerph17124273

Zanchetta, M. B., Abdala, R., Massari, F., Rey, P., Spivacow, R., Miechi, L., Longobardi, V., & Brun, L. R. (2021). Postmenopausal women with sarcopenia have higher prevalence of falls and vertebral fractures. *Medicina (Buenos Aires)*, 81(1), 47–53. https://pubmed.ncbi.nlm.nih.gov/33611244/

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