2022, *Retos, 45,* 760-766

Effects of the Intrasession Exercise Sequence of Concurrent Training on Older Women's Body Composition and Physical Fitness

Efectos de la secuencia de ejercicios intrasesión del entrenamiento concurrente sobre la composición corporal y la aptitud física de las mujeres mayores

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Abstract. The sequence of concurrent training sessions is a determining variable in physiological adaptations; however, its effects on body composition and physical condition have been little explored in older women. For this reason, the primary aim of this research is to determine the effects of the intrasession exercise sequence of concurrent training on older women's body composition and physical fitness. The present study was conducted under a randomized experimental design. The population sample consisted of 38 physically inactive women aged between 60 and 75 years. These women were randomly assigned to one of the training groups: strength + endurance (SE, $n = 19$) or endurance + strength (ES, $n = 19$.) The intervention was the same for both training groups; the only difference was the exercise sequence of both components: one group first trained strength and then endurance, and the other did the opposite. The variables evaluated before and after the intervention were body composition and physical fitness. A two-way repeated measures ANOVA was used to determine statistically significant differences in pre- and post-test means within each group. Cohen's d effect size was also calculated to determine the magnitude of the group differences. The ES group had significant differences in mass ($p = 0.036$, $d = 0.834$), fat percentage ($p = 0.044$, $d = 0.419$), arm curl ($p = 0.041$, $d = 1.429$), step ($p = 0.023$, $d = 1.423$), and grip strength ($p = 0.001$, $d = 0.831$). The SE group reported significant differences in mass ($p = 0.035$, $d = 0.545$), fat percentage ($p = 0.023$, $d = 0.882$), muscle percentage ($p = 0.001$, $d = 3.536$), chair stand ($p = 0.001$, $d = 2.579$), arm curl ($p = 0.001$, $d = 1.530$), step ($p = 0.001$, $d = 1.369$), and grip strength ($p = 0.001$, $d = 0.85$). When comparing the effects of the two interventions, strength followed by endurance training was more effective in: fat percentage, arm curl, chair sit-and-reach (cm) the muscle percentage and chair stand variables. The main conclusion of this research is that concurrent training starting with strength followed by endurance, in older women, is more effective in improving body composition and physical condition compared to endurance training followed by strength.
Keywords: Strength, endurance, concurrent training.

Resumen. La secuencia de las sesiones de entrenamiento concurrente es una variable determinante en las adaptaciones fisiológicas; sin embargo, sus efectos sobre la composición corporal y la condición física se han explorado poco en mujeres mayores. Por esta razón, el objetivo del texto es determinar los efectos de la secuencia de ejercicios intrasesión del entrenamiento concurrente sobre la composición corporal y la aptitud física de las mujeres mayores. El presente estudio se realizó bajo un diseño experimental aleatorizado. La muestra poblacional estuvo conformada por 38 mujeres físicamente inactivas de entre 60 y 75 años. Estas mujeres fueron asignadas al azar a uno de los grupos de entrenamiento: fuerza + resistencia (FR, n = 19) o resistencia + fuerza (RF, n = 19.) La intervención fue la misma para ambos grupos de entrenamiento; la diferencia fue la secuencia de los ejercicios. Las variables evaluadas antes y después de la intervención fueron la composición corporal y la forma física. Se utilizó un ANOVA de medidas repetidas de dos factores para determinar diferencias estadísticamente significativas en las medias antes y después de la prueba dentro de cada grupo. El tamaño del efecto d de Cohen, se calculó para determinar la magnitud de las diferencias de grupo. El grupo RF tuvo diferencias significativas en las variable de peso (p = 0.036, d = 0.834), porcentaje de grasa (p = 0.044, d = 0.419), flexión de brazos (p = 0.041, d = 1.429), paso (sp = 0.023, d = 1.423) y fuerza de agarre (p = 0.001, d = 0.831). El grupo FR reportó diferencias significativas en peso (p = 0.035, d = 0.545), porcentaje de grasa (p = 0.023, d = 0.882), porcentaje de músculo (p = 0.001, d = 3.536), en soporte de silla (p = 0.001, d = 2.579), flexión de brazos (p = 0.001, d = 1.530), pasos (p = 0.001, d = 1.369) y fuerza de agarre (p = 0.001, d = 0.85). Al comparar los efectos de las dos intervenciones, el entrenamiento de fuerza seguido del entrenamiento de resistencia fue más efectivo en: porcentaje de grasa, flexiones de brazos, sentarse y alcanzar la silla , porcentaje muscular y pararse de una silla. La principal conclusión de esta investigación es que el entrenamiento concurrente que comienza con fuerza seguido de resistencia, en mujeres mayores, es más efectivo para mejorar la composición corporal y la condición física en comparación con el entrenamiento de resistencia seguido de fuerza. Al comparar los efectos de las dos intervenciones, la fuerza seguida por el entrenamiento de resistencia fue más efectiva en las variables de porcentaje muscular y soporte en silla. La principal conclusión de esta investigación es que el entrenamiento concurrente en mujeres mayores es más efectivo para el porcentaje de músculos y la prueba de apoyo en silla cuando el orden de la sesión es la fuerza seguida por el entrenamiento de resistencia.
Palabras clave: fuerza, resistencia, entrenamiento concurrente.

Fecha recepción: 16-12-21. Fecha de aceptación: 13-04-22
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Introduction

Aging is a biological process in which, even in the absence of chronic disease, a series of physiological changes occur, resulting in the progressive loss of skeletal muscle functionality (de Souto Barreto et al., 2016; Lopez et al., 2018). Two of the components most affected during this stage of life are body composition and fitness, which are directly associated with disorders such as sarcopenia and dynapenia that affect functionality and quality of life (Izquierdo et al., 2005). These changes are influenced by genetic, behavioral, and environmental factors (Ben-Shlomo et al., 2016). Regarding behavioral factors, elements such as exercise and diet are modifiable and essential to reduce the adverse effects of aging (Edholm et al., 2017) (Montilla et al., 2021) . In developing countries, health systems present difficulties that make them ineffective; for this reason, strategies should focus on modifiable factors that prevent the appearance of noncommunicable diseases (Lear et al., 2017).

One of the most effective strategies to mitigate the adverse health effects during aging is implementing training programs (Yanez et al., 2021) (Hawley-Hague et al., 2016) . Various studies have shown that including physical activity in the daily routines of individuals who have been sedentary for most of their lives can produce positive changes in their lipid, body, and metabolic profiles and extend life expectancy (Fragala et al., 2019; Sherrington et al., 2020). At present, diverse training methods have been developed to specifically affect health indicators for preventing chronic noncommunicable diseases (Krèmárová et al., 2018). One of the most frequent forms of exercise in the elderly population is concurrent training, which is defined as the combination of movements focused on the development of muscular strength (MS) and exercises aimed at improving endurance (E) during the same session (intrasession), on the same day (intersession), or alternate days (intramicrocycle) (Wilson et al., 2012). This work-out method has been a matter of debate in recent years because physical adaptations result from the accumulation of the stimuli to which the body is subjected during an exercise session; thus, the physiological responses of MS and E training are antagonistic (Karavirta et al., 2011; Timmons et al., 2018). Then, training these two components in the same period becomes a challenge for the health worker.

Concurrent training in the elderly population has had inconclusive results; some experimental studies have determined that 36 sessions of combined strength and endurance training in the same session bring significant improvements to health-related fitness components (cardiorespiratory fitness, MS, and body composition) (Takeshima et al., 2004). Moreover, Cadore et al. (2010) discovered that training the aerobic component before the muscle component can negatively interfere with strength gains, producing the so-called «interference» phenomenon.

The intrasession sequence in concurrent training is a variable that has been explored in different population groups; however, its effects on body composition and physical condition have no conclusive scientific evidence. When reviewing the literature on this topic, most suggest that strength followed by resistance training is more effective in generating neuromuscular adaptations, but its effects on components such as flexibility and cardiorespiratory capacity have not been explored in depth. In the Colombian population, no research has evaluated this study phenomenon.

Given the discrepancies found in the literature, the researchers have focused on determining the most effective way to periodize the training variables (sequence, frequency, duration, volume, and intensity) and guarantee the proper achievement of the objectives throughout a training plan (Fyfe et al., 2014). One of the least explored elements of this work-out method is whether the sequence in which sessions are completed can influence their effects. Accordingly, this research aims to determine the effects of the intrasession exercise sequence of concurrent training on older women's body composition and fitness.

Method

Design and population sample

The present study was conducted using a randomized experimental design. For the size calculation, the GEE method was taken as a reference for clinical studies with pre-post effects. The required sample size was calculated before the start of our study based on a previous study by Timmons et al (2018). Under the conditions of á = 0.05 and 1 «â = 0.8, a minimum sample of 35 subjects was needed to evidence changes in fitness and composition from 12 weeks of concurrent training. However, considering a potential 10 % sample loss, 38 participants entered the study.

The inclusion criteria were as follows: (1) women aged between 60 and 75 years; (2) belonging to the group «Fitness WOMG» Bogotá, Colombia. This group of people meets twice a week to carry out social activities such as organizing events; (3) reported being physically inactive through the International Physical Activity Questionnaire (d» 1,500 metabolic equivalent of task) (Arango-Vélez et al., 2020). It excluded participants whose health was at risk because of physical exercise; the Physical Activity Readiness Questionnaire (PAR-Q) was administered for this indicator (Warburton et al., 2021). This study was designed following the deontological standards recognized by the Declaration of Helsinki and the Colombian Ministry of Health Resolution 008430/1993, which regulates clinical research in humans. This project was approved by the Fundación Universitaria del Área Andina Committee (code CVI2019-IM-B60).

All participants in this project were informed of the research's objectives and the potential risks of their participation and provided written informed consent. Subsequently, these women were randomly assigned to one of the training groups: strength + endurance (SE, *n* = 19) or endurance + strength (ES, *n* = 19). A simple randomization technique was completed with the program Research Randomizer. Each patient was assigned to each group based on a predetermined sequence provided by the statistical program. A total of 35 women completed the entire training protocol and were included in the analyses. Three participants did not finish the training plan because they missed more than 10 % of the exercise sessions. No participant was injured during the completion of the training programs (Figure 1).

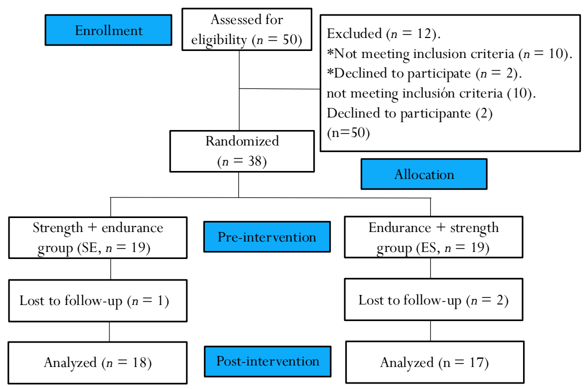

Figure 1. Study flow chart
Source: Own elaboration

Instruments and procedures

Body composition: It was assessed by a segmental bioelectrical impedance analysis using Tanita IRONMAN BC-1500. The protocol was to get on the equipment, grab the handles, and extend them forward for five seconds. With this analysis, fat percentage, muscle percentage, visceral fat, and metabolic age were determined. The evaluations were carried out in the morning, with the bladder empty and on a non-conductive surface. Height was measured with a portable stadiometer with a 0.1 mm precision and 0–2.50 m range (Seca® 274, Hamburg, Germany). Waist circumference (WC) and hip circumference were measured with a SECA 203 measuring tape, following the International Society for the Advancement of Kinanthropometry (ISAK) anatomical references (Silva & Vieira, 2020).

Physical fitness: It was assessed using the Senior Fitness Test (SFT) battery; for this, the protocols established by Rikli and Jones (2013) were followed. The battery consists of six physical tests, of which the following five were performed: chair stand (repetitions), arm curl (repetitions), 2-min step (repetitions), chair sit and reach (cm), and back scratch (cm). This battery has been validated and implemented in research carried out with the Colombian elderly population (Cobo-Mejía et al., 2016). The instructor explained each test individually, and the participants performed a test for each procedure to become familiar with the technique. Subsequently, the official test was performed, recording the results. The rest time between each test was five minutes, and the order was the same for all subjects. No unsuccessful attempts were recorded.

Additionally, a protocol for measuring grip strength was followed, which involved the participant standing with the arms fully extended and gripping the tester as hard as possible for three seconds. This test employed a dynamometer (TKK 540 Grip-D, Takey, Tokyo, Japan), and participants had two attempts for each limb. The best of the two attempts was recorded. This protocol has been validated in the elderly, and there are reference values for the Colombian population (Ramírez Vélez et al., 2019).

Intervention

The training plan frequency was three times a week for three months, totaling 36 sessions. A circuit method between 50 and 70 % of 1 repetition maximum (1RM) was used for the strength component, including squat, military press, flat press, and bicep curl. The protocol developed by Kraemer et al. (1995) was implemented to determine the value of 1RM in each exercise. This protocol has been suggested as the most recommended for untrained women without additional prior familiarization sessions (Benton et al., 2009). From sessions 1 to 12, the participants worked at an intensity at 50% of 1RM, from 13 to 24 at 60% and from 25 to 36 at 70%. The number of repetitions per exercise was 12–15, and each circuit was completed three times. The rest period between sets was two minutes, and between circuits 3–5 minutes. For endurance, various cardiovascular exercises were used (jogging, exercise bike, aerobic dance) at 70–85 % maximum heart rate (MHR) determined with the Tanaka formula (208.75 – (0.73 * age)), for 40 minutes per session. From sessions 1 to 12, participants worked at an intensity at 70% MHR, from 13 to 24 at 75%, and from 25 to 36 at 80%.

Only one style of exercise was performed per session, and styles were changed from session to session. At the end of the training program, all participants performed each exercise the same number of times. A Polar FT1 heart rate monitor monitored each participant's heart rate. All training sessions were supervised by a physical exercise professional who guaranteed that the number of repetitions per exercise was met and that the technique was applied correctly.

The only characteristic that changed between the intervention groups was the intrasession exercise sequence of the two main training components: Group 1 worked first on strength followed by endurance, and Group 2 did it the other way round.

Statistical analysis

Normal distribution and homogeneity parameters were checked using Shapiro-Wilk and Levene tests, respectively. Continuous variables were expressed as mean and standard deviation. The differences between groups in the resulting baseline measurements (pre-intervention) were compared using a t-test for independent samples. A two-way repeated measures ANOVA was used to determine statistically significant differences in pre- and post-test means within each group. Cohen's *d* effect size was also calculated to determine the magnitude of the group differences. The criteria to interpret the ES magnitude were as follows: trivial (< 0.2), small (0.2–0.59), moderate (0.60–1.19), large (1.2–2.0), or very lare (> 2.0) (Hopkins, 2002). The level of statistical significance was set at $p < 0.05$. All statistical analyses were carried out using IBM SPSS software, version 24.0 (Chicago, IL, USA).

Results

Table 1 shows the pre-intervention results of all the variables evaluated. The body composition test results had no significant differences between groups ($p > 0.05$). Regarding fitness, there were differences in the step and chair stand tests ($p < 0.05$).

Table 1.
Comparison of Baseline Characteristics

Characteristic	SE Group (*n*: 18)	ES Group (*n*: 18)	*p*-value
Body composition			
Age (years)	66.1 (2.1)	65.1 (3.8)	0.345
Mass (kg)	61.8 (8.73)	64.8 (5.7)	0.268
Size (m)	157.8 (0.06)	159.8 (0.09)	0.246
Fat percentage (%)	35.8 (5.46)	38.7 (7.4)	0.673
Muscle percentage (%)	25.0 (2.67)	23.1 (4.5)	0.373
Metabolic age (years)	78.6 (9.8)	75.6 (6.7)	0.473
Visceral fat (1 to 20)	9.2 (2.4)	8.1 (3.4)	0.273
Physical fitness			
Chair stand (rep)	16.7 (3.6)	24.7 (4.6)	0.001**
Arm curl (rep)	12.9 (1.5)	15.9 (1.2)	0.543
Step (rep)	58.5 (11.6)	75.3 (11.6)	0.032*
Chair sit-and-reach (cm)	-17.1 (7.9)	-15.2 (9.9)	0.968
Back scratch (cm)	-24.7 (10.8)	-23.7 (5.8)	0.563
Grip strength	23.8 (6.6)	25.8 (5.6)	0.363

Note. Values are presented as means and standard deviations. *p-value < 0.05; **p-value < 0.001

Table 2 shows the comparisons between the groups at the two points when they were evaluated. In the ES group, there were significant differences in mass ($p = 0.036$, $d = 0.834$), fat percentage ($p = 0.044$, $d = 0.419$), arm curl ($p = 0.041$, $d = 1.429$), step ($p = 0.023$, $d = 1.423$), and grip strength ($p = 0.001$, $d = 0.831$). In the SE group, there were significant differences in mass ($p = 0.035$, $d = 0.545$), fat percentage ($p = 0.023$, $d = 0.882$), muscle percentage ($p = 0.001$, $d = 3.536$), chair stand ($p = 0.001$, $d = 2.579$), arm curl ($p = 0.001$, $d = 1.530$), step ($p = 0.001$, $d = 1.369$), and grip strength ($p = 0.001$, $d = 0.85$). When comparing the effects of the two interventions, strength followed by endurance training was more effective in: fat percentage, arm curl, chair sit-and-reach (cm) the muscle percentage and chair stand variables.

Table 2.
Comparison between Physical Fitness and Body Composition before and after the Intervention

Characteristic	SE Group Pre-intervention *n*: 19	SE Group Post-intervention *n*: 18	*p*-value	Cohen's *d*	ES Group Pre-intervention *n*: 19	ES Group Post-intervention *n*: 17	*p*-value	Cohen's *d*	Group interaction
Body composition									
Mass (kg)	61.8 (8.7)	57.5 (7.5)	0.035*	0.545	64.8 (5.7)	59.5 (4.6)	0.036*	0.834	0.754
Size (cm)	157.8 (0.06)	157.6 (0.06)	0.893	0.031	159.8 (0.09)	159.7 (0.09)	0.967	0.000	0.435
Fat percentage (%)	35.8 (5.4)	31.5 (4.6)	0.023*	0.882	38.7 (7.4)	35.9 (6.3)	0.044*	0.419	0.084
Muscle percentage (%)	25.0 (2.67)	29.4 (3.4)	0.001**	3.536	23.1 (4.5)	26.4 (3.2)	0.435	0.685	0.034***
Metabolic age (years)	78.6 (9.8)	76.6 (7.6)	0.456	0.235	75.6 (6.7)	73.4 (4.6)	0.435	0.353	0.423
Visceral fat (1 to 20)	9.2 (2.4)	9.0 (1.2)	0.378	0.171	8.1 (3.4)	7.3 (3.6)	0.834	0.110	0.831
Physical fitness									
Chair stand (rep)	16.7 (3.6)	28.5 (5.6)	0.001**	2.579	24.7 (4.6)	27.6 (2.2)	0.056	0.603	0.023***
Arm curl (rep)	12.9 (1.5)	17.6 (3.6)	0.001**	1.530	15.9 (1.2)	20.5 (4.5)	0.041*	1.429	0.732
Step (rep)	58.5 (11.6)	70.6 (6.7)	0.001**	1.369	75.3 (11.6)	85.6 (14.5)	0.023*	1.423	0.643
Chair sit-and-reach (cm)	-17.1 (7.9)	-15.1 (6.9)	0.446	0.139	-15.2 (9.9)	14.2 (5.9)	0.356	0.099	0.623
Back scratch (cm)	-24.7 (10.8)	-23.7 (5.8)	0.356	0.214	-23.7 (5.8)	-21.7 (6.8)	0.564	0.326	0.032
Grip strength (kg)	23.8 (6.6)	28.6 (3.2)	0.001**	0.853	25.8 (5.6)	29.5 (4.59)	0.001**	0.831	0.045

Note. Values are presented as means and standard deviations. *p-value < 0.05; **p-value < 0.001, ****P < 0.05, significant time vs. group interaction

Discussion

Our research's main findings were that concurrent training is a helpful exercise method for improving body composition and physical fitness in older women; however, these improvements vary according to the intrasession exercise sequence. In this sense, strength followed by endurance training is more effective to improve fat percentage, arm curl, chair sit-and-reach the muscle percentage and chair stand variables. In 5 tests of those evaluated, the effect size was greater for those who trained strength followed by resistance, which represents from a clinical perspective that this sequence of training order presents greater changes in body composition and physical condition in older women, which means an impact on health and quality of life.

These results are consistent with a meta-analysis that included 13 clinical trials with a population of both genders aged 13–65 and established that if the main objective of concurrent training is to increase the MS of the lower body muscles, it is advisable to work on strength before endurance during the training session. However, if the goal is to improve aerobic capacity, the sequence in which these two components are trained does not produce differentiated effects (Murlasits et al., 2018).

Although most of the studies that have evaluated the effect of the intrasession exercise sequence of concurrent training on various health indicators have been conducted in men, a recent study carried out in 21 postmenopausal women determined that 12 weeks of concurrent training in water is a valuable method for improving health and fitness. Nevertheless, the sequence of training strength before endurance is a more effective strategy for improving lower body muscle performance (Pinto et al., 2015).

A study similar to our research, but carried out in 26 older adult men, determined that training strength before endurance is a more effective method for achieving neuromuscular adaptations than training these components the other way round during a session. It determined that these changes only occurred at the neuronal level and not in the morphological component, which contrasts with our research results. In our sample, there were significant changes in some variables of fitness and body composition, indicating that adaptations took place both at the neuromuscular and morphological levels. These discrepancies between studies suggest that gender is a variable that influences the effects of concurrent training (Cadore et al., 2013).

On the contrary, a clinical trial conducted in forty healthy female volunteers (age = 67.35 ± 1.40 years old) determined an eight-week concurrent training program produced positive changes in female subjects' body composition and physical fitness. However, there was no benefit derived from training sequence (Banitalebi & Bovirhasani,2015)

On the other hand, in our research, there were no significant changes in the flexibility component in the two intervention groups. These results contrast with de Farias et al.'s (2014), who determined in 20 women aged 40 to 70 years that 24 concurrent training sessions improve 50 % of performance in tests that evaluate flexibility of the lower body muscles. These differences could be due to the absence of a specific time in the central part of the training to work on this component. Based on the importance of flexibility for the functionality of older women, we suggest that future research incorporate this component independently in concurrent training sessions.

In the Colombian population, several studies have concluded that various concurrent training methodologies improve body composition, metabolic profile, and physical fitness (Arango et al., 2016; Mora & Ibagon, 2020). However, the influence of training sequence is a poorly explored field. Public policies in Colombia establish that the government must design multiple strategies to improve the quality of life of older adults. Therefore, the results of this research are an outstanding contribution to fulfilling this objective.

The main limitation of this research was not having a control group that did not perform any physical exercise, which could have given greater validity to the results Besides, the practical implications of this study focus on consolidating a valid concurrent training methodology in which physical exercise professionals can support their training plans for this population.

Conclusion

The main conclusion of this research is that concurrent training starting with strength followed by endurance, in older women, is more effective in improving body composition and physical condition compared to endurance training followed by strength.

Acknowledgments

We express our sincere gratitude to Fundación Universitaria del Área Andina for providing the financial

support to complete this project.

Conflicts of interest

The authors report no conflicts of interest.

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