Blasco-Lafarga, C.; Monteagudo, P.; Cordellat, A.; Roldán, A. (201x) Inspiratory Muscle Strength, Handgrip Strength and Muscle Mass in Active Elderly Women. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. X (X) pp. xx. Http://cdeporte.rediris.es/revista/___*

ORIGINAL

INSPIRATORY MUSCLE STRENGTH, HANDGRIP STRENGTH AND MUSCLE MASS IN ACTIVE ELDERLY WOMEN

FUERZA INSPIRATORIA, FUERZA DE PRENSIÓN Y MASA MUSCULAR EN MUJERES MAYORES ACTIVAS

Blasco-Lafarga, C.[1,2]; Monteagudo, P.[2,3]; Cordellat, A.[1,2]; Roldán, A.[1,2]

[1] Physical Education and Sports Department, University of Valencia, Valencia (Spain) m.cristina.blasco@uv.es
[2] UIRFIDE (Sports Performance and Physical Fitness Research Group), University of Valencia, Valencia (Spain) ana.cordellat@uv.es, Pablo.Monteagudo@uv.es, ainoa.roldan@uv.es
[3] Education and Specific Didactics Department, Jaume I University, Castellon, (Spain).

Spanish-English translators: Víctor Gutiérrez Martínez, victor@idiomasleon.es

ACKNOWLEDGEMENTS

The authors would like to thank the Elderly Training Association (EcM) for the support received, both from the technicians who run the programmes and help in the assessment process, and from the elderly people who participated in them.

Código UNESCO / UNESCO Code: 241106 Fisiología del Ejercicio / Exercise Physiology; 241117 Fisiología de la Respiración / Respiratory Physiology; 3212 Salud Pública / Public Health
Clasificación Consejo Europa / Council of Europe classification: 17. Otras: Actividad Física y Salud / Others: Physical Activity and Health; Entrenamiento Deportivo / Sports training.

Recibido 28 de agosto de 2019 **Received** August 28, 2019
Aceptado 9 de febrero de 2020 **Accepted** February 9, 2020

RESUMEN

El objetivo del estudio fue analizar la relación entre la fuerza de la musculatura inspiratoria (MIP), la fuerza periférica medida como prensión manual (HG), y la masa muscular (MM), en mujeres mayores sanas y activas. Tras recoger 126 mediciones de usuarias del programa de entrenamiento multicomponente EFAM-UV© y comprobar la influencia de la edad sobre MM, HG y MIP, incluidos sus gráficos de dispersión y R^2, se analizó la asociación entre estas variables, con y sin la covariable edad (Coeficientes Pearson o Spearman según corresponda). La esperada relación negativa entre edad y MM, y edad y HG, fue moderada, y se redujo para Edad vs. MIP (r=-0,178; R^2 <2%). MIP, HG y MM no mostraron asociación. Envejecimiento y entrenamiento son procesos selectivos. Una MIP baja a pesar de la buena aptitud física justificaría estos resultados y confirmaría que, aun siendo activas, las mujeres mayores deben entrenar específicamente la musculatura inspiratoria.

PALABRAS CLAVE: Aptitud física, ejercicio, entrenamiento respiratorio, envejecimiento activo, evaluación respiratoria, sarcopenia.

ABSTRACT

The aim of this study was to analyse the relationship between inspiratory muscle strength (MIP), peripheral strength measured with a handgrip test (HG), and muscle mass (MM) in healthy active elderly women. After collecting 126 measurements from women undergoing the multicomponent training program EFAM-UV©, and after testing the influence of age on MM, HG and MIP, including their Scatter plots and R^2, the relationship between these variables was analysed, with and without Age as a covariate (Pearson or Spearman Coefficients as appropriate). The expected negative association between age and MM, and age and HG, was moderated and got reduced when considering Age vs. MIP (r=-0.178; R^2 <2%). Moreover, there was no relationship between MIP, HG and MM. Aging and Exercise Training are both selective processes. Low MIP values despite a good physical fitness would justify these results, confirming that even being active, elderly women should train inspiratory muscles specifically.

KEYWORDS: Physical fitness, exercise, respiratory training, active aging, respiratory assessment, sarcopenia.

INTRODUCTION

Sarcopenia, a progressive and widespread loss of muscle mass and strength (1), in both healthy and pathological older people (OP), is one of the major problems facing the OP. As stated by the *European Working Group on Sarcopenia in Older People* (2), we are facing a loss of muscle mass, both in quality and in quantity, which is related to a loss of functionality, reduced mobility and physical fragility (3) accompanied by increased risk of fractures, falls (4) and even future dependence, also affecting the quality of life and mental health, among others (2).

However, recently, Shaw et al. (5) studied the loss of muscle mass, strength and physical function in an independent manner, concluding that the loss of muscle mass is much slower than the loss of strength, and that physical function is the last to be reduced. Thus, the evaluation of changes in strength associated with age helps to diagnose sarcopenia prior to the loss of muscle mass or functionality, and therefore quick and simple tests such as the hand grip test have become a common test in the OP evaluation (6). The so-called *Handgrip Test* (HG) has confirmed to be a predictor of loss of functionality, disability, even mortality (7), and its high values can be considered as a reflection of healthy ageing (8).

On the other hand, sarcopenia is a widespread process and it is expected that not only the peripheral muscles are affected, but also that there are losses in the respiratory muscles (1), accompanied by losses in strength and respiratory function associated with age. In fact, Jeon et al. (9) relate low muscle mass levels to alterations in lung function.

Structural and physiological changes, with special attention to the deterioration of the immune system, explain that the loss of muscle mass at respiratory level can cause loss of strength above 20% by the age of 70 (10), a factor that is associated with the increase in dyspnea during activities of daily living (ADL), limitation of physical activity (PA) and decreased performance during exercise (11). In this sense, the strength of the expiratory muscles can be measured by the maximal expiratory pressure (MEP), while the strength of the inspiratory musculature is measured by the maximal inspiratory pressure (MIP) -ATS/ERS 2002 (12)-. And if we focus on the latter, the influence of the age is confirmed, further indicating that the pattern that follows their loss is different in men and women (13, 14), although studies that measure only women, and especially elderly women, are still scarce.

It therefore seems important to go in depth in the relationship between age, muscle mass and respiratory strength, as well as their influence on the functionality of the respiratory system, since not only age per se, but also the loss or reduction of the mobility characteristic of ageing, contributes to accentuate the loss of muscle mass (15, 16). On the other hand, PA helps to maintain the musculoskeletal system (17), and can therefore prevent respiratory deterioration. Bamrotia et al. (18) compared a group of OP who performed regular PA during 150 min per week to a group of OP with a sedentary lifestyle, concluding that regular PA practice maintained lung function above average, in addition to better preparing them to deal with diseases related to the respiratory system. Specifically on respiratory muscles, Summerhill et al. (19) concluded that active OP had higher respiratory strength values compared to inactive OP.

Finally, and as we have already pointed out, gender is a factor to be taken into account in this process. In fact, both age and gender act as a negative condition of performance in the application of strength and the execution of functional tasks in older people (20). Women have lower values of muscle mass, strength and physical function (21), which at respiratory level is reflected in 30% less of inspiratory strength compared to men (13, 14). Although with the age the loss of strength is lower in relation to men (14), the fact that the decrease in muscle mass is associated with hormonal factors increases their predisposition to suffer from sarcopenia diseases after menopause (22) making women a risk group. However, studies that analyse the relationship between body composition and respiratory function in the elderly female population are still scarce. Moreover, as far as we know, there are no studies that analyse the relationship between muscle mass, respiratory function -measured as inspiratory strength- and handgrip strength -as a reflection of peripheral strength- in a large and exclusive sample of active elderly women.

Thus, the aim of the present study was (a) to analyse the association of inspiratory muscle strength (MIP) with handgrip strength, and with the muscle mass, in a group of older, healthy and active women, subject to a regular multicomponent training programme, as well as (b) to identify the importance of age on these factors and their associations. Knowing how ageing affects these muscle systems in active older women, and to what extent the loss of muscle mass is reflected equally in the strength of both, whether specifically trained or not (c), is important and can help detect and prevent problems associated with sarcopenia in this population.

MATERIAL AND METHODS

Participants

The study included 126 measurements from elderly women users of the multicomponent training programme EFAM-UV© (23) (the Spanish acronym for *Functional Training in Older Adults of the University of Valencia*) carried out over two years (2017 to 2019). Inclusion criteria: woman over 60 years old, participant in the multicomponent training programme EFAM-UV© for at least one year, and non-smoker. Exclusion criteria: wearing dental prosthesis, suffering or having suffered from heart, respiratory or chest wall disease, cognitive impairment or retinopathy, or any other contraindication to the practice of physical exercise.

Design and procedure

The study, which is responsible for applied quantitative and cross-sectional research, meets the ethical standards of the Declaration of Helsinki and was approved by the ethics committee of the responsible academic entity (H1506353751695). At the beginning of each course in the programme, all women received information regarding membership in a research programme and signed an informed consent.

As indicated in Figure 1, the body composition, height, blood pressure, oxygen saturation (SaO_2), spirometry, maximal inspiratory pressure (MIP), handgrip strength (HG) and cardiorespiratory fitness, among others, were evaluated. In all cases, they were instructed on the measurements, which were distributed over 3 days with a minimum of 48 hours separation.

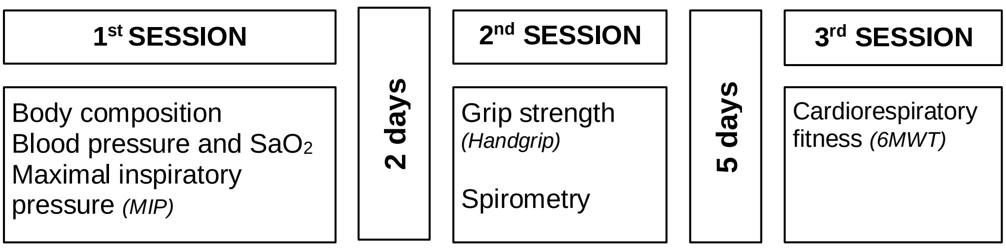

Figure 1. Evaluation protocol

SaO_2: Oxygen saturation; 6MWT: six-minute walk test.

Multicomponent training programme EFAM-UV©

The women of the study regularly participated in the multicomponent training programme EFAM-UV© (23), which is carried out for 8 months, in two weekly 60 minutes sessions (from October to May). EFAM-UV© combines walking education and postural correction tasks with rhythm and motor skills activities, under a dual task methodology, so that the strength and balance of the OP is improved as a basis for perfecting their cognitive, neuromuscular and cardiovascular abilities. The training environment is complex and includes tasks related to activities of daily living, without respiratory work as specific objective. It is added to the 8 months, 15 days prior to the pre assessment and another 15 when the programme ends. Graduates in Physical Activity and Sport Science carry both, the programme and its evaluation out. In this case, the data collected from 2017 to 2019 have been used, including users of EFAM-UV© training groups from 3 localities, and after at least two months from the start of the programme.

Variables and instruments

Along with the determination of *muscle mass, the height, blood pressure and oxygen saturation* were evaluated to identify the sample. After measuring height with the SECA 222 stadiometer (SECA; Medical Scale and Measuring Systems, Hamburg, Germany), the body composition was evaluated by bioimpedance with the BC-545 scale (TANITA; Corporation of America, Inc., Arlington Heights, IL). After resting 5 mins sitting in a chair, blood pressure was checked on the left arm (Omron M3 monitor; IM-HEM-7131-E), while SaO_2 was measured in the right middle finger (WristOX2-3150 pulse oximeter; Nonin Medical Inc., Minneapolis, MN, USA). For blood pressure (systolic –SBP– and diastolic –DBP–) 2 measurements were carried out with 1 minute separation, using the average of the two for final analysis. During all this time SaO_2 was measured until a stable value was obtained. For these measurements, women came in fasting.

Maximal inspiratory pressure. To evaluate the strength of inspiratory muscles (MIP test), following the protocol of Neder et al. (24), the women were seated in a chair with their feet on the floor and their backs straight, and they inhaled as hard and fast as possible with a nose clip, without extending their backs. Three measurements were taken and if the difference between them was >10%, up to 5 measurements were taken. Similar to other studies with older people (25, 26), the Powerbreathe® K5 electronic device (Powerbreathe K5, HaB International Ltd. UK) was used.

Handgrip test. Grip strength (HG) was evaluated by the Takei 5401 adaptable dynamometer (Takei Scientific Instruments CO., LTD). Following the protocol of Vianna et al. (27), the contraction was maintained for 5 seconds, with the arm stretched along the body, and 2 measurements were taken on each side, with 1 minute rest between them. This was considered the best value for the final analysis.

Spirometry. With the purpose of ruling out major respiratory illness or limitation, the lung capacity was evaluated according to the guidelines of García-Río et al. (28), by means of a portable spirometer (Spirobank spirometer USB, Medical International Research, Rome, Italy). Women were seated with their backs straight, without crossing their legs and with a nose clip. After a maximum inspiration, they should release the air as hard as possible keeping the exhalation for a minimum of 6 seconds to ensure the validity of the curve. Three measurements were taken, and up to a maximum of 8 in case any curve was not valid, leaving enough time to ensure recovery (28). The best value of the interest variables: forced vital capacity (FVC), maximum forced expiratory volume in first second (FEV_1), forced expiratory flow ($FEF_{25\%-75\%}$) and peak expiratory flow (PEF) was considered for the subsequent analysis.

Cardiorespiratory fitness test. Similarly, the 6-minute walk test (6MWT) was evaluated according to the protocol of Rikli & Jones (29), in a 20m x 5m rectangle, thus ensuring the functional level of the sample. Women walked as fast as possible, but without running for 6 min, being encouraged in each lap. They were warned of the time at 3 and 5 min.

Statistical treatment

The analysis of the data was performed with the SPSS statistics package version 23 (IBM SPSS Statistics for Windows), considering the data from the tests available for each variable. Once the normality of the sample (K-S) was analysed, the descriptors of all the variables were calculated, expressed by means of the Mean and Standard Deviation (Mean ± SD). The coefficient of variation (CV) was added to obtain greater information on the sample dispersion. In order to find out the relationship between age and muscle mass, as well as between age and inspiratory strength and peripheral strength, the Spearman Coefficient was used, since the age variable did not present a normal distribution. Following Sullivan & Feinn (30), the value of R^2 in the scatter plots was also considered as a measure of the size of the effect of these associations. Subsequently, in order to determine the relationship between inspiratory strength, peripheral strength and absolute muscle mass, the Pearson Coefficient was used in this case. Finally, partial correlations were made by controlling the age factor (r^a) to observe the role of age in these relationships. The *p-value* of significance was considered as *$p<0.05$.* To assess the degree of association, the Hopkins classification was used (31), where 0.1 trivial; 0.1-0.3 small; 0.3-0.49, moderate; 0.5-0.69, large; 0.7-0.89, very large; and >0.9 to 1, almost perfect.

RESULTS

Characteristics of the sample

As shown in Table 1, heterogeneity is a characteristic of the OP, also in active women. Importantly, and despite being trained, with high values in the 6MWT (32)and hand grip strength above the 95 percentile for their mean age (27), the evaluated women were placed in a low range for the expected values of maximum inspiratory strength (14, 33), a variable not specifically trained.

Table 1. Characteristics of the sample

n=126	Mean ± SD	CV (%)	
Anthropometric characteristics			
Age (years)	72.59 ± 4.96	6.83	
Height (metres)	1.54 ± 0.05	3.24	
Weight (Kg)	66.62 ± 10.39	15.60	
Muscle Mass (Kg)	37.77 ± 4.22	11.17	
Physiological characteristics			
SaO_2 (%)[1]	95.58 ± 1.64	1.72	
SBP (mmHg)[1]	136.26 ± 17.49	12.84	
DBP (mmHg)[1]	77.94 ± 8.4	10.82	
FEV_1 (L)[2]	1.97 ± 0.50	25.38	
FVC (L)[2]	2.72 ± 0.58	21.32	
$FEF_{25\%-75\%}$ (L/s)[2]	1.85 ± 0.67	36.21	
PEF (L/s)[2]	3.90 ± 1.39	35.64	
Performance characteristics			**Reference values*
MIP (cmH_2O)	48.28 ± 16.65	34.49	65.00 ± 26.00
HG (Kg)[3]	25.32 ± 4.31	21.48	> Percentile 95
6MWT (metres)	536.33 ± 61.81	11.52	492.86 ± 79.55

[1] n=125; [2] n=91; [3] n=121

SaO_2: Oxygen saturation; SBP: systolic blood pressure; DBP: diastolic blood pressure; FEV_1: maximum forced expiratory volume in first second; FVC: forced vital capacity; $FEF_{25\%-75\%}$: forced expiratory flow; PEF: peak expiratory flow; MIP: maximal inspiratory pressure; HG: handgrip strength; 6MWT: six-minute walk test.

Influence of age on inspiratory strength, peripheral strength and absolute muscle mass

We found a moderate and negative association between age and muscle mass, and age and peripheral muscle strength (Table 2). However, this association was reduced to small when considering inspiratory muscle strength.

Table 2. Association between age, inspiratory strength, peripheral strength and absolute muscle mass

n=126	MIP	HG	MM
Age	-0.178*	-0.361***	-0.403***

$^{*}p<0.05$; $^{***}p<0.001$

MM: muscle mass; HG: handgrip test; MIP: maximal inspiratory pressure

Again, we see that the value of the association when considering age and MIP was reduced against MM and HG in the scatter plots (Figure 2). The size of the effect when considering Age vs. MIP falls and R^2 was reduced below what Sullivan & Feinn (30) proposed as small (section 2C; R^2 = 0.025).

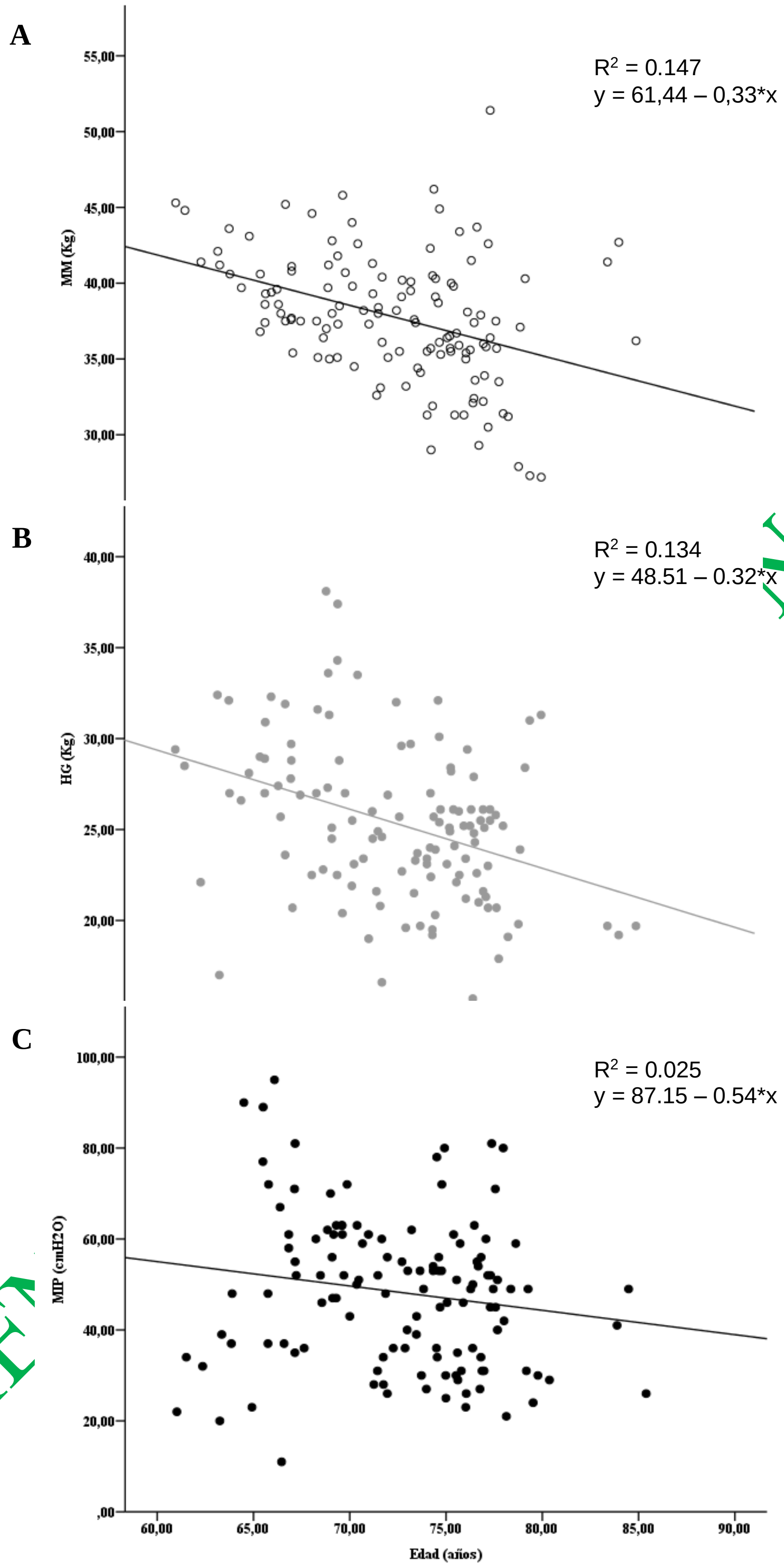

Figure 2. Relationship between age and muscle mass (A), peripheral muscle strength (B) and inspiratory muscle strength (C).
MM: muscle mass; HG: handgrip test; MIP: maximal inspiratory pressure

Relationship between inspiratory strength and absolute muscle mass and between inspiratory strength and handgrip strength

Finally, as shown in Table 3, no association was found between the two strength measures (inspiratory muscle strength and handgrip strength), nor between inspiratory muscle strength and muscle mass.

Table 3. Absence of association between inspiratory strength, peripheral strength and absolute muscle mass

n=126	MM	HG
MIP	0.038	0.166
MIP[a]	-0.012	0.128

MIP: maximal inspiratory pressure; MIP[a]: maximal inspiratory pressure controlling age; MM: muscle mass; HG: handgrip test

DISCUSSION

The main finding of this study is that inspiratory strength is not related to the general muscle mass or grip strength in a group of healthy and active older women, subjected to multicomponent training. In fact, our women were in a good physical condition (cardiorespiratory fitness, muscle mass and grip strength) for a low inspiratory strength. Furthermore, the proportion of the variance explained by age in inspiratory strength is almost non-existent, compared to higher values when considering grip strength, and especially muscle mass. The values of MIP -variable not specifically trained- were generally low and more heterogeneous, especially in younger women of our sample, compared to a more trained and homogeneous muscle mass and grip strength for the same ages (Figure 2). This could explain some of these divergences. In fact, cardiorespiratory fitness measured in a walk test, central objective of the programme, was the most homogeneous variable. It therefore seems to be confirmed that both ageing and training are selective processes in their consequences, and do not affect equally general muscle mass and specific strength, especially when it comes to different muscle systems, which are also subject to different levels of demand. The beneficial effect of regular PA and training for the containment of age-related deterioration is also confirmed. Taking into account that muscle mass and strength do not appear to age according to a uniform pattern when considering different muscle systems, our data reinforces the need to consider the evaluation and training of each system to ensure a comprehensive treatment of the health of the OP, at least in the female population.

MIP reflects the state of inspiratory muscles, so that low values in this test can be associated with a weakness of the diaphragm that can affect gas exchange, oxygen distribution or ventilation (34), thus limiting ADL. Given the importance of having simple tests that anticipate and minimise age-related losses (21), early detection of these changes can help prevent, delay and even reverse the deterioration of respiratory muscles.

Although women do not experience the weight of age on their inspiratory strength until the age of fifty, once this stage is over they do seem to suffer a moderate and progressive loss (14, 33), although this is lower than the loss found in men, who have more strength but they also lose more (13, 14). This negative association between Age and MIP, however, is reduced to a trivial relationship and with a small R^2 in our study, below what was shown for HG and MM (in this order), and also below previous values in studies with similar samples (14, 35, 36). In addition, the low MIP of our younger women (Figure 2C) is striking in comparison with these previous studies, as in them the MIP is higher in the first age group (14, 36), and especially higher among healthier women (14).

In this sense, EFAM-UV© is a periodised programme that is initiated with a neuromuscular and cognitive orientation (balance and strength predominance, with instructions and double task), to evolve at the end of the macrocycle towards more cardiovascular activities (37). Some measurements have coincided with neuromuscular mesocycles, but even in their most cardiovascular phase, multicomponent training seems not a sufficient stimulus to improve MIP. This fact and the fact that we do see a moderate and negative association with age in our sample for grip strength and muscle mass (Table 2, Figure 2A and 2B), leads us to think that a greater effect of training on younger women, but only on specifically trained variables, may explain some of these differences. In fact, McConnell & Copestake (35) confirm a greater negative association between age and MIP (r=-0.456) in older women who perform cardiovascular activities (walking, dancing, cycling, running or tennis). In addition, in their study with healthy and active Brazilian population, with identical assessment protocol of MIP, Neder et al. (36) found an R^2 of 0.464 for age vs MIP in women between 20 and 80 years, and a positive correlation between MIP and VO_2max (r= 0.81), and between MIP and self-reported PA (r=0.47). It is true that these latter associations could already be mediated by the influence of age and gender, co-variables that their authors do not consider (36).

In the absence of further studies to improve our understanding of the values of inspiratory strength offered by electronic devices, which seem to be underestimating inspiratory strength in relation to previous normative values (26, 36), we consider that MIP assessment is a simple and low-cost tool that would allow us to assess respiratory muscles specifically. Likewise, it seems that it would be appropriate to complement existing exercise programmes in the elderly women population, or to implement respiratory training programmes specifically, if necessary, as it has been already suggested (26).

Regarding the relationship between MIP and other strength variables such as handgrip strength in OP, Enright et al. (13) noted a significant, positive and moderate correlation (r=0.48; *p<0.001)* between both, but these authors considered men and women together, as well as smokers and non-smokers, without specifying the level of PA. In addition, they did not consider the influence of age. The same as Shin, Kim (38), when analysing 65 adults over 60 (r=0.560), or Efstathiou et al. (39) in a younger mixed population (20 to 60 years old, r=0.71). In fact, the latter found that sex and HG were clear MIP predictors (39). However, the fact that in our study, the tendency to a trivial association between MIP and HG disappears when considering the influence of age, which had previously shown its relationship with HG, detracts from this relationship between variables, at least in the female population. Furthermore, in our sample, women train the upper part, but not the inspiratory strength.

In this sense, new studies are required considering only the population of older women, because different works that have included only men or both genders together, corroborate positive associations between respiratory strength and different manifestations of strength, pointing, perhaps, to the fact that greater male strength may be behind this association not found in our sample of women. Bahat et al. (1) confirmed the association between inspiratory strength and handgrip strength in men only. Moreover, Simoes et al. (40) found a significant association between MIP and MEP and knee flexion and extension strength at 60º, thus considering men and women together. It will also be necessary to review these associations after inspiratory muscle training in both genders.

Something similar seems to occur in the relationship between inspiratory strength and MM, which has not been significant in our sample, despite the fact that these are active women for their age and PA is a factor that conditions MM (41). Compared to our results, Shin et al. (38) did suggest inspiratory muscle sarcopenia when they found an association between MIP and skeletal muscle index (SMI) in a group of OP -although not with MEP-. However, recently, Sawaya et al. (42) analysed this same relationship in a group of healthy young adults taking into account gender, and found that the initial association between SIM and MIP (r=0.56) disappeared in both genders when analysed separately, in line with our results.

It therefore seems that gender differences are important in these associations, and differences in respiratory training needs could be as well. As already mentioned, structural differences such as thoracic cage morphometry (43)or the size of the airways, which are smaller in women than in men (44), together with lower general strength capacity, would explain why women present lower values in both lung function and respiratory strength, and thus run a greater risk of going below normal over the years. Furthermore, as already seen in previous works of the group (26), high physical fitness by the standards of the adult female population does not ensure respiratory strength, which highlights the need to train the inspiratory muscles specifically in older women. Hand grip strengths above the percentile 95 (27), and cardiorespiratory fitness values (six-minute walk test) 8.82% above Rikli & Jones values, have (32) not been accompanied by a high inspiratory strength in our sample, despite training.

On the other hand, given the role of respiratory muscles as a support to provide the peripheral muscles with oxygen, especially when increasing the exercise intensity (45), and given the beneficial effect of respiratory training programmes as support for improved performance, both in young elite athletes (45), as in older women (25, 26, 46), it seems that assessing this variable and monitoring their behaviour in relation to other variables may be particularly interesting for the health of older women. Studies such as those by Rodrigues et al. (47)

already found improvements in MIP after 5 weeks of inspiratory training in this population, as well as Souza et al. (48) after 8 weeks. As points Ozdal (49) out, although some jobs involving stabilisation of the trunk may involve respiratory improvements in the initial weeks of adaptation to exercise (8 weeks), from that moment onwards, specific training is required to continue improving at respiratory levels.

CONCLUSION

Thus, inspiratory strength is not associated with grip strength and muscle mass in active elderly women, so the three require specific assessment and training. Ageing and training are selective and complex processes that do not affect muscle mass and strength of different muscle systems. Similarly, older women must specifically train their inspiratory muscles, as regular PA does not ensure high levels of strength in them. The extension of the MIP evaluation outside the hospital setting, thanks to electronic devices, should help detect early changes in this manifestation of respiratory strength, and anticipate solutions to the process of its deterioration, since, with age, older women see their health and abilities diminish.

REFERENCES

1. Bahat G, Tufan A, Ozkaya H, Tufan F, Selçuk Akpinar T, Akin S, et al. Relation between hand grip strength, respiratory muscle strenght and spirometric measures in male nursing home residents. The Aging Male. 2014;17(3):136-40.
2. Cruz-Jentoft A, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al. Sarcopenia: revised European consensus on definition and diagnosis. Age & Ageing. 2018;48(1):16-31.
3. Kell RT, Bell G, Quinney A. Musculoskeletal Fitness, Health Outcomes and Quality of Life. Sports Medicine. 2001;31(12):863-73.
4. Curtis E, Litwic A, Cooper C, Dennison EM. Determinants of Muscle and Bone Aging. Journal of Cellular Physiology. 2015;230(11):2618-25.
5. Shaw S, Dennison E, Cooper C. Epidemiology of Sarcopenia: Determinants Throughout the Lifecourse. Calcified tissue international. 2017;101(3):229-47.
6. Cruz-Jentoft A, Pierre J, Bauer J, Boirie Y, Cederholm T, Landi F, et al. Sarcopenia: European consensus on definition and diagnosis. Age and Ageing. 2010;39:412-23.
7. Bohannon RW. Hand-grip dynamometry predicts future outcomes in aging adults. Journal of geriatric physical therapy. 2008;31(1):3-10.
8. Dodds RM, Sydall HE, Cooper R, Benzeval M, Deary IJ, Dennison EM, et al. Grip Strength across the Life Course: Normative Data from Twelve British Studies. Plos One. 2014;9(12):e113637.
9. Jeon YK, Shin MJ, Kim MH, Mok JH, Kim SS, Kim BH, et al. Low pulmonary function is related with a high risk of sarcopenia in community-dwelling older adults: the Korea National Health and Nutrition Examination Survey (KNHANES) 2008-2011. Osteoporosis International. 2015;26:2423-9.

10. Lowery EM, Brubaker AL, Kuhlmann E, Kovacs EJ. The aging lung. Clinical Interventions in Aging. 2013;8:1489-96.
11. Mills DE, Johnson MA, Barnett YA, Smith WH, Sharpe GR. The Effects of Inspiratory Muscle Training in Older Adults. Medicine & Science in Sports & Exercise. 2015;47(4):691-7.
12. European RS, Society AT. ATS/ERS Statement on respiratory muscle testing. American Journal of Respiratory and Critical Care Medicine. 2002;166(4):518-624.
13. Enright P, Kronmal R, Manolio T, Schenker M, Hyatt R. Respiratory Muscle Strength in the Elderly: correlates and reference values. American Journal of Respiratory and Critical Care Medicine. 1994;149:430-8.
14. Harik-Khan R, Wise R, Fozard J. Determinants of Maximal Inspiratory Pressure. American Journal of Respiratory and Critical Care Medicine. 1998;158:1459-64.
15. Christos I, Alexandros M, Aikaterini F, Kiriaki T, Lambrini K. Diseases of the Musculoskeletal System in the Elderly. Journal of Pharmacy and Pharmacology. 2015;3:58-62.
16. Enríquez Reyna MC, Carranza Bautista D, Navarro Orocio R. Nivel de actividad física, masa y fuerza muscular de mujeres mayores de la comunidad: Diferencias por grupo etario. Retos Nuevas tendencias en educación física, deporte y recreación. 2019;35(1):121-5.
17. Hunter SK, Pereira HM, Keenan KG. The aging neuromuscular system and motor performance. Journal of Applied Physiology. 2016;121(4):982-95.
18. Bamrotia JB, Patel DK, Joshi AN. Evaluation of respiratory function in physically active elderly males in comparison to males having sedentary lifestyle. National Journal of Physiology, Pharmacy and Pharmacology. 2017;7(1):108-12.
19. Summerhill EM, Angov N, Garber C, McCool FD. Respiratory Muscle Strength in the Physically Active Elderly. Lung. 2007;185(6):315-20.
20. Cuesta-Vargas A, Giné-Garriga M, González-Sánchez M. Función física entre subgrupos de mayores de 55 años físicamente activos. Revista Internacional de Medicina y Ciencias de la Actividad Física y del Deporte/International Journal of Medicine Science of Physical Activity and Sport. 2015;15(59):543-58.
21. Shaw SC, Dennison EM, Cooper C. Epidemiology of Sarcopenia: Determinants Throughout the Lifecourse. Calcified tissue international. 2017;101(3):229-47.
22. Maltais M, Desroches J, Dionne I. Changes in muscle mass and strength after menopause. Musculoskelet Neuronal Interact. 2009;9(4):186-97.
23. Blasco-Lafarga C, Martínez-Navarro I, Cordellat A, Roldán A, Monteagudo P, Sanchis-Soler G, et al., inventors EFAM-UV(c): Método de Entrenamiento Funcional Cognitivo Neuromuscular. España 2016.
24. Neder JA, Andreoni S, Lerario MC, Nery LE. Reference values for lung function tests. II. Maximal respiratory pressures and voluntary ventilation. Brazilian Journal of Medical and Biological Research. 1999;32(6):719-27.
25. Alvarenga GM, Charkovski SA, Santos LK, Silva MA, Tomaz GO, Gamba HR. The influence of inspiratory muscle training combined with the Pilates method on lung function in elderly women: A randomized controlled trial. Clinics. 2018;73:e356.

26. Roldán A, Cordellat A, Monteagudo P, García-Lucerga C, Blasco-Lafarga N, Gómez-Cabrera M, et al. Beneficial Effects of Inspiratory Muscle Training Combined With Multicomponent Training in Elderly Active Women. Research Quarterly for Exercise and Sport. 2019:1-8.
27. Vianna LC, Oliveira RB, Araújo CGS. Age-Related Decline in Handgrip Strength Differs According to Gender. Journal of Strength and Conditioning Research. 2007;21(4):1310-4.
28. García-Río F, Calle M, Burgos F, Casan P, del Campo F, Galdiz JB, et al. Espirometría. Archivos de Bronconeumología. 2013;49(9):388-401.
29. Rikli RE, Jones CJ. The Reliability and Validity of a 6-Minute Walk Test as a Measure of Physical Endurance in Older Adults. Journal of Aging and Physical Activity. 1998;6(4):363-75.
30. Sullivan GM, Feinn R. Using Effect Size - or Why the P Value Is Not Enough. Journal of Graduate Medical Education. 2012;4(3):279-82.
31. Hopkins WG. A scale of magnitudes for effect statistics. A new view of statistics. 2002;502:411.
32. Rikli RE, Jones CJ. Development and Validation of Criterion.Referenced Clinically Relevant Fitness Standards for Maintaining Physical Independence in Later Years. The Gerontologist. 2013;53(2):255-67.
33. Black LF, Hyatt RE. Maximal respiratory pressures: normal values and relationship to age and sex. American review of respiratory disease. 1969;99(5):696-702
34. Sclauser Pessoa I, Parreira VF, Fregonezi G, Sheel AW, Chung F, Reid WD. Reference values for maximal inspiratory pressure: A systematic review. Canadian Respiratory Journal. 2014;21(1):43-50.
35. McConnell AK, Copestake AJ. Maximum Static Respiratory Pressures in Healthy Elderly Men and Women: Issues of Reproducibility and Interpretation. Respiration. 1999;66:251-8.
36. Neder JA, Andreoni S, Lerario MC, Nery LE. Reference values for lung function tests. II. Maximal respiratory pressures and voluntary ventilation. Brazilian Journal of Medical and Biological Research. 1999;32:719-27.
37. Blasco-Lafarga C, Martínez-Navarro I, Cordellat A, Roldán A, Monteagudo P, Sanchis-Soler G, et al., inventorsEFAM-UV(c), Método de Entrenamiento Funcional Cognitivo Neuromuscular. España2016.
38. Shin HI, Kim DK, Seo KM, Kang SH, Lee SY, Son S. Relation between respiratory muscle strength and skeletal muscle mass and hand grip strength in the healthy elderly. Annals of rehabilitation medicine. 2017;41(4):686-92.
39. Efstathiou ID, Mavrou IP, Grigoriadis KE. Correlation between maximum inspiratory pressure and hand-grip force in healthy young and middle-age individuals. Respiratory care. 2016;61(7):925-9.
40. Simoes LA, Dias J, Marinho KC, Pinto C, Britto R. Relationship between functional capacity assessed by walking test and respiratory and lower limb muscle function in community.dwelling elders. Revista Brasileira de Fisioterapia. 2010;14(1):24-30.
41. Gómez-Cabello A, Carnicero JA, Alonso-Bouzón C, Tresguerres JA, Alfaro-Acha A, Ara I, et al. Age and gender, two key factors in the associations between physical activity and strength during the ageing process. Maturitas. 2014;78:106-12.

42. Sawaya Y, Ishizaka M, Kubo A, Sadakiyo K, Yakabi A, Sato T, et al. Correlation between skeletal muscle mass index and parameters of respiratory function and muscle strength in young healthy adults according to gender. The Journal of Physical Therapy Science. 2018;30(12):1424-7.
43. Molgat-Seon Y, Peters CM, Sheel AW. Sex-differences in the human respiratory system and their impact on resting pulmonary function and the integrative response to exercise. Current Opinion in Physiology. 2018;6:21-7.
44. Dominelli PB, Ripoll JG, Cross TJ, Baker SE, Wiggins CC, Welch BT, et al. Sex differences in large conducting airway anatomy. Journal of Applied Physiology. 2018;125(3):960-5.
45. Akinoglu B, Kocahan T, Özkan T. The relationship between peripheral muscle strength and respiratory function and respiratory muscle strength in athletes. Journal of Exercise Rehabilitation. 2019;15(1):44-9.
46. Aznar-Lain S, Webster AL, Canete S, San Juan AF, Lopez Mojares LM, Perez M, et al. Effects of inspiratory muscle training on exercise capacity and spontaneous physical activity in elderly subjects: a randomized controlled pilot trial. Int J Sports Med. 2007;28(12):1025-9.
47. Rodrigues GD, Gurgel JL, Gonçalves TJ, da Silva Soares PP. Inspiratory muscle training improves physical performance and cardiac autonomic modulation in older women. European Journal of Applied Physiology. 2018;118(6):1143-52.
48. Souza H, Rocha T, Pessoa M, Rattes C, Brandao D, Fregonezi G, et al. Effects of Inspiratory Muscle Training in Elderly Women on Respiratory Muscle Strength, Diaphragm Thickness and Mobility. Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences. 2014;69(12):1545-53.
49. Ozdal M. Influence of an eight-week core strength training program on respiratory muscle fatigue following incremental exercise. Isokinetics and Exercise Science 2016;24:225-30.

Número de citas totales / Total references: 49 (100%)
Número de citas propias de la revista / Journal´s own references: 1 (2.1%)