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original article

Effects of long-term resistance training on obesity indicators: a systematic review

Efeitos de longo prazo do treinamento resistido nos indicadores de obesidade: uma revisão sistemática

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Abstract – Several studies have reported the effect of exercise on the control of excess body fat; however, the criteria for different types of exercise have not yet been established in the literature, mainly regarding long-term resistance exercises. The objective of the present study was to determine by a systematic review the long-term action of resistance training on obesity indicators. Original scientific studies were included, classified according to the intervention of traditional (TRT) and combined (CRT) resistance training and analyzed in terms of their methodological quality. Articles were surveyed in the following databases: MEDLINE via PubMed, Science Direct, Scopus, Web of Science, and Lilacs. Based on the analysis of 28 papers selected from the 1199 articles reviewed, it was noted that higher rates of reduction in body mass index and body fat percentage occurred when performing CRT compared to TRT. However, more evidence is needed in order to standardize the variables of resistance training (number of exercises, repetitions, number of series, intervals, speed of execution, and load intensity), so that the best training model may be identified and the methodological quality of the experiments may be improved in an attempt to reduce the risk of bias.

Key words: Body fat; Overweight; Resistance exercise.

Resumo – *Vários estudos relatam o efeito do exercício físico no controle do excesso de gordura corporal, entretanto, a falta de fixação de critérios para os diferentes tipos de exercícios ainda não está estabelecida na literatura principalmente no exercício resistido quando analisado em longo prazo. Assim, o objetivo do estudo foi verificar, por meio de uma revisão sistemática, a ação de longo prazo do treinamento resistido em indicadores de obesidade. Foram incluídos estudos científicos originais, classificados em função da intervenção do treinamento resistido tradicional (TRT) e combinado (TRC) e analisados pela qualidade metodológica dos estudos. A busca dos artigos foi realizada nas bases de dados: Medline via Pubmed, Science Direct, Scopus, Web Science e Lilacs. Dos 1199 artigos encontrados, através dos 28 selecionados ao final da análise, pôde-se notar que as maiores taxas de redução do índice de massa corporal e da proporção de gordura corporal ocorreram quando da realização do TRC em comparação com o TRT. Entretanto, são necessárias mais evidências de forma a padronizar as variáveis do treinamento resistido (quantidade de exercícios, repetições, quantidade de séries, intervalos, velocidade de execução e intensidade de carga) para que se possa identificar o melhor modelo de treinamento e aprimorar a qualidade metodológica dos experimentos na tentativa de diminuir os riscos de viés.*

Palavras-chave: *Exercício resistido; Gordura corporal; Sobrepeso.*

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INTRODUCTION

Physical inactivity has become a source of concern because of its influence on greater body fat (BF) accumulation. This relationship leads to a higher rate of cardiovascular events and mortality among individuals with a low level of physical conditioning[1] and is also associated with other non-communicable chronic diseases[2]. Obesity has become an epidemic health problem both in developed and developing cuntries[3].

A study conducted by the World Health Organization (WHO) detected a high prevalence of obesity in the adult population of various countries[3]. In Brazil, the prevalence of obesity and overweight has been considerably increasing over the last few years. The Family Budget Survey conducted by the Brazilian Institute of Geography and Statistics (IBGE in the Portuguese acronym)[4] has pointed out that obesity increased from 2.8% to 12.4% among adult men and from 8% to 16.9% among adult women from 1985 to 2009. According to the same survey, the prevalence of excess body weight has considerably increased from 18.5% to 50.1% among women and from 28.7% to 48% among men during the same period.

Because of the high association of overweight and obesity with the development of cardiovascular diseases, changes in life style such as the practice of physical exercises and changes in eating habits are usually stimulated. These strategies, however, are poorly effective on a long-term basis[1].

The long-term effect of aerobic training on the reduction and control of body weight is the model most extensively studied and recommended. However, fewer studies on the influence of resistance exercises are available within this context[5,6].

The use of resistance exercises to reduce BF accumulation is based on the proposal of a longer-lasting increase in resting metabolic rate (RMR) and of higher daily energy expenditure (DEE). A frequently explored method used to increase DEE is to perform exercises that increase oxygen uptake after activity, i.e., exercises that will generate higher oxygen consumption after exercise as a momentary adjustment, defined as excess post-exercise oxygen consumption (EPOC)[7,8].

Thus, the objective of the present study was to conduct a systematic literature review to determine the long-term effect of resistance training on the variation of values equivalent to the body mass index (BMI) and on indicators of BF.

METHODOLOGICAL PROCEDURES

A survey of the Medline databases was carried out from June 17 to June 22, 2014 via Pubmed, Science Direct, Scopus, Web of Science, and Lilacs.

Inclusion criteria were: clinical studies with resisted training conducted on sedentary human subjects older than 19 years who did not follow specific diets, and long-term response of obesity indicators to resistance training. No limit was imposed on the language of publication of the article or the year of publication. Regarding long-term responses, studies involving at least 8 weeks of training with a frequency of at least twice a week were included so that an acceptable chronic effect could be detected.

The key words used in Medline via PubMed were: Search ((((((((((“obesity”[Title/Abstract]) OR “obesity”[MeSH Terms]) OR “overweight”[MeSH Terms]) OR “overweight”[Title/Abstract]) OR “weight gain”[Title/Abstract]) OR “weight gain”[MeSH Terms]) OR ((“abdominal obesities”[Title/Abstract] OR “abdominal obesity”[Title/Abstract]))) OR “central obesity”[Title/Abstract]) OR “visceral obesity”[Title/Abstract])) AND (((((((((“resistance training”[Title/Abstract]) OR “resistance training”[MeSH Terms]) OR “training, resistance”[Title/Abstract]) OR “strength training”[Title/Abstract]) OR ((“training strength”[Title/Abstract] OR “training strengthens”[Title/Abstract]))) OR ((“weight lifting exercise program”[Title/Abstract] OR “weight lifting exercise programs”[Title/Abstract] OR “weight lifting exercises”[Title/Abstract]))) OR ((“weight bearing strengthening program”[Title/Abstract] OR “weight bearing strengthening programs”[Title/Abstract]))) OR ((“weight bearing exercise program”[Title/Abstract] OR “weight bearing exercise programme”[Title/Abstract] OR “weight bearing exercise programmes”[Title/Abstract] OR “weight bearing exercise programs”[Title/Abstract] OR “weight bearing exercises”[Title/Abstract]))) OR ((“weight bearing exercise programs”[Title/Abstract] OR “weight bearing exercises”[Title/Abstract]))) Filters: Clinical Trial; Humans; Adult: 19+ years.

The studies were surveyed and selected by two investigators in an independent and blind manner, with no conflict occurring. The studies were first selected by reading the title and abstract and later by reading the full text. After a complete reading, a manual search was conducted in the reference list.

The outcomes considered for resistance training were: BMI, BF percentage and the sum of skinfold thickness measurements. The Cochrane Critical Table of Bias Risk was used to analyze the methodological quality of the studies[9].

RESULTS

A total of 1199 articles were detected, 1136 of which were excluded because they were not related to the theme under study, as determined by reading the titles and abstracts. Of the 63 articles left after this first step, 14 were replicates, 7 were review articles and 15 did not meet the inclusion criteria (11 of them used specific diets, three were conducted on children, and one concerned the measurement of calorie expenditure), with 27 articles being left. At the end of the search, one article was added by manual search in view of the importance of its content and in order to contextualize the research problem, as indicated in Figure 1:

Since traditional resistance training varies in terms of the models of intervention, we opted to divide the analyses according to the function

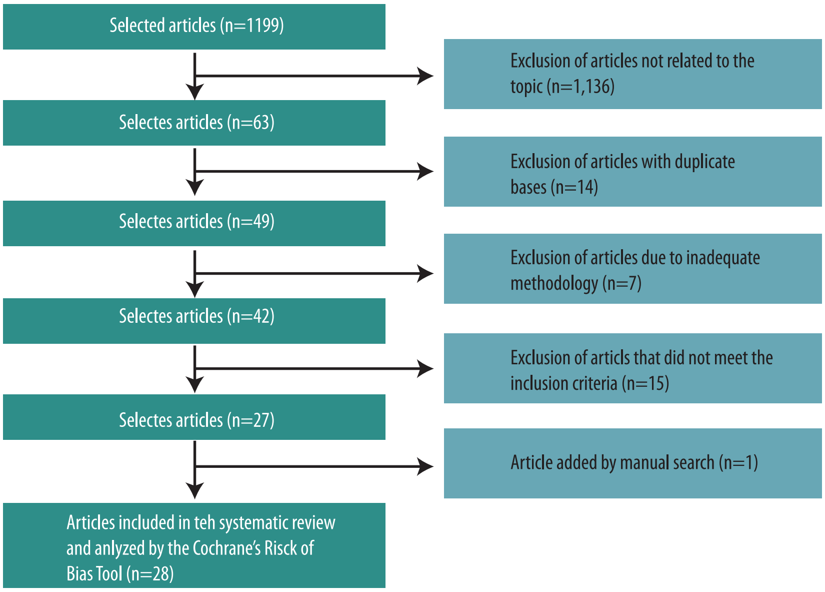

Figure 1. Flow diagram of article selection.

of intervention of traditional resistance training (TRT) (only resistance exercises) and of combined resistance training (CRT) (resistance exercises plus aerobic exercises).

The 17 studies using TRT involved 6 to 82 volunteers aged 22 to 76 years; of these, eight involved subjects of both sexes, five involved only men, and four only women (Table 1).

The training period ranged from 8 to 14 weeks, with a predominance of 12 weeks of training (6 studies). The weekly frequency of training was 2 to 5 times per week, with most studies (n = 11) using a frequency of 3 times per week. The number of exercises used for training ranged from 5 to 10, with 8 exercises being the most common training volume (6 studies). The number of series ranged from 1 to 5, with a volume of 3 series being the most frequently used (7 studies). The number of repetitions ranged from 4 to 20, with series of 8 to 15 repetitions being most frequently used (9 studies). Two studies used a time of one minute for the repetitions[13,27]. The percent load used, cited in 8 studies[11,12,17,25-27,35,37], ranged from 20 to 90% one repetition maximum (1 RM), with the interval of load intensity most frequently used being 50 to 80%. The interval between exercise series, cited in 11 studies, ranged from 30 seconds to 3 minutes, with no predominance of a specific interval (Table 2). Only two articles cited the speed of execution (2"X2")[11,18] (a result not shown in the table).

In the specific case of TRT, the BMI values showed significant reductions in 2 articles[10,27], while in 7 other articles[11,13,14,16,17,25,35] they were unchanged. In 2 studies[26,37] the BMI values tended to be reduced, although with no indication of statistical significance. In 5 articles[12,18,19,28,29] the BMI values increased, although not significantly (Table 1).

A significant reduction in BF percentage was reported in 2 of the 17 articles analyzed[16,29], while 6 articles[13,24-26,28,37] reported a nonsignificant reduction. Fat percentage increased in one article[18] and 2 studies[27,28] reported a significant reduction in the sum of skinfold measurements. A significant reduction in estimated fat weight was observed in one article[12] (Table1).

Regarding the criterion of methodological quality of the articles involving TRT, some weaknesses could be observed. Only the study by Stensvold *et al.*[12] showed a low risk of bias in all items evaluated and only 2 articles (11.8%) clearly cited the sequence generation, 11 (64.7%) did not clearly describe this item, and 4 (23.5%) did not cite it at all. Regarding blind allocation, 3 articles (17.7%) used allocation in an appropriate manner, 9 9 (52.9%) did not report it clearly, and 5 (29.4%) did not report it at all. In 8 articles (47%) the data were not influenced by subject blinding, 7 articles (41.2%) did not describe this item in a clear manner, and 2 (11.8%) did not mention it at all. Analysis of incomplete results revealed that 8 articles (47%) did not have incomplete results, 5 (29.4%) did not leave this item clear in the text, and 4 (23.6%) did not mention it at all. Analysis of selective outcome reports revealed that only one article (5.9%) was free of this bias, 14 articles (82.4%) did not make this topic clear, and 2 (11.7%) did not report it at all. The analysis of whether the article was free from other biases showed that 6 articles (35.3%) met this criterion, in 6 articles (35.3%) the analysis was impaired, and 5 (29.4%) had a high risk of having another bias (Figure 2).

The studies of the behavior of BMI and BF percentage after CRT (16 studies) involved 10 to 606 volunteers aged on average 22 to 69 years, with 7 of them involving subjects of both sexes, 5 involving only men, and 4 only women (Table 1).

The training period ranged from 8 to 52 weeks, with a 12-week period predominating (7 studies), and the weekly frequency ranged from 2 to 5 times, with most studies (n = 11) using 3 time a week. The number of exercises used for training ranged from 4 to 12, with no specific number predominating. The number of series ranged from 1 to 6, with a volume of 3 series being the one most frequently used (6 studies). The number of repetitions ranged from 8 to 20, with a predominance of 8 to 12 repetitions (7 studies). In three studies[13,30,31] a time of 30 seconds to 1 minute was used to perform the repetitions. The percent load used, cited by 10 studies[12,15,20,22,23,25,32-34,36] ranged from 40 to 75% 1 RM, and the load interval most frequently employed was 40 to 60% (6 studies). The interval between exercise series, cited by 6 studies[13,19,20,31,34,36], ranged from 0 to 2 minutes, with no predominance of a specific interval (Table 2). Only one article[30] mentioned the speed of execution (5" to perform the movement) (result not shown in the table).

BMI values were analyzed in 12 of the 16 articles. Significant BMI reductions were detected in 5 of them[15,21,22,25,34] and nonsignificant reductions in 3 other articles[13,19,36]. No change was observed in one article[23] and a nonsignificant increase in BMI was observed in 3 others[12,20,32]. A significant reduction in BF percentage was observed in 11 articles and a nonsignificant reduction in fat weight was observed in 2[12,13].

With respect to the criterion of methodological quality of the articles involving CRT, important limitations were detected (Figure 2). Only the studies of Stensvold *et al.*[12] and Ho *et al.*[25] showed a low risk of bias in all items assessed (not shown in the table). Only 3 articles (18.7%) clearly mentioned the sequence generation, 11 articles (68.8%) did not present it clearly, and 2 (12.5%) did not mention it at all. Three articles (18.7%) performed allocation in an appropriate manner, 10 (62.6%) did not present allocation clearly, and 3 (18.7%) did not mention it at all. Regarding subject blinding, in 9 articles (56.3%) the data were not influenced by this topic, 6 articles (37.5%) did not present the item clearly, and 1 article (6.2%) did not mention it at all. Seven articles (43.8%) did not show incomplete results, 7 (43.8%) did not clearly show if the results were incomplete, and 2 (12.4%) did not cite this item. Analysis of selective outcome reports revealed that 2 articles (12.4%) were free from this bias and 14 (87.6%) did not clarify the analysis. Analysis of the absence of other biases revealed that 5 articles (31.3%) met this criterion while this item could not be analyzed in 9 (56.3%), and 2 articles (12.4%) showed a high risk of another bias.

Table 1. Behavior of the values equivalent to the body mass index and of the body fat indicators in adults after a period or traditional resistance training (TRT) and combined resistance training (CRT).

Study	Age years Mean±SD	N (M/F)	EG (%)	CG (%)
TRT				
Martins *et al.*[10] (Portugal)	76±8	63 (25/38)	BMI (-0.98)*	BMI (-0.68)
Kanegusuku *et al.*[11] (Brazil)	63.9±0.7	28 (9/19)	BMI (Ø)	BMI (Ø)
Stensvold *et al.*[12] (Norway)	50.9±7.6	11 (M) (F)	BMI (+0.31) FW (-5.88)*	BMI (+0.32) FW (-0.86)
Alvarez *et al.*[13] (Chile)	33.9±9.3	8 (M)	BMI (Ø) %BF (-1.39)	BMI (+0.70) %BF (+1.86)
Schyerve *et al.*[14] (Norway)	46.2±2.9	40 (M) (F)	BMI; %BF (Ø)	¦
Banz *et al.* [16] (USA)	48±6	12 (M)	BMI (Ø) %BF (-15.11)*	¦
Hazley *et al.*[17] (United Kingdom)	53±9	6 (3/3)	BMI (Ø)	BMI (-3.22)
Tibana *et al.*[18] (Brazil)	33.9±8.6	14 (F)	BMI (+1.21) %BF (+0.77)	¦
Souza *et al.*[19] (Brazil)	48.7±5.5	9 (M)	BMI (+0.36)	BMI (-0.24)
Willis *et al.*[24] (USA)	50.1±11.6	44 (18/26)	%BF (-1.68)	¦
Ho *et al.*[25] (Australia)	52±1.1	16 (3/13)	BMI (Ø) %BF (-1.14)	BMI (Ø) %BF (+0.43)
Jimenez *et al.*[26] (Colombia)	23.7±5.4	16 (M)	BMI (-2.74) %BF (-5.68)	BMI (-1.32) %BF (-2.27)
Alvarez *et al.*[27] (Chile)	¦	35 (F)	BMI (-2.35)* ∑SF (-13.4)*	¦

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Study	Age years Mean±SD	N (M/F)	EG (%)	CG (%)
Misra *et al.*[28] (India)	40.8±8.1	30 (22/8)	BMI (+0.42) %BF (-1.08) ∑SFT (-5.3)* ∑SFL (-8.27)*	¦
Schmitz *et al.*[29] (USA)	36±5	82 (F)	BMI (+6.53) %BF (-8.30)*	¦
Guelfi *et al.*[35] (Australia)	49±7	33 (M)	BMI (Ø) FW (-2.55)*	BMI (Ø) FW (+3.02)
Gomes *et al.*[37] (Spain)	22±1.2	26 (M)	BMI (-0.4) %BF (-5.04)	BMI (+0.7) %BF (+0.62)
CRT				
Stensvold *et al.*[12] (Norway)	52.9±10.4	10 (M) (F)	BMI (+0.33) FW (-2.43)	BMI (+0.32) FW (-0.86)
Alvares *et al.*[13] (Chile)	43.3±8.1	10 (F)	BMI (-1) FW (-1.15)	BMI (+0.70) %BF (+1.86)
Barone *et al.*[15] (USA)	64.6±5.7	51 (25/26)	BMI (-2.72)* %BF (-9.21)*	BMI (-0.67) %BF (-0.53)
Souza *et al.*[19] (Brazil)	47.5±5.1	10 (M)	BMI (-0.32)	BMI (-0.24)
Sousa *et al.*[20] (Portugal)	69.1±5	16 (M)	BMI (+0.71) %BF (-8.01)*	BMI (-0.38) %BF (-3.45)
Balducci *et al.*[21] (Italy)	58.8±8.5	606 (M) (F)	BMI (-2.89)*	BMI (-0.62)
Stewart *et al.*[22] (USA)	63(61.5-64.5)	51 (25/26)	BMI (-2.72)* %BF (-9.23)*	BMI (-0.67) %BF (-0.53)
Guirardo *et al.*[23] (Brazil)	68±8	16 (6/10)	BMI (Ø)	¦
Willis *et al.*[24] (USA)	47±10.3	37 (16/21)	%BF (-5.20)*	¦
Ho *et al.*[25] (Australia)	53±1.3	17 (3/14)	BMI (-1.5)* %BF (-2.18)*	BMI (Ø) %BF (+0.43)
Kang *et al.*[30] (South Korea)	21.5	12 (F)	%BF (-5.11)*	%BF (+4.09)
Bocalini *et al.*[31] (Brazil)	64.4±4	69 (F)	%BF (-10)*	%BF (+2.91)
Shaw *et al.*[32] (South Africa)	28.7	28 (M)	BMI (+0.85) %BF (-13.05)*	BMI (+0.75) %BF (-1.41)
Park[33] (South Korea/Japan)	¦	10 (M)	%BF (-24.88)*	%BF (+5.70)
Safarzade *et al.*[34] (Iran)	25-45	30 (F)	BMI (-3.57)* %BF (-7.53)*	BMI (+0.38) %BF (-1.02)
Ahmadizad *et al.*[36] (Iran)	40.9±3.2	24 (M)	BMI (-0.7) %BF (-19.73)*	BMI (Ø) %BF (+3.52)

N: sample number; M: male F: female; EG: experimental group; CG: control group; BMI: body mass index; FW: fat weight; %BF: body fat percentage; ∑SF: sum of skinfolds; ∑SFT: sum of trunk skinfolds; ∑SFL: sum of limb skinfolds; SD: standard deviation; Ø: no change; ¦: no control group; *: statistically significant difference.

Table 2. Characteristics of the application of the variables of traditional resistance training (TRT) and combined resistance training (CRT).

Study	TP	TF	Load	QE	Series	QR	RI
		Δ	%	N	N	N	
	†		(†)		(†)	(†)	(†)
TRT							
Martins *et al.*[10] (Portugal)	16	3	∅	8	1(1-4) 2(5-12) 3(13-16)	8-12(1-4) 8-15(5-12) 12-5(13-16)	180″
Kanegusuku *et al.*[11] (Brazil)	16	2	70-90	7	2	4-10	180″
Stensvold *et al.*[12] (Norway)	12	3	80	8	3	8-12	∅
Alvarez *et al.*[13] (Chile)	12	3	∅	5	3	60″	120″
Schyerve *et al.*[14] (Norway)	12	3	∅	∅	3	30	30″
Banz *et al.*[16] (USA	10	3	∅	8	3	10	∅
Hazley *et al.*[17] (United Kingdom)	8	2	50(1-4) 60(5-8)	9	1(1) 2(2-8)	15	<30″
Tibana *et al.*[18] (Brazil)	8	3	∅	7	3	8 a 12	60″
Souza *et al.*[19] (Brazil)	16	3	∅	6	3	10(1-8) 8(9-16)	60″(1-8) 90(9-16)
Willis *et al.*[24] (USA)	32	3	∅	8	1(1-2) 2(3-4) 3(5-32)	8-12	∅
Ho *et al.*[25] (Australia)	12	5	75	5	4	8-12	60″
Jimenez *et al.*[26] (Colombia)	8	4	50-80	8	∅	∅	∅
Alvarez *et al.*[27] (Chile)	8	2	20(1-3) 25(4-6) 30(7-8)	4	3 4 5	60″	60″
Misra *et al.*[28] (India)	12	3	∅	6	2	10	∅
Schmitz *et al.*[29] (USA)	104	2	∅	8-10	3(1° ano) 2(2° ano)	8-10	∅
Guelfi *et al.*[35] (Australia)	12	3	75 85	9	3 4	8 10	90″
Gomes *et al.*[37] (Spain)	10	3	50 70 90	5	3	10 6 3	90″
CRT							
Stensvold *et al.*[12] (Norway)	12	3	40-50	8	2	15-20	∅
Alvares *et al.*[13] (Chile)	12	5	∅	5	3	60″	120″
Barone *et al.*[15] (USA)	24	3	50	7	2	12-15	∅
Souza *et al.*[19] (Brazil)	16	3	∅	6	3	10(1-8) 8(9-16)	60″(1-8) 90″(9-16)

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Study	TP	TF	Load	QE	Series	QR	RI
		Δ	%	N	N	N	
	†		(†)		(†)	(†)	(†)
Sousa *et al.*[20] (Portugal)	36	3	65(1-8) 75(9-24) 70(25-28) 65(29-32)	9	3	12 8-10 8-10 10-12	30″
Balducci *et al.*[21] (Italy)	52	2	∅	4	∅	∅	∅
Stewart *et al.*[22] (USA	26	3	50	7	2	10-15	∅
Guirardo *et al.*[23] (Brazil)	24	3	60	∅	3	8-12	∅
Willis *et al.*[24] (USA	32	3	∅	8	1(1-2) 2(3-4) 3(5-32)	8-12	∅
Ho *et al.*[25] (Australia)	12	5	75	5	2	8-12	∅
Kang *et al.*[30] (South Korea)	12	3	∅	5	3-6	30″	∅
Bocalini *et al.*[31] (Brazil)	12	3	∅	12	∅	45″	40″
Shaw *et al.*[32] (South Africa)	8	3	60	9	3	15	∅
Park *et al.*[33] (South Korea/Japan)	12	6	60(1-12) 70(13-24)	10	∅	∅	∅
Safarzade *et al.*[34] (Iran)	8	∅	60-70	9	3	8-10	30″
Ahmadizad *et al.*[36] (Iran)	12	3	50-60	11	4	12	30″

TP: training period; TF: training frequency; †: weeks; Δ: times per week; QE: quantity of exercises; QR: quantity of repetitions; RI: recovery interval; N: number; %: percent; ∅: not cited.

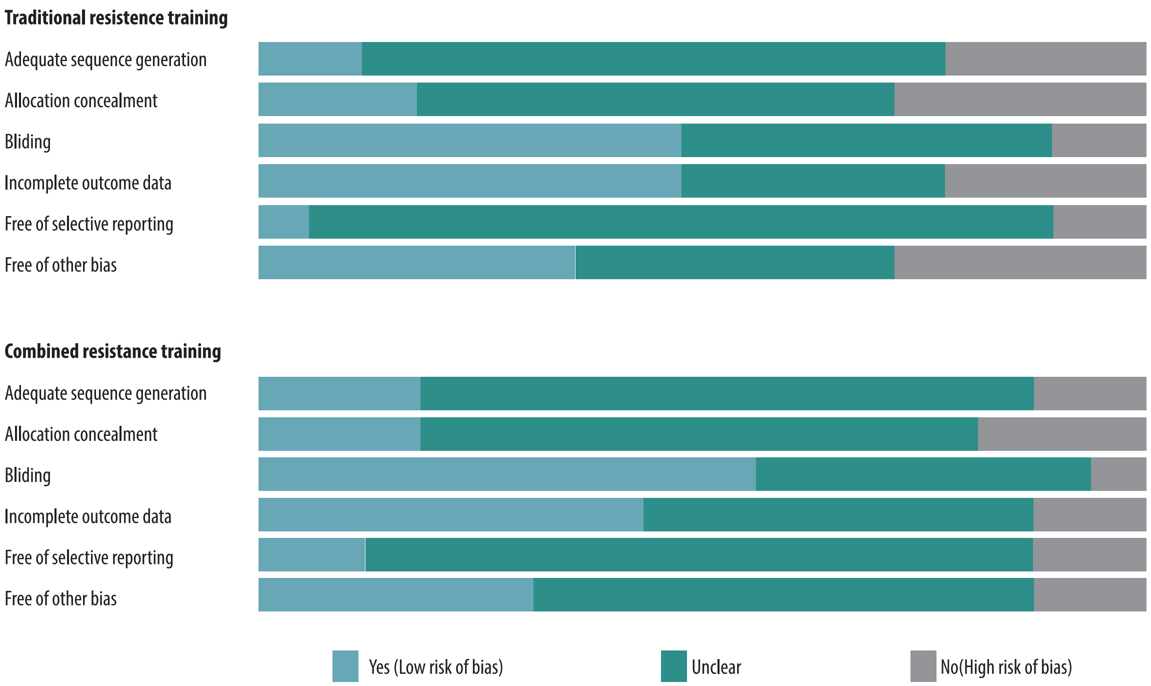

Figure 2. Analysis of the quality of articles involving TRT and CRT according to the Cochrane Critical Table of Bias Risk (percentage of the studies).

DISCUSSION

Analysis of the long-term effect of TRT on the variation of values equivalent to the BMI and of BF indicators revealed that 10 articles reported the variation in BF percentage, with a statistically significant reduction being observed in only 2 studies[16,29]. This variation in TRT studies may be explained by the fact that this training model does not permit aerobic exercise, which is a type of exercise that reduces the percentage of BF[18], indicating that aerobic training is significantly better than TRT for the reduction of fat mass[25].

Analysis of BMI equivalent values revealed that in seven of the 16 TRT studies [11,13,14,16,17,25,35] the BMI did not change and in five[12,18,19,28,29] it increased. This behavior may be explained by the fact that TRT induces significant strength gains associated with muscle hypertrophy, which increase fat-free mass[18]. This has been reported to cause stability or even an increase in BMI values even though most studies were conducted on adults.

Eleven of the 17 studies were conducted on samples of 30 subjects or less[11-13,16-19,25,26,28,37], a fact that may have generated imprecise estimates, explaining the absence of statistically significant results.

Analysis of the results according to sex revealed that BMI equivalent values and BF indicators were analyzed without sex distinction in 8 of the 17 studies, while 5 studies were conducted only on men and 4 only on women, a fact representing a limiting factor for data analysis according to this variable.

The absence of a control group in 7 studies[14,16,18,24,27-29] also impaired the analysis of their results by preventing comparison to the results of the experimental groups. Most of the studies were conducted on adults aged on average more than 30 years and only two studies included young subjects[26,37].

Other factors that should be taken into consideration were the training variables, which were diversified in the composition of the TRT studies. In addition to diversification, some studies such as that conducted by Banz *et al.*[16], which obtained the best results for BF percentage, that conducted by Willis *et al.*[24] and Misra *et al.*[28], which obtained a significant reduction in the sum of skinfold thicknesses, and that conducted by Schimitz *et al.*[29] did not mention the load proportion, the interval between exercises or the speed of movement execution, i.e., they did not mention three of the six training variables, a fact that also impaired the analysis of the results obtained.

The analysis of the long-term action of CRT on the variation of BMI equivalent values and BF indicators demonstrated that a variation in BF percentage was observed in 11 studies, with a significant reduction of BF percentage in all studies. This result obtained in CRT studies compared to TRT studies may be explained by the higher EPOC induced by the CRT model, which increased the basal metabolic rate over a longer period of time[8].

In 8 of the 12 CRT studies that analyzed the BMI, this parameter was reduced[13,15,19,21,22,25,34,36], in three[12,20,32] it increased, and in one[23] it did not change. These results may be explained by the low load intensity (50 to 60%) applied in most studies, which would not have induced more marked changes in muscle mass, resulting in a reduction or a small variation of BMI. In addition, CRT includes aerobic exercises that reduce fat mass[18].

In 11 of the 16 CRT studies, the sample size was 30 subjects or less[12,13,19,20,23,25,30,32-34,36], a fact that may have led to imprecise estimates even though these studies reported significant results.

Analysis of the results according to sex revealed that BMI equivalent values and BF indicators were analyzed without sex distinction in 8 of the 17 studies, while 5 studies were conducted only on men and 4 only on women, a fact representing a limiting factor for data analysis according to this variable.

In contrast to TRT, only two CRT studies[23,24] did not use a control group, with the quality of analysis of the latter studies being more refined by permitting comparison with the experimental group. Most of the TRT and CRT studies were conducted on adults aged on average more than 30 years, with only three studies[30,32,34] using young subjects.

The training variables were also diversified in CRT studies. Two of them (Balducci *et al.*[21] and Willis *et al.*[24]) did not mention the load proportion, the interval between exercises or the speed of movement execution and 9 additional studies did not mention the interval between exercises, an important variable in CRT since some variables need to be adjusted in CRT in order to obtain a high EPOC when the objective is to obtain changes in body composition by means of resistance training. The training model should involve resistance and combined exercises with the use of the "circuit training" method[38], with a faster execution of the exercises, a short interval for recovery between series[39] and with a high load proportion[40].

CONCLUSION

Considering the long-term effect, CRT apparently induced greater changes in BF percentage compared to TRT. A larger number of CRT studies obtained better results in terms of a change in BMI and in BF percentage than did TRT studies.

Age did not appear to interfere with the results since the variation in mean age range of the subjects studied was discrete and similar in the TRT and CRT studies. However, the low methodological quality of the studies, with few of them showing a low bias risk and most of them involving no control groups, does not permit us to state that the changes observed could be effective in view of the possible biases interfering with the outcomes reported.

Further studies are needed in order to determine how the resistance training variables should be applied. The determination of the load proportion used (mentioned in half the studies analyzed), the interval between the repetitions of each exercise (mentioned in less than half of the studies analyzed), the speed of execution of the exercises (mentioned in only 2 of the 28 studies analyzed), the number of exercises, of series and of repetitions, and the training model used are items to be considered in an attempt to render resistance training more effective in the variation of BF indicators. In addition, the methodology used in the study should take into consideration the norms of application of clinical studies, especially the inclusion of a control group.

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