Journal of Strength and Conditioning Research Publish Ahead of Print
DOI: 10.1519/JSC.0000000000001895

Effects of 12-week concurrent high-intensity interval strength and endurance training programme on physical performance in healthy older people

RUNNING HEAD: Concurrent HIIT and older people

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CONFLICT OF INTERESTS AND SOURCE OF FINDINGS

The authors declare economic support has been received from Spanish Ministry of Economy and Competitiveness (Research, Development and Innovation I+D+I DEP2012-40069, ERGOLOC project).

ABSTRACT

This study aimed to analyse the effect of 12-week low-volume HIIT-based concurrent training programme on body composition, upper- and lower-body muscle strength, mobility and balance in older adults, as well as to compare it with a low- moderate-intensity continuous training. 90 active older adults were randomly assigned to experimental (EG, n=47), and control (CG, n=43) groups. Body composition and physical functioning were assessed before (pre-test) and after (post-test) a 12-week intervention. A 2-way repeated measures ANOVA was used to test for an interaction between training programme and groups. The time x group interaction revealed no significant between-group differences at pre-test ($p \geq 0.05$). The group x time interaction showed significant improvements for the EG in body composition parameters ($p < 0.05$) and physical functioning (muscle strength: $p < 0.001$; mobility: $p < 0.001$; and balance: $p < 0.05$); while the CG remained unchanged ($p \geq 0.05$). This HIIT-based concurrent training programme led to greater improvements in body composition, muscle strength, mobility and balance in healthy older people than a regular low- moderate-intensity continuous training, despite the reduction in overall training volume.

Key Words: Aging; Intermittent training; Physical functioning

INTRODUCTION

Aging is accompanied by a progressive decrease in aerobic fitness, strength and muscle mass (10). These decrements have been associated with increased incidence of type 2 diabetes (18), cardiovascular disease (34) and risk of falls (28). Logically, an important loss in aerobic fitness and strength dramatically impairs autonomy and functional capacity, increasing dependency in older people (25).

To counteract this, physical activity has been widely recommended due to its positive effects on the maintenance and/or increase in skeletal muscle mass and strength, and in aerobic fitness (10,14). Several studies have shown that strength training improves both strength and power during aging (21,29) and that endurance training also enhances aerobic fitness in this population (8,38). In view of this, the prescription of both endurance and strength training (i.e., concurrent training) is fundamental to improve functional capacity in older populations (2,10,14,28).

Public health recommendation for exercise is similar in many developed countries (10,14), and it suggests a target of 150 minutes a week of moderate aerobic intensity activity in bouts of 10 minutes or more - often expressed as 30 minutes of brisk walking or equivalent activity five days a week, 75 minutes of vigorous-intensity activity, or some combination of moderate and vigorous activity, with muscles strengthening exercises on at least 2 days per week. However, despite public health recommendations inactive behaviours keep present in older adults (30) so, it seems clear that many people, especially in older age groups, find it hard to achieve this level of activity.

In this context, in last years a trend related to low-volume and high-intensity training has strongly risen as a time-efficient option. High-intensity interval training (HIIT) describes physical exercise that is characterized by brief, intermittent bursts of vigorous activity, interspersed by periods of rest or low-intensity exercise (17). This training method let people spend shorter time training as well as being perceived as more enjoyable than continuous training (4). As indicated by Gibala et al. (17), when estimated energy expenditure is equivalent, HIIT can serve as an effective alternate to traditional endurance training, inducing similar or even superior changes in a range of physiological, performance and health-related markers in both healthy individuals and diseased populations.

The benefits of HIIT have been studied and determined for both health (17) and athletic performance (15) with a growing interest in its use and utility in older people (1,6,19,20,24). Compared with lower-intensity workloads, intensive exercises require activation of a larger motor unit, with increased recruitment of fast oxidative and glycolytic muscle fibers, an increase in the intensity of chemical processes in the muscle and greater levels of neuromuscular engagement (27,33) so that more research is needed to ensure an accurate HIIT prescription.

The aim of this study was to analyse the effect of a 12-week low-volume HIIT-based concurrent training programme on body composition, upper- and lower-body muscle strength, mobility and balance in older adults (> 65 years old), as well as to compare it with a low- moderate-intensity continuous training. The authors hypothesized that HIIT - including both types of exercises (endurance and resistance) – may be a time-efficient option and an effective training method for older adults (as it has been demostrated in other populations).

METHODS

Experimental approach to the problem

This research analysed the effect of a HIIT-based concurrent training programme on physical performance in healthy older people. Using a randomized, between-group design (experimental group [EG] and control group [CG], respectively), 90 older adults were assessed.

Subjects

A group of 90 older adults (age = 72 ± 5 years), including 64 females and 26 males, voluntarily participated in this study. Figure 1 shows the flowchart of this study. Inclusion criteria were: (a) being older than 65; (b) being considered regularly active according to the public health recommendation for exercise, which is similar in many developed countries: 150 minutes a week of moderate intensity activity in bouts longer than 10 minutes (2,10,14,28); (c) being free of cardiovascular and neuromuscular disorders; (d) and being considered physically independent according to the Spanish version of Barthel Index (7); (e) not to have acute or terminal illness, and severe dementia (Mini Mental State Examination <10) (12). The exclusion criteria were: (a) artificial prosthesis; (b) participation in any periodised training programme other than walking on their own; (c) any symptom that a medical examiner deemed as warranting exclusion; (d) any disease that contraindicated the exercise program or required special care (i.e., coronary artery disease, thrombosis, moderate or severe bone, lung or renal diseases) and; (e) any disease requiring the daily intake of drugs affecting the athletic performance, in order to avoid any influence on fitness measures.

FIGURE 1 ABOUT HERE

Participants were randomly assigned to one of the following groups: EG (n = 47), and CG (n = 43). More information about participants is shown in Table 1.

TABLE 1 ABOUT HERE

The study was conducted in adherence to the standards of the Declaration of Helsinki (2013 version), and the informed consent and the study were approved by the Bioethics Committee from the University of Jaen (Jaen, Spain).

Study design

This is a parallel group randomized trial that was designed to test the efficacy of an alternative training model in which older individuals performed a periodised concurrent training programme (HIIT-based strength training combined high-intensity interval endurance training) instead of regular (non-periodised) low- moderate-intensity aerobic training. Before the experimental protocol, body composition was assessed and a familiarisation with physical tests was done. Then, 72 h later, physical functioning was tested through different tests. The gap between testing sessions and the beginning and the end of training programme was 72 hours too. Participants were then assigned to one of the following groups: (a) concurrent training group (EG); (b) and control group (CG) that kept training in the same conditions than before the experimental period (a non-periodised plan, based on walking sessions, accumulating 150-200 min/week). Training was performed 3 days a week (Monday, Wednesday, and Friday) for 12 weeks in the same sport facilities. Body composition and physical functioning were reassessed after the experimental period.

Materials and testing

Body composition assessment

Height (m) was measured using a stadiometer (Seca 222; Seca, Hamburg, Germany), and body mass (kg), fat percentage, and skeletal muscle mass (%) were measured with a portable eight-polar tactile electrode bioelectrical impedance analyzer (InBody R20; Biospace, Gateshead, UK). The validity of this bioelectrical impedance analyzer has been previously reported (5). BMI was calculated as body mass divided by height squared.

Physical functioning

The tests conducted in this study are usually performed to assess functional capacity in older people (31). The main functional capacity components studied were lower body muscle strength, upper body muscle strength, mobility and balance.

- Lower body muscle strength: The 30-s chair stand test (30-s CST) (23) was used to assess lower body muscle strength. This test involves counting the number of times within 30 s that individuals can rise to a full stand from a seated position with their back straight and feet flat on the floor and without pushing off the chair with their arms.
- Upper body muscle strength: Handgrip strength test (HS) was used. This test involves using a hand dynamometer with adjustable grip (TKK 5101 Grip D; Takey, Tokyo Japan). The optimal grip span was calculated with the formula suggested by a previous study (32). Each participant performed this test twice with each hand. Participants need to fully extend their arm so that it forming a 30° angle relative to their trunk. The maximum score (in kg) for each hand was recorded, and the mean score of left and right hand was used in the subsequent analysis.
- Mobility: The gait speed (GS) test was used. This test involves walking 10 m in the shortest possible time. In the analysis, the first and the last metre were eliminated because of acceleration and deceleration (16). The best time of two trials was recorded and used for the analysis. Times (in seconds) were measured using 2 double-light barriers (WITTY; MicrogateSrl, Bolzano, Italy; accuracy of 0.001 seconds). The photocells were positioned approximately 0.8 m above the floor, with the first pair was positioned along the starting line and the second along the finish line. The subjects began the test with one foot on the starting line in a frontal erect position, and time measurement started when subjects passed the first photoelectric cells. We did not

provide a starting signal so that the subjects were able to individually start the test. Thus, reaction time did not influence our findings.

- Balance: A FreeMed© BASE model baropodometric platform was used for the stabilometric measurements (Sensormedica, Rome, Italy). The platform's surface is 555 × 420 mm, with an active surface of 400 × 400 mm and 8 mm thickness manufactured by Sensormedica® (Sensormedica). Calculations of centre of pressure (CoP) movements were performed with the FreeStep© Standard 3.0 software (Sensormedica). The postural test consisted of quiet stance on a firm surface with eyes open. The subjects stood relaxed on the platform, barefoot, with the head in a straight-ahead position, their arms along the body, the heels together and feet at an angle of about 30º open to the front. Before starting, subjects stood in the same central position of the feet related to the force platform. The duration of each record in each condition was 50 s. Conditions were based on a previous study (11). The body sway was quantified by displacement of the CoP in the anterior-posterior and in the medial-lateral direction. The following parameters were recorded and subsequent used for analysis: length and area of the path described by the CoP.

Training programme

Participants from EG performed a periodised concurrent training programme, including high-intensity circuit strength training combined with high-intensity interval endurance training (two sets of circuit strength training interspersed with endurance training, with no recovery in between, and with the next order: strength-endurance-strength). All training sessions were supervised by two experienced personal trainers. The training plan included 3 sessions per week on non-consecutive days, for 12 weeks. All training sessions began with a 5-7 min warm-up (consisting low-intensity walking and running, and dynamic mobility exercises) and finished with a 4-5 min cool down (based on stretching and relaxation exercises). Sessions lasted ~35-40 min (warm-up and cold down included), with an overall weekly volume of 105-120 min (a reduction of 32-40% according to baseline values). A detailed description of the 12-week training programme is reported in Table 2.

TABLE 2 ABOUT HERE

Strength training was distributed into 1 min blocks by progressing from 20:40 (weeks 1-4) to 40:20 work:rest ratio (in seconds) (weeks 9-12). External load was low and self-paced with participants having the option to perform exercises with (3, 5, 7 kg medicine ball) or without external load. Instructions were given about intensity: ´perform as many repetitions as you can during work period´. This plan included the following exercises: sit to stand (chair), medicine ball forward chest/overhead throws, farmer walk, resistance band shoulder press, hip marching seated on a fitball, bench step ups, resistance band row (standing), medicine ball squat to overhead throws, foot lader drills (weeks 5-12), twisting medicine ball pass with partner (weeks 9-12). Two sets of this circuit were performed in every session, interspersed with endurance training (with no recovery in between).

Endurance training included walking and running periods and was performed on a 400 m outdoor track. Periodisation was established according to metres covered walking or running in every lap: from just walking (weeks 1-4) to walking:running 150:50 m, respectively (weeks 9-12). Instructions were given about intensity: ´meeting walking and running periods, cover the greatest number of laps possible in the established work period´.

On the other hand, participants from CG kept training in the same way than before starting the experiment (3-4 walking sessions per week, accumulating ~150-200 min/week at low-moderate intensity).

Statistical analysis

The data were analysed with the statistical program SPSS v.21.0 for Windows (SPSS Inc., Chicago, USA) and the significance level was set at $P<0.05$. Descriptive statistics are represented as mean (*SD*). Tests of normal distribution and homogeneity (Shapiro-Wilk and Levene´s, respectively) were conducted on all data before analysis. The chi-square test and the *t*-test were used to compare socio-demographic variables between the groups. A 2x2 analysis of variance (ANOVA) with repeated measures (group x measurement) was conducted for the dependent variables (body composition variables, 30-s CST, HS, GS and balance). The alpha was adjusted by Bonferroni correction. Additionally, the magnitudes of the differences between values were also interpreted using the *Cohen´s d* effect size (ES) (36). Effect sizes of less than 0.4 represented a small magnitude of change while 0.41–0.7 and greater than 0.7 represented moderate and large magnitudes of change, respectively (36).

RESULTS

No significant between-group differences ($p \geq 0.05$) in anthropometric characteristics, physical independence, sex distribution, or training background, were found at baseline (before training intervention).

The results obtained regarding the body composition parameters are shown in Table 3. The 2 x 2 ANOVA conducted revealed significant time effects and time-by-group interactions for body mass, fat mass, muscle mass and BMI ($p < 0.001$), but not for percentage of muscle mass ($p \geq 0.05$). As for the time x group (groups comparison: CG vs. EG), both groups showed similar values at pre-test ($p \geq 0.05$), whilst some significant interactions were found at post-test (fat mass, muscle mass and BMI, $p < 0.05$). As for group x time interaction (within-group), the EG experienced significant improvements in body mass, fat mass, muscle mass (in kg) and BMI ($p < 0.001$), whereas the CG did not experience significant changes in any variable ($p \geq 0.05$).

TABLE 3 ABOUT HERE

The results obtained in the physical functioning tests are reported in Table 4. Regarding muscle strength assessment (30-s CST and HS tests), the 2 x 2 ANOVA conducted revealed significant time effects and time-by-group interactions ($p < 0.001$). The time x group interaction revealed no between-group differences at pre-test ($p \geq 0.05$), but significant differences at post-test ($p < 0.001$ and $p = 0.048$, respectively). Finally, the within-group comparison (group x time) reported differences in EG (p < *0.001*, with significant improvements in both 30-s CST and HS tests*)*, whereas the CG did not experience significant changes in any variable ($p \geq 0.05$).

As for the mobility assessment (GS test), the 2 x 2 ANOVA revealed significant time effects and time-by-group interactions ($p < 0.001$). The time x group interaction revealed no differences at pre-test ($p = 0.922$), but significant differences at post-test ($p = 0.007$), whereas the within-group comparison (group x time) reported a significant improvement in the EG (p < *0.001)* with CG remained unchanged ($p \geq 0.05$).

As for the balance assessment (ellipse area and length), significant time effects were found ($p < 0.001$), with a significant time-by-group interaction for length ($p = 0.006$). The between-group comparison (time x group) showed no differences at pre-test

($p \geq 0.05$) and differences at post-test for length ($p = 0.003$), whilst the group x time interaction reported significant reductions in the EG for both variables ($p = 0.031$ and < 0.001, respectively) with no changes in the CG ($p \geq 0.05$).

TABLE 4 ABOUT HERE

DISCUSSION

This study aimed to test the effect of a low-volume HIIT-based concurrent training programme on physical functioning in healthy older adults (> 65 years old), as well as to compare it with a low- moderate-intensity continuous training. The main finding of this study was that this training programme that combines strength and endurance training performed at high intensity in each session, led to larger improvements in body composition (-2.15% body mass, -4.20% fat mass, +6.23% muscle mass), muscle strength (+7.69% HS, +28.5% 30-s CST), mobility (+8.8% GS) and balance (-39% area, -8.3% length) in healthy older people (> 65 years old) than a regular low- moderate-intensity continuous training, despite the reduction in overall training volume (30-40%).

Physical activity plays a key role in the maintenance of health at any age, and that is why public health recommendations include regular physical activity throughout our entire life (10,14). As we mentioned earlier in the introduction section, aging is characterised by a progressive decrease in aerobic fitness, strength and muscle mass (10) so, physical activity is a must to counteract this process. In this context, some previous works have determined the effectiveness of strength training to avoid the progressive decrease in strength and muscle mass during aging (21,29). Muscular strength has been recognized as an important component in the pathogenesis and prevention of chronic diseases (37). Specifically, higher levels of strength have been associated with decreased risk of all-cause and cardiovascular disease-related mortality (3) whilst low strength levels are particularly important in older adults who are at risk for early death and losing functional independence. On the other hand, other studies have focused on endurance training and its benefits for maintaining and enhancing aerobic fitness in older adults (8,38). Low cardiorespiratory fitness is a strong, independent risk factor for early mortality from cardiovascular disease-related causes (26).

In order to join benefits from both training methods (endurance and strength training), some works have included concurrent training into training plans for older people (9,35,38), and significant improvements in cardiorespiratory fitness, muscular strength and body composition were reported, concluding, in consonance with our findings, that concurrent training seems to be the best strategy from the perspective of promoting health in that population. Nevertheless, while the benefits of aerobic and resistance training alone are well documented, the literature examining the combination of both (concurrent training) is limited (9,22,35,38). Besides, differences in methods and training programmes performed in those previous studies make difficult reach a consensus about prescription of concurrent training in older people.

Despite well-known benefits of concurrent training, inactive behaviours keep present in modern society (30) and, among possible reasons `time´ has been noted (24). The aforementioned concurrent training programmes included 3 workouts a week, lasting from 50 min/session (35) to 70 min/session (9). Therefore, it seems clear that there is a demand for effective training methods that minimize training volumes, in terms of time, and encourage exercise adherence during advancing age. In view of this, the current HIIT-based plan maintains the same frequency (3 ss/wk) but reduces training volume (with workouts lasting ~30 min), and that is possible by increasing training intensity (i.e., HIIT).

A growing body of literature (1,6,19,20,24) is examining the effects of HIIT in an older adult population. Our findings support previous research highlighting the positive effects of HIIT on quality of life (24), physical function and cardiovascular health (1,24). This training method has been successfully tested even in patients with chronic heart failure (13) and, similar to this work and the aforementioned in older people, no adverse events relating to the exercise intervention were reported so, our data show that HIIT appears to be well-tolerated in healthy ageing men.

It is unfortunate that this study did not include more men, in order to make possible a sex comparison. Additionally, intensity was not monitored during the training programme and physical activity was not objectively measured at baseline so that, those variables may be considered as limitations. Likewise, the inclusion of a cardiorespiratory test (i.e., 6 min walk test) would let us measure any change in aerobic capacity and this must be addressed in future studies. Notwithstanding these limitations, the current study determines the effectiveness of a time-efficient training programme for improving physical functioning and body composition in a large sample of healthy older people.

In summary, the present low-volume HIIT-based concurrent training programme (that combines strength and endurance training in each session) led to larger gains in body composition, muscle strength, mobility and balance in healthy older people (> 65 years old) than a regular low- moderate-intensity continuous training, despite the reduction in overall training volume (-30-40%).

Practical applications

From a practical point of view, this is useful information for coaches who works with older people due to the efficacy of this training programme has been tested with significant results. Since this periodised training plan does not require expensive equipment or facilities, it is an easy-to-perform programme that, at the same time, let people reduce training time compared to more traditional guidelines which may be a key factor to make adults more active and create physical activity adherence.

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FIGURE LEGEND

Figure 1. Study chart.

Table 1. Characteristic of participants (mean ±SD and n, %).

Variable		Whole-group (n=90)	CG (n=43)	EG (n=47)	p-value
Age (years)		72.83 (5.69)	72.09 (5.78)	73.50 (5.58)	0.238
Height (m)		1.55 (0.07)	1.55 (0.08)	1.54 (0.07)	0.562
BMI (kg/m^2)		30.01 (4.19)	30.35 (4.07)	28.97 (3.53)	0.119
Sex* (n, %)	Male	26 (28.9%)	13 (30.2%)	13 (27.7%)	0.427
	Female	64 (71.1%)	30 (69.8%)	34 (72.3%)	
Barthel Index (0-100)		99.02 (0.65)	99.26 (0.22)	98.96 (0.70)	0.712
Training experience (years)		4.13 (2.41)	3.88 (1.92)	4.09 (2.35)	0.312
Sessions per week		4.01 (0.65)	3.88 (0.51)	4.37 (0.89)	0.483
Training volume (min/week)		176.22 (20.94)	182.35 (16.48)	174.96 (21.33)	0.148

*Chi^2 test

Table 2. Detailed description of the 12-week concurrent training programme, including number of sets and repetitions, recovery and work times and progression.

Weeks	Circuit strength training*		Aerobic training**		Total training volume (min)
	Number of exercises	Work:Rest ratio (s)	Volume (min)	Walking:Running ratio (m)	
1-4	8	20:40	10	*Just walking*	26
5-8	9	30:30	12	350:50	30
9-12	10	40:20	10	150:50	30

No recovery between strength and aerobic training or vice versa. *Instructions given were: perform as many repetitions as possible during work period. **Instructions given were: cover the longest distance possible during the established work period

Table 3. Body composition parameters (mean±SD) before (pre-test) and after (post-test) a 12-week training programme.

Variables	Groups	Pre-test	Post-test	P-value (group x time)	ES
Body mass (kg) ^ §	CG	73.09 (11.83)	73.40 (11.63)	0.183	0.026
	EG	71.48 (11.59)	69.95 (11.02)	<0.001	0.134
p-value (time x group)		0.539	0.179		
Fat mass (%) ^ §	CG	39.95 (8.71)	39.82 (8.97)	0.803	0.014
	EG	40.81 (6.98)	36.61 (5.05)	<0.001	0.695
p-value (time x group)		0.624	0.048		
Fat mass (kg) ^ §	CG	29.13 (6.36)	29.21 (6.58)	0.891	0.012
	EG	29.18 (4.99)	25.61 (3.50)	<0.001	0.851
p-value (time x group)		0.892	0.041		
Muscle mass (%)	CG	33.96 (7.13)	35.15 (7.48)	0.944	0.069
	EG	32.93 (4.20)	39.16 (9.51)	0.121	0.286
p-value (time x group)		0.118	0.663		
Muscle mass (kg) ^ §	CG	24.79 (5.21)	25.80 (5.51)	0.135	0.185
	EG	23.52 (3.01)	27.39 (6.65)	0.011	0.750
p-value (time x group)		0.102	0.048		
BMI (kg/m^2) ^ §	CG	30.35 (4.07)	30.40 (4.05)	0.128	0.031
	EG	28.97 (3.53)	28.32 (3.38)	<0.001	0.695
p-value (time x group)		0.119	0.014		

^ indicates significant time effects; § indicates significant time-by-group interactions; group x time interaction: within-group comparisons; time x group interaction: between-group comparisons

CG: control group; EG: experimental group; BMI: body mass index; ES: Cohen´s d effect size

Table 4. Physical test performance (mean±SD) before (pre-test) and after (post-test) a 12-week training programme.

Variables	Groups	Pre-test	Post-test	P-value (group x time)	ES
HS (kg) ^ §	CG	21.27 (7.16)	20.55 (6.6)	0.052	0.162
	EG	21.43 (6.56)	23.08 (6.54)	<0.001	0.250
p-value (time x group)		0.915	0.048		
30-s Chair test (reps) ^ §	CG	15.11 (3.27)	15.85 (4.29)	0.337	0.194
	EG	15.98 (4.73)	20.54 (5.11)	<0.001	0.925
p-value (time x group)		0.401	<0.001		
GS (m/s) ^ §	CG	1.80 (0.38)	1.77 (0.38)	0.059	0.078
	EG	1.81 (0.24)	1.97 (0.25)	<0.001	0.638
p-value (time x group)		0.922	0.007		
Ellipse area (mm^2)^	CG	164.19 (119.71)	125.81 (125.03)	0.076	0.213
	EG	118.94 (97.95)	71.97 (66.58)	0.031	0.489
p-value (time x group)		0.098	0.052		
Length (mm) ^ §	CG	116.38 (17.25)	116.62 (17.04)	0.933	0.013
	EG	116.80 (10.93)	107.13 (8.69)	<0.001	0.970
p-value (time x group)		0.901	0.003		

CG: control group; EG: experimental group; GS: gait speed; HS: handgrip strength test; ES: Cohen´s d effect size

^ indicates significant time effects; § indicates significant time-by-group interactions; group x time interaction: within-group comparisons; time x group interaction: between-group comparisons

Figure

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