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Role of the exercise of high intensity intervals (HIIT) in health in the older adults: A systematic review of randomized clinical trials

José Daniel Jiménez García[1], Agustín Aibar Almazán[2],
Fidel Hita Contreras[2], David Cruz Días[2], Raquel Fábrega Cuadros[2],
and Antonio Martínez Amat[2]
[1]University of Cádiz (Spain); [2]University of Jaén (Spain)

Despite growing interest in high-intensity interval training as a time-effective way for older adults to improve their health, there is little consensus regarding the better way to plan a HIIT intervention. Given the loss of function and health problems of an older adult population, the identification and characterization of interventions and strategies is a fundamental prerequisite. The goals of this review are examining high-intensity interval training as a way to improve health, and finding out the highest-intensity viable HIIT protocol. Studies were included in this systematic review if: (1) they studied a population of older adults; (2) prescribed an intervention that can be described as high intensity; and (3) reported health-related outcome measures. The resulting 14 papers were included in our study. The present review found that high-intensity interval training is an effective tool to improve indicators of body composition as well as cardiometabolic and cardiovascular health, with 90-95% HRmax cycle ergometer sessions held two-three times a week, with a minimum session length of 40 minutes, in an intervention at least 12-week long, effecting significant improvements on the health of participants. Recommendations regarding optimal exercise duration and rest intervals must remain ambiguous given the scarcity of published literature and the methodology and limitations of those studies that are already available.

Keywords: high intensity interval training (HIIT), systematic review, older people, body composition, cardiometabolic health y cardiovascular health.

Papel del ejercicio interválico de alta intensidad (HIIT) en la salud de adultos mayores: una revisión sistemática de ensayos clínicos aleatorizados. Existe un creciente interés en el entrenamiento de alta intensidad en personas mayores, aunque hay poco consenso sobre la mejor manera de planificar una intervención HIIT. Los objetivos de esta revisión son examinar el entrenamiento en intervalos de alta intensidad como una forma de mejorar la salud y descubrir el protocolo HIIT viable de mayor intensidad. Los estudios se incluyeron en esta revisión sistemática si: (1) estudiaron una población de adultos mayores; (2) prescribió una intervención que puede describirse como de alta intensidad; y (3) informaron medidas de resultado relacionadas con la salud. Los 14 documentos resultantes se incluyeron en nuestro estudio. La presente revisión encontró que el entrenamiento HIIT es una herramienta efectiva para mejorar los indicadores de composición corporal, así como la salud cardiometabólica y cardiovascular, con 90-95% de sesiones de ergómetro de ciclo de FCmáx realizadas dos o tres veces por semana, con una duración mínima de la sesión de 40 minutos, en una intervención de al menos 12 semanas de duración, logrando mejoras significativas en la salud de los participantes. Las recomendaciones sobre la duración óptima del ejercicio y los intervalos de descanso deben seguir siendo ambiguas dada la escasez de literatura publicada y la metodología y las limitaciones de los estudios que ya están disponibles.

Palabras clave: entrenamiento interválico de alta intensidad (HIIT), revisión sistemática, personas mayores, composición corporal, salud cardiometabólica y salud cardiovascular.

Correspondencia: José Daniel Jiménez García. University of Cádiz, Department of Physical Education. C/ República Saharaui, nº 12. C.P.: 11519. Puerto Real, Cádiz (Spain). E-mail: josedaniel.jimenez@uca.es

The number of people over 60 is growing faster than any other age group worldwide, and it is expected to go from 688 million in 2006 to almost two billion by 2050 (WHO, 2007). This aging is associated with increases the risk of falling, of disability, and of depending on the help of others (Latham et al., 2003; Henderson et al., 2009). Falls are one of the most serious and costly problems for public health (Latham et al., 2003).

Risk factors for falls among older adults can be classified as either extrinsic or intrinsic. Three of the most common intrinsic risk factors are muscle weakness, balance deficit, and an unsteady gait (Rubenstein and Josephson, 2002; AGS, 2001; Granacher et al., 2011), and all three are linked to the performance of daily activities for which muscle strength is required (Muehlbauer, Besemer, Wehrle, Gollhofer, and Granacher, 2012). It has been observed that the adult population suffers from a decrease in muscle mass which has several causes (cellular, neural, metabolic, and hormonal; Henderson et al., 2009; Howley et al., 2003; Clark et al., 2008), which is associated with low levels of muscle strength and low physical performance as measured by gait speed (≤80 cm/s), grip strength, and muscle mass (Cruz-Jentoft et al., 2010). Human beings lose 20-30% of skeletal muscle between the ages of 20 and 80 (Carmeli et al., 2002). A decrease in muscle mass might be linked to a delay in postural reactions when faced with external threats (Woollacott et al., 1990; Ceglia, 2009), which in turn might be interpreted as a loss of balance (Orr et al., 2006) and ultimately result in a fall (Rubenstein, 2006). Today, several prevention programs exist, and randomized controlled trials concerning fall risk factors have shown their beneficial effect on the health of an older population (WHO, 2007; WHO, 2009; Tinetti and Kumar, 2010).

Physical exercise has proven to have a favorable effect on the health of older adults. However, a lack of time is often the greatest obstacle for the regular practice of exercise (Stutts, 2002). To address this hurdle, high-intensity interval training (HIIT) was developed, featuring short intermittent bursts of high intensity activity followed by periods of rest or low-intensity activity. Although this form of training has traditionally been focused on sports performance, in the last years it has been hailed as a key means to improve metabolic and cardiorespiratory function in a variety of populations (Kessler, Sisson, and Short, 2012). Safety is a main concern in HIIT, particularly for risk populations, but several studies have proven it to be safe and well tolerated by subjects in several healthy populations (Kessler et al., 2012) as well as for subjects with associated clinical pictures as, for instance, heart disease (Rognmo Ø et al., 2012).

The goal of the present review, therefore, is to provide a systematic synthesis of the effects of HIIT on the body composition and cardiometabolic and cardiovascular health markers of older adults, and to outline the potential structure, intensity, frequency, and length of an optimal HIIT protocol.

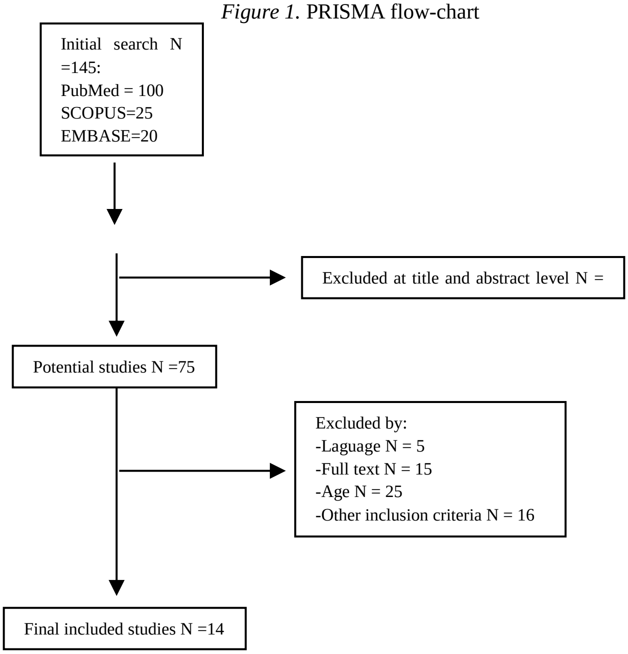
METHODS

This systematic review adheres to the PRISMA statement (Liberati et al., 2009) and followed a structured, albeit unpublished, protocol.

Data sources and bibliographical search strategy

Two of the authors performed independent searches in PubMed, EMBASE, and SCOPUS, with no language filters, for publications between January 1st 2007 and June 1st 2017, concerning randomized controlled trials (RCT) looking into the effect of high-intensity interval training and its benefits regarding fall risk factors in elderly populations. The following search terms were used: "(HIIT or high interval training or high intensity exercise or HIT) and (older adults or elderly or older men or older women)". Manual searches were carried out in conference summaries and doctoral dissertations of the last few years to identify additional potentially relevant papers (Figure 1).

Figure 1. PRISMA flow-chart



Inclusion criteria

The inclusion criteria for this systematic review were: i) the study was a RCT; ii) it looked into the effects of a HIIT program on an older population; iii) the effects were compared with a control group or with a different type of training. Studies were not restricted to a specific set of languages. Studies were excluded if: i) no human subjects were considered; ii) there was no control or comparison group; iii) no report was included concerning follow-up assessments for risk factors in an elderly population. (Figure 1)

Data extraction

One of the authors (JDJ) extracted key data from the papers and transferred them to a standardized Excel sheet, and a second author (AM) verified the data thus collected against their original source. For each paper, data were extracted concerning the authors, year of publication, country, main condition of interest, structure, type, and description of HIIT training, follow-up (in weeks), and average age, as well as the percentage of subjects in each of the following types of training: high-intensity interval training (HIIT), continuous intensity training (CIT), control group (CONTROL). Risk of bias was also included. These parameters are displayed in Tables 1, 2, and 3.

Study groups

The primary results concern the effects of a HIIT program on the health of an older population during the follow-up assessment performed on the HIIT, CONTROL, or CIT groups. The secondary results deal with the variations occurred between base line and follow-up assessment values in both groups.

Data synthesis

Given the limited number of existing studies and the highly heterogeneous nature of the interventions (the type of HIIT) and results (changes in body composition as well as cardiometabolic and cardiovascular health markers) we have summarized the findings of the RCTs under consideration in a descriptive manner.

RESULTS

Database searches yielded 145 studies. After removing duplicates, we screened 70 titles/abstracts for eligibility. Out of these, 14 studies were deemed relevant. The selection process is shown in Figure 1. All 14 studies examined the effects of HIIT interventions on an elderly population, whose characteristics are summarized in Table 1.

Table 1. Descriptive findings of the randomized controlled trials included

Author (year)	Country	Main condition	Setting	Type of HIIT	Description of HIIT	Follow-up (weeks)	Variables	Tool
Maillard, 2016	France	Pre- and postmenopausal women	City	CYCLE ERGOMETER	Twice times a week. Tuesdays and Thursdays. Training comprised 8" at 80% Hrmax sprint and 12" of recovery. Sessions were 20 minutes in length.	16	Visceral fat and abdominal fatty mass.	Absoprtiometry echocardiograph.
Ellingsen, 2017	Germany	Older adults with cardiovascular conditions	City	WALK/CYCLE	Three times a week, 38 minutes per session. Each session comprised Four blocks of four minutes (90-95% Hrmax).	12	Aerobic capacity and left-ventricle measurements.	Echocardiograph
Onambélé, 2010	United Kingdom	Healthy older adults	City	STRENGTH TRAINING	Twice times a week. Each session comprised six series at 50% of Perceived 1RM, with three-minute rest intervals between series.	12	Endocrine factors.	Dynamometer, echograph, and ultrasound scanner.
Grace, 2017	Australia	Sedentary and athletic older adults	City	CYCLE ERGOMETER	One training session every five days. Each session comprised six series of 30" sprint runs with five minute low-resistance recovery periods.	6	Arterial blood pressure, diastolic blood pressure and metabolic capacity.	Echocardiograph and spirometry.
Bruseghini, 2015	Italy	Active older adults	City	CYCLE ERGOMETER/IST	Three times a week, seven repetitions of two minutes at 80-90% Vo2 Max. Four months later, IST training. Strength, knee extension, and bench pressing at 40% Vo2 max.	8	Risk of cardiometabolic disease and Anthropometric variations.	Gas analyzer and blood pressure monitor.
Mnadrup,2017	Denmark	Pre- and postmenopausal women	City	CYCLE ERGOMETER	Three times a week, one hour training with warm-up and cool-down. Progressive increase in intensity until 95% of Hrmax.	12	Menopause-related risk factors.	Absorptiometry, blood sample, and photometer.
Jabbour, 2017	Canada	Healthy older adults	City	CYCLE ERGOMETER	Three times a week, six series of 6" at 100% Vo2 max, with two-minute recovery periods.	6	Maximum strength related to age changes (old and young).	Bioimpedance and submaximal oxygen consumption.
Knowles, 2015	Scorland	Sedentary and active older adults	City	CYCLE ERGOMETER	Two training blocks, the second being HIIT, twice a week with six series of 30" sprint runs	12	Aerobic aptitude, motivation for sport practice and HRQL.	Spirometry and SF-36.
Bell , 2015	Canada	Sedentary older adults	City	CYCLE ERGOMETER / DUMBBELLSPESAS	HIIT: ten Series x one minute at 95% Hrmax with two-minute recovery periods.	6	Myofibrillar and sarcoplasmic rates.	Absorptiometry.

HRmax= Maximum heart rate; RM= Repetition maximum; IST= Isoinertial strength training; Vo2= Oxygen consumption; HIIT= High-intensity interval training.

Table 1 (next). Descriptive findings of the randomized controlled trials included

Author (year)	Country	Main condition	Setting	Type of HIIT	Description of HIIT	Follow-up (weeks)	Variables	Tool
Globas, 2011	Switzerland	Older adults with cerebrovascular accidents	Elderly home	WALKING	Three times a week, 45 minutes per session. Varying with the patient, up to 80% Hrmax.	12	Ability to walk and cardiovascular conditioning.	Spiroergometer and treadmill with walking test.
Hakan, 2009	Sweden	Oldr adults with dementia	City	DAILY ACTIVITIES	Two times a week, with walking, squats, and balance exercises similar to daily activities. Every exercise 8-12 repetitions to máximum velocity.	12	Degree of dependence in personal care in the short and long term.	KATZ index, (30s-CST), and MMSE.
Mejías Peña, 2016	USA	Healthy older adults	City	CYCLE ERGOMETER	Twice a week, Tuesdays and Thursdays, 30 minutes per session, with 20 minutes at 70-75% Hrmax, including one-minute periods at 90-95% Hrmax.	10	Autophagy and TLR signaling.	Spirometry and blood sample.
Nemoto, 2007	Japan	Healthy older adults	City	WALKING	Four times a week, each session comprised five low-intensity series at 40% Vo2 max, and three-minute intervals at 85% Vo2 max.	12	Muscle strength, Vo2 and arterial blood pressure.	Blood pressure monitor and gas analyzer.
García Pinillos, 2019	Spain	Active and healthy older adults	City	STRENGTH TRAINING	Three times a week, 35-40 minutes per session. Squats, medicine ball, throwings, In one-minute blocks, at repetition maximum, with two-minute recovery intervals.	12	Upper- and lower-body composition, mobility, and balance.	Bioimpedance, (30s-CST), and treadmill with photoelectric cells.

HRmax= Maximum heart rate; RM= Repetition maximum; IST= Isoinertial strength training; Vo2= Oxygen consumption; HIIT= High-intensity interval training.

Risk of bias

The degree of methodological rigor of the studies we have included (according to our assessment of their potential risk of bias) is presented in Table 3. Two of the studies were considered to be free from risk of bias (Ellingsen et al., 2017; Globas et al., 2011), one study only scored two risk-of-bias points in our assessment (Hakan et al., 2009), five of the studies only scored two points (Maillard et al., 2016; Onambélé, Breen, and Stewart, 2010; Bell et al., 2015; Mejías-Peña et al., 2016; Nemoto, Gen-no, Masuki, Okazaki, and Nose, 2007), and six studies scored three or higher in our assessment (Grace et al., 2017; Bruseghini et al., 2015; Mandrup et al., 2017; Jabbour et al., 2015; Knowles, Herbert, Easton, Sculthorpe, and Grace, 2015; García-Pinillos et al., 2019).

Body mass and composition

Out of the 14 studies we included, four reported the effect of HIIT compared with moderate-intensity exercise or with a control group regarding fatty mass percentage (n=2) or lean mass percentage (n=2). The results showed that HIIT may induce significant changes in body composition (Table 2), with three of the studies contemplating interventions over 12 weeks in length (Maillard et al., 2016; Mandrup et al., 2017; García-Pinillos et al., 2019). None of these studies scored less than three points for risk of bias. In addition, two out of the four studies that reported a beneficial effect of HIIT on body composition involved a population of postmenopausal women (Millard, Mandrup), who experienced significant reductions in fatty mass percentages, as displayed in Table 2.

Table 2. Main findings of the trials included

Table 2 Main findings of the trials included.

	HIIT group			CONTROL group			MIT group			Main findings regarding HIIT
Author (year)	N	Age	SD	N	Age	SD	N	Age	SD	
Maillard, 2016	8	70,5	9,5				9			Significant abdominal fatty mass reduction in both groups ($p<0.05$) and visceral fatty mass reduction in the HIIT group ($p<0.01$).
Ellingsen, 2017	88	60	5,2	76			77			Significant left ventricle improvement with HIIT ($p=0.45$).
Onambélé, 2010	15	60		15						Muscle strength increase with HIIT compared with control training ($p<0.05$). No changes in 1RM increase. Increases in TUG test -11.6 +- 4.8 % and In gait speed: -15.6% +- 1.7 % ($p<0.05$).
Grace, 2017	(SED)22	62,7	5,2	(ATL)17	61,1	5,4				Improvement in systolic blood pressure and average group arterial blood pressure SED ($p<0.05$). Increase in metabolic capacity in SED and ATL with HIIT ($p=0.01$) Decrease of diastolic blood pressure in athletic older adults ($p=0.005$).
Bruseghini, 2015	6	68	4	6	68	4				Significant decrease of fatty mass percentage ($p=0.00002$) and abdominal fat ($p= 0.0165$). Decrease of the waist-hip ratio ($p= 0.00063$).
Mnadrup,2017	(PRE) 38	49,2	1,1	(POST) 37	53,4	2,8				Significant decrease in weight ($p<0.0001$), fatty mass ($p<0.001$), Diastolic blood pressure ($p<0.05$), HR at rest ($p<0.0001$), and plasma insulin contraction ($p<0.05$).
Jabbour, 2017	30	54,4	2,3	17	26,2	2,4				Significant increase in maximum strength ($p<0.01$).
Knowles, 2015	(SED) 25	63	5	(ACT) 19	61	5				Significant increase in Vo2 max ($p<0.001$), physical function, ($p<0.001$), and general health (p00,046) in SED. Increase in physical function ($p=0.002$) and general health ($p=0.01$) in active older adults.
Bell , 2015	8	67	4	7	67	4	7	67	4	Significant increase in sarcoplasmic proteins (p<0,05).
Globas, 2011	18	68,6	6,7	18	68,7	6,3				Sig.ificant increase in gait speed ($p=0.001$), balance (p<0,05), and SF12 mental health ($p<0.001$).
Hakan, 2009	91	85,3	6,1	100	85,3	6,1				Group with dementia improved significantly in daily activities
										after 12 weeks ($p<0.03$).
Mejías Peña, 2016	10	69,7	1	13	69,7	1				Significant increase in peak Vo2 with HIIT ($p<0.003$). At the protein level, Increase in LC311/LC31 ($p<0.004$) and decrease in P62/SQSTM1 ($p<0.005$).
Nemoto, 2007	68	63	6	59	63	6	62	63	6	Increase in knee flexion of 13%, of 17% in peak Vo2, and of 8% in aerobic capacity, all with $p<0.0001$. Decrease in systolic blood pressure ($p=0.01$).
García Pinillos, 2019	47	72	5	43	72	5				Improvements in body composition ($p<0.05$), physical function (muscle strength; $p<0.001$), and balance ($p<0.001$).

Cardiovascular and cardiometabolic health

Table 3. Risk-of-bias assesment

Author (year)	1	2	3	4	5	6	SCORE
Maillard, 2016	N	U	Y	Y	Y	Y	4/6
Ellingsen, 2017	Y	Y	Y	Y	Y	Y	6/6
Onambélé, 2010	Y	U	U	Y	Y	Y	4/6
Grace, 2017	N	U	U	Y	Y	N	2/6
Bruseghini, 2015	N	Y	Y	N	N	Y	3/6
Mnadrup,2017	N	Y	N	Y	N	Y	3/6
Jabbour, 2017	N	Y	N	N	Y	Y	3/6
Knowles, 2015	N	N	Y	N	Y	Y	3/6
Bell, 2015	Y	Y	Y	N	U	Y	4/6
Globas, 2011	Y	Y	Y	Y	Y	Y	6/6
Hakan, 2009	Y	U	Y	Y	Y	Y	5/6
Mejías Peña, 2016	Y	Y	N	N	Y	Y	4/6
Nemoto, 2007	Y	N	Y	N	Y	Y	4/6
García Pinillos, 2019	Y	N	N	N	Y	Y	3/6

Criteria items: 1. Was the randomization sequence generation adequate? 2. Was the treatment allocation concealed?
3. Was the outcome assessor blinded to the intervention? 4. Were losses to follow-up and exclusions correctly described?
5. Was intention-to-treat analysis used for statistical analyses? 6. Are reports of the study free of suggestion of selective outcome reporting?
Unsure (U), Yes (Y), No (N).

Three studies researched the effect of HIIT on blood pressure, and all those concluded that it has beneficial effects (Table 2). More specifically, only one of the studies scored less than three points for its risk of bias (Grace et al., 2017; Table 3). Grace et al. and Nemoto et al. reported significant improvements in SBP, with Grace et al.'s showing significant decreases of this parameter in a group of sedentary elderly subjects when compared with a group of athletes (p=0.001) after a HIIT intervention. Meanwhile, Nemoto et al., with a sample of 187 healthy older adults, reported significant improvements in comparison with the CIT and CONTROL groups (p<0.0001). In addition, the study by Mandrup et al., involving premenopausal and postmenopausal populations, reported significant improvements in the diastolic blood pressure of the postmenopausal group when compared with the premenopausal subjects after both underwent a HIIT intervention (p<0.005), as displayed in Table 2. Concerning potential improvements in cardiometabolic and cardiovascular health indicators, studies examined the left ventricle (n=1), metabolic capacity (n=1), HR at rest (n=1), glucose levels (n=1), and aerobic capacity (n=1), as seen in Table 1. Regarding cardiovascular health indicators, Elligsen et al. reported improvements in the left ventricle of a population of 165 older adults after a 12-week HIIT intervention in comparison with a CIT group, with a risk-of-bias score of 6/6 (Table 2). In addition to this, results by Grace et al. point at improvements in metabolic capacity in groups of sedentary and active older adults after a HIIT intervention, although this is the paper with the highest risk of bias (2/6, see Table 3). The analysis of blood insulin levels carried out by Mandrup et al.

shows significantly higher reductions in the postmenopausal HIIT group than in the premenopausal one after a 12-week intervention ($p<0.05$). The same study reports significant improvements in HR at rest for both groups after the HIIT intervention ($p<0.0001$). Aerobic capacity also increased in an active elderly population in the study carried out by García Pinillos et al. (2019), where it grew significantly more in the HIIT group than in the CONTROL after a 12-week strength-training intervention ($p<0.0001$; Table 2). Their study scored 3/6 for risk of bias (Table 3).

High-intensity training intervention

All the studies included in this review provided a description of their intervention protocol, including information concerning the structure, duration, intensity, and frequency of sessions, as well as the length of the intervention. All these key aspects are detailed in Table 1. According to five of the 14 studies which showed the most substantial improvements in the health of an elderly population (Maillard et al., 2016; Ellingsen et al., 2017; Mandrup et al., 2017; Mejías-Peña et al., 2016; Nemoto et al., 2007), and specifically for cardiovascular and body composition indicators (Table 2), it can be suggested that the optimal intervention would be a cycle ergometer exercise, practiced with an intensity of 90-95% HRmax, two to three times a week, at least during 40 minutes, with a minimum length of 12 weeks. However, the exact duration of sessions and recovery intervals remain vague given the variation between studies, a notion that William, Eddols also supported in a systematic review carried out this year for studies with a young population.

DISCUSSION AND CONCLUSIONS

The goal of this review was to provide a synthesis of the scientific literature concerning the effects of HIIT in an elderly population, and to establish its potential impact on body composition and cardiometabolic and cardiovascular health. In addition we aimed at providing a definition for an optimal HIIT protocol, specifying the ideal structure and intensity of its sessions, as well as its overall length.

In previous studies analyzing the effects of HIIT on at-risk populations (Kessler et al., 2012) or with associated clinical pictures such as heart disease (Rognmo et al., 2012), it was suggested that HIIT was a safe practice, but they did not establish a fixed protocol. The present review shows improvements in health indicators of an elderly healthy population (Onambélé et al., 2010, Jabbour et al., 2015; Mejías-Peña, 2016; Nemoto et al., 2007), a sedentary population (Grace et al., 2017; Bell et al., 2015), a population with cerebrovascular conditions (Ellingsen et al., 2017; Globas et al., 2011), and a population affected by dementia (Littbrand, Lundin-Olsson, Gustafson, and Rosendahl, 2009). However, differences in the types of training, the intervention protocols, and the duration of the program must be taken into account. Considering our conclusions, it may be safe to say that at least 12 weeks are required for significant adaptations to appear.

In an elderly population, differences between subjects regarding health indicators and body composition may obscure the interpretation of results, particularly among several studies, although in our review all papers reported improvements in body composition. In two of the cases significant improvements were reported in the reduction of fatty mass percentage for postmenopausal women (Maillard et al., 2016; Mandrup et al., 2017). The same effect appeared in the works of Bruseguini et al. (2015) and García Pinillos et al. (2019), where significant reductions were reported in percentage of fatty mass and body composition, respectively, for an active older population. As for cardiovascular and cardiometabolic health, the work of Grace et al. described significant improvements in blood pressure for a group of sedentary elderly subjects when compared with a group of athletes after a HIIT intervention. The same is true for the studies performed on healthy older adults by Knowles et al. (2015) and Mejías et al. (2016), which reported significant Vo2 improvements after 10 and 12 weeks of HIIT in a cycle ergometer when compared with their CONTROL groups. It must be taken into account, however, that in addition to methodological limitations the interpretation of our findings may be skewed by the mixed levels of risk of bias among the studies under consideration.

One additional factor that may contribute to the ambiguity of results concerning the efficacy of HIIT is the compensation effect. More specifically, one study suggested that young subjects tend to compensate an increase in activity levels in any given day with the activity level of the following day (Ridgers, Timperio, Cerin, and Salmon, 2014). In addition, the activitystat hypothesis suggests that an increase in physical activity in one part of the day may result in a compensating decrease in another part (Rowland, 1998). As for differences in the effect of HIIT among genders, no conclusion could be drawn from the studies under consideration, since only two of them provided a breakdown by gender. That was the case of the works of Mandrup et al. (2017) and Maillard et al. (2017), which only considered pre- and postmenopausal women. This limitation must be considered in future research, since the effect of training interventions on body composition (Lazaar et al., 2007; Martínez-Vizcaino et al., 2014), cardiorespiratory health (Obert et al., 2003), and cardiometabolic health (Martínez-Vizcaino et al., 2014) indicators may be gender-dependent among older adults. Future research should consider providing a breakdown of results, including gender- and age-related differences associated with the practice of HIIT.

Although the studies included in this review have furthered our understanding of the effect of HIIT on al older population under laboratory-based conditions, sample size and the specifics of intervention delivery may rise some questions regarding the large-scale implementation of HIIT. Previous research has reported the successful implementation of HIIT protocols on older adults with certain health problems, as was the case of Devin et al. (2016), where a population with colon cancer underwent a four-week intervention, and of Ramos et al., in which a population with metabolic syndrome underwent a 16-week intervention. As in most of the studies considered in our review, they reported significant improvements for their HIIT groups in at least some variable.

Given the promising results regarding the efficacy of HIIT, researchers may want to contemplate how long-term HIIT interventions may be integrated in physical activity programs aimed at an older population. Despite the suggestion that HIIT is preferable to aerobic exercise (Ramos et al., 2016), more research is required in that regard. Lastly, doubts arise about the sustainability of postintervention improvements in the body composition and the cardiometabolic and cardiovascular health of older adults, as studies providing a follow-up are still scarce. This follow-up should be incorporated within the research design of future studies to ensure that the benefits of HIIT can be sustained after the intervention.

Some factors may be considered in order to reduce the differences found in RCTs regarding the benefits for body composition and cardiometabolic and cardiovascular health.

Firstly, inclusion criteria varied greatly among the studies. Some included subjects who were already physically active (Knowles et al., 2015; Grace et al., 2017; García-Pinillos et al., 2019), whereas other required their participants to be sedentary older adults (Maillard et al., 2016; Jabbour et al., 2017; Bell et al., 2015; Mejías-Peña et al., 2016; Nemoto et al., 2007).

Furthermore, great variations were observed in the analysis of the methodological quality of RCTs. Curiously enough, trials including a cycle ergometer training scored higher in quality as far as cardiorespiratory variables were concerned (Knowles et al., 2015; Mejías-Peña et al., 2016).

Conclusions

High-intensity interval training is an effective method of improving body composition and metabolic and cardiovascular health indicators in an older population. However, evidence suggesting additional health benefits remains ambiguous. The results of our review suggest that cycle ergometer training sessions at an intensity of 90-95% HRmax, two to three times a week, at least during 40 minutes, with a minimum length of 12 weeks, are able to elicit beneficial effects on several health indicators. Further recommendations regarding length of sessions and rest periods are still ambiguous given the scarcity of available studies and their methodological limitations. Also, the limited length of HIIT programs hindered the comparison of the long-term effects of RCTs with those with longer follow-ups. Longer interventions and follow-up periods in RCTs will definitely help compare their results with those of longitudinal studies. By normalizing the type of training, the weeks of intervention, and the amount of effort, compatibility between RCTs could be ensured. In summary, the methodological aspects of RCTs must be standardized if we are to obtain a clear picture of the relationship between training and health improvement in older adults, thus reducing discrepancies among different types of studies.

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