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Effects of Simple Resistance Training on Body Composition of Female

—A Meta-Analysis

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Abstract

Resistance training (RT) is considered to be a way to increase muscle mass and loss fat. This study analyzed the effects of simple RT on female fat mass (FM), body fat percentage (BF%), fat-free mass (FFM) and muscle mass (MM), in order to clarify whether the role of simple RT is also applicable to female subjects in losing fat and increasing muscle mass. Method: The PubMed and Web of Science databases were searched, and the time was up to March 14, 2019. Two authors simultaneously screened articles, and twenty-three randomized controlled trials, with a total of 917 participants (483 in the resistance training group (RTG) and 434 in the control group (CG)) were included and their quality assessed. The Cochrane bias risk assessment tool was used to evaluate the quality of the documents, and the Reviewer Manager 5.3 software performs statistical processing on the data. Results: RT significantly reduced females' FM (WMD: 1.17; 95% CI: 1.03, 1.30; P < 0.00001) and BF% (WMD: 0.54; 95% CI: 0.09, 0.98; P = 0.02). It also significantly increased their FFM at the same time (WMD: −0.81; 95% CI: −0.93, −0.69; P < 0.00001). But there was no statistically significant increase in their MM (WMD: −0.20; 95% CI: −0.59, 0.19; P = 0.32). Conclusion: The results of this study confirm that RT can effectively reduce females' FM and BF%, and increase their FFM significantly. But it does not help MM growth for all females. Therefore, RT cannot be used as a training method for females to increase MM as the main purpose. However, it can be recommended for females as a means of developing body composition, including reducing their FM and increasing FFM.

Keywords

Resistance Training, Female, Body Composition, Meta-Analysis

单纯抗阻力训练对女性身体成分的干预效果

——Meta分析

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摘　要

抗阻力训练(RT)被认为是增肌减脂的运动方式，本研究通过分析单纯的RT对女性体脂量(FM)、体脂率(BF%)、去脂体重(FFM)和肌肉量(MM)的影响，以明确单纯RT的减脂增肌作用是否对女性受试者也适用。方法：搜索了PubMed和Web of Science数据库，时间结点至2019年3月14日。由两名作者同时进行文献筛选，纳入符合条件的23项研究，涉及917名女性受试者，包括单纯的抗阻力训练组(RTG) 483名和对照组(CG) 434名。运用Cochrane偏倚风险评估工具进行文献质量评价，Reviewer Manager 5.3软件对数据进行统计学处理。结果：RT能显著性降低女性的FM (WMD: 1.17; 95% CI: 1.03, 1.30; P < 0.00001)和BF% (WMD: 0.54; 95% CI: 0.09, 0.98; P = 0.02)；同时也能明显增加女性的FFM (WMD: −0.81; 95% CI: −0.93, −0.69; P < 0.00001)，但对女性MM的增长无明显作用(WMD: −0.20; 95% CI: −0.59, 0.19; P = 0.32)。结论：RT的确可以有效降低女性的FM和BF%、明显增加她们的FFM，但RT对女性的MM增长并无帮助。因此，RT不能作为女性以增长MM为主要目的的训练方式，但可以推荐给部分女性作为改善身体成分(包括减脂和增加FFM)的训练手段。

关键词

抗阻力训练，女性，身体成分，Meta分析

1. 引言

RT 是指身体克服阻力以达到肌肉增长和力量增加的过程[1]，它是全面身体锻炼不可缺少的一部分，长期以来被作为增长肌肉力量、体积、耐力和维持去脂体重的有效办法[2]。研究发现，RT 能延缓肌肉老化，改善速度、平衡性、协调性、弹跳力、柔韧性及其他运动方面的素质，提高基础代谢率、促进能量消耗和减少身体脂肪堆积，从而有效地预防和减少随年龄增长而容易出现的摔倒和骨折等现象[3] [4]。与此同时，RT 对慢性病患儿如囊性纤维化、脑瘫、肌肉萎缩症，白血病和肥胖症等许多临床病症也有健康益处[5]。

通过查阅文献发现，目前运动干预女性身体成分的研究中，更多采用的是有氧运动或综合干预方式。现有的 meta 分析文献中，较多的是分析有氧训练、振动训练结合 RT [6]、或是 RT 结合肌酸、牛奶等作为补充剂[7] [8]的综合干预方式。已有的 RT 对人体身体成分影响的 meta 分析中，研究对象较多是疾病患者，如：II 型糖尿病患者[9]、慢性阻塞性肺疾病患者[10]或乳腺癌患者[11]等，再或是单独的青少年儿童[12]、老年人[13]或绝经后女性[14]等人群。另外，在结果指标选取上，多为肌肉力量[15]、体重、体脂肪量、体脂率、去脂体重、肌肉量、或骨密度[16]等指标中的一个或两个指标进行的分析。因此，本研究采用 meta 分析法[17]聚焦于运动干预对女性身体成分的影响，将运动干预手段确定为单纯的 RT，以排除其他干预方式的影响；将研究的对象确定为排除其他疾病(超重或肥胖除外)的所有女性，以扩大样本数量；

又同时选取了体脂肪量(FM)、体脂率(BF%)、去脂体重(FFM)和肌肉量(MM)四个结局指标，以更全面的反映身体成分，研究的目的在于明确 RT 的减脂增肌作用是否对女性适用，以帮助有不同锻炼需求的女性能找寻到更适合自身的锻炼方式。

2. 方法

2.1. 检索策略

以关键词在 PubMed 和 Web of science 两大数据库进行检索，时间结点至 2019 年 3 月 14 日。检索公式为：1) PubMed：((“resistance training”[Title/Abstract] OR“resistance exercise”[Title/Abstract]) AND (“body composition”[Title/Abstract] OR“BMI”[Title/Abstract] OR“body fat percentage”[Title/Abstract] OR“muscle mass”[Title/Abstract] OR“muscle strength”[Title/Abstract]))；2) Web of science：TI = ((“resistance training” OR“resistance exercise”) AND (“body composition”OR“BMI”OR“body fat percentage”OR“muscle mass” OR “muscle strength”))。

2.2. 文献纳入与排除标准

文献纳入标准包括：1) 研究对象仅为女性。2) 实验组为 RT 干预，对照组不进行任何干预。3) 实验的结果指标包含 FM、BF%、FFM、MM 中之一，且数据表现形式为 Mean ± SD 或 Mean ± SE。4) 纳入文献的实验设计为随机对照试验。

文献排除标准包括：1) 重复发表。2) 干预方式与 RT 无关。3) 对照组有干预(如摄入补充剂、运动或饮食不同)。4) 无所需结果指标及其数据。5) 非随机对照试验 RCT (如前后对照试验、文献综述或 meta 分析、个案研究及动物实验等)。6) 研究对象有其余疾病(除超重或肥胖外)。

2.3. 信息提取

两名研究人员从纳入文献中提取信息，包括研究设计、受试者人口统计学(样本量、年龄和特征)、身体成分指标(FM、BF%、FFM 和 MM)及其数据(Mean ± SD 或 Mean ± SE)和 RT 的干预信息(运动总时间、频率、组数、重复次数和负荷)。

2.4. 文献质量评估数据处理

采用 Cochrane 偏倚风险评估工具[17]作为质量评估工具，包括 7 个项目：1) 随机序列的产生(选择偏倚)、2) 分配隐藏(选择偏倚)、3) 参与人员和试验人员的施盲(执行偏倚)、4) 效应指标盲检(观察偏倚)、5) 试验结果数据的完整性(失访偏倚)、6) 试验结果的选择性报告(报告偏倚)、7) 其他偏倚。以随机序列的产生为例，评估标准在 Cochrane 手册中有详细描述。以评估试验研究对随机序列是否存在产生“低风险偏移(Low risk of bias)”或“高风险偏移(High risk of bias)”或“不确定风险偏移(Unclear risk of bias)”。如果文献描述了合理的随机序列产生方法，诸如“参考随机数字表格”，“应用计算机随机数字生成器”，“投掷硬币”，“洗牌或信封”，“投掷骰子”，“抽签”或“最小化”，则该项目被评为“Low risk of bias”；如果文献中描述的随机序列的产生方法具有非随机因素，例如“以奇数甚至生产日期随机序列”，“直接以参与者喜好进行分配”，或“直接以干预措施的有效性进行分配”，则该项目评估为“High risk of bias”；如果它没有提供足够的信息来评估“Low risk of bias”或“High risk of bias”，则评估该项目为“Unclear risk of bias”。质量评估仅用于衡量科学证据的强度，但并不用于确定文献的纳入或排除。

2.5. 数据处理

根据 Cochrane 偏倚风险评估工具[17]提供的公式：

1) $SE = \frac{SD}{\sqrt{n}}$；

2) Mean 差值 = Meanfinal − Meanbaseline；

3) $SD差值 = \sqrt{SD_{baseline}^2 + SD_{final}^2 - 2*R*SD_{baseline}*SD_{final}}$ (若未报告相关值则默认 R 取 0.5)，计算得出每个结果变量干预前后净变化差值的平均数和标准差作为主要效应量参数。运用 Reviewer Manager 5.3 对纳入文献进行 meta 分析。当 $I2 < 50\%$，$P > 0.10$，可认为同质，选用固定效应模型；当 $I2 \geq 50\%$，$P < 0.10$，可认为异质，选择随机效应模型。如果 $P < 0.10$ 且无法判断异质性的来源，则对结果指标采用描述性分析。由于本研究数据为连续型数据，为防止研究者预估之外的偏倚与异质性出现，采用随机效应模型计算文献间加权均数差 WMD (Weight Mean Difference)、Z 值和 95%可信区间 CI 值表示合并效应值。另外，用 Reviewer Manager 绘制森林图时，系统默认的研究事件为“不利因素”，其横坐标左侧为干预，右侧为对照。但本研究为 RT，属于“有利因素”，故将横坐标左侧设为 CG，右侧为 RTG。$P < 0.05$ 表示有显著性差异，$P < 0.01$ 表示有非常显著性差异。

3. 研究结果

3.1. 文献筛选和纳入文献信息

图 1 显示了文献筛选的流程。在通过关键词搜索数据库后共获得文献 1064 篇，去除重复的 60 篇文献，再通过阅读标题及摘要后排除 935 篇文献。排除的主要原因包括：不是随机对照试验；CG 也有干预；研究对象含有男性或是有疾病(除超重或肥胖外)等。对剩余 69 篇文章的全文进行了审核，有 46 篇因不符合研究纳入标准而被排除在外，排除的主要原因是无所需结果指标数据。最终 23 篇文献被纳入进行评价分析(基本信息见表 1)：被试者年龄上范围跨度较大，最低至 12 岁，最高至 77 岁；在样本量上文献的实验组/对照组人数也较为平均；在结果指标的纳入上较多文献有 FM、BF%、FFM、MM 的四个指标中其中 2~3 个，只有少量文献只有其中一个。所有文献均说明了 RT 的具体负荷构成，即干预总时间、频率、组数、重复次数，除有四篇文献未提及 RT 的强度外，其余文献均有说明(见表 2)，负荷且均符合 ACSM 推荐的运动方案：全身主要肌群的参与、每周 2~3 次、每次至少 1 组、每组 8~10 次的重复 RT、中老年和身体虚弱者采用 10~15 次重复[18]。

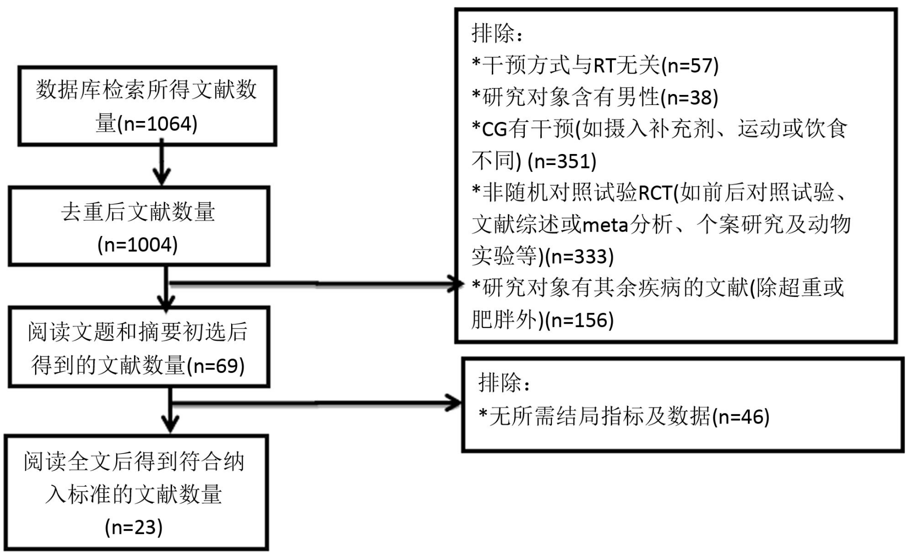


Figure 1. Flow chart of articles screening (n = number of articles)
图 1. 文献筛选流程图(n = 文献数量)

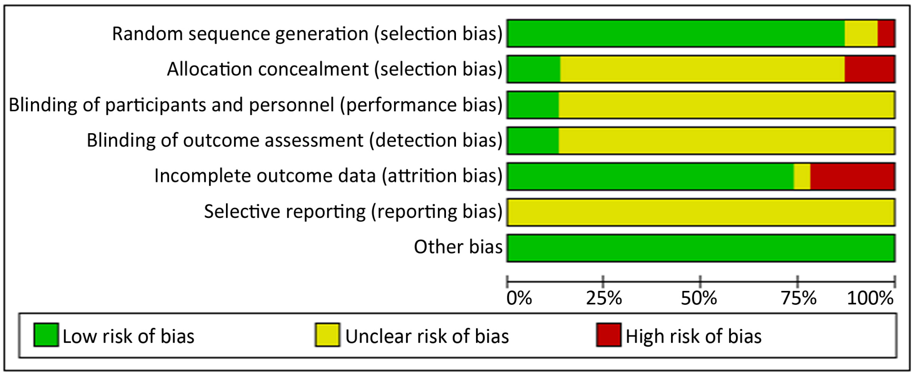


Figure 2. Evaluation results of bias risks of articles
图 2. 文献偏倚风险的评估结果

纳入的 23 篇文献的质量评价结果如图 2 所示：86.95%的 RCT 的随机序列的产生评价为“低风险偏倚(Low risk of bias)”，8.7%的评价为“不确定风险偏移(Unclear risk of bias)”，4.35%的评价为“高风险偏移(High risk of bias)”；13.04%的分配隐藏评价为“低风险偏倚(Low risk of bias)”，73.92%的评价为“不确定风险偏移(Unclear risk of bias)”，13.04%的评价为“高风险偏移(High risk of bias)”；13.04%的 RCT 的参与人员和试验人员的施盲的评价为“低风险偏倚(Low risk of bias)”，86.96%的评价为“不确定风险偏移(Unclear risk of bias)”;13.04%的 RCT 效应指标盲检评估的评价为“低风险偏倚(Low risk of bias)”，86.96%的评价为“不确定风险偏移(Unclear risk of bias)”；73.91%的 RCT 的试验结果数据的完整性评价为“低风险偏倚(Low risk of bias)”，4.35%的评价为“不确定风险偏移(Unclear risk of bias)”，21.74%的评价为“高风险偏移(High risk of bias)”；试验结果的选择性报告全部评价为“不确定风险偏移(Unclear risk of bias)”；其他偏倚全部评价为“低风险偏倚(Low risk of bias)”。纳入分析的文献存在一定的偏倚性，但文献总体质量处于中等偏上。除 Cunha, P. M.等[22]、Liao, C. D.等[28]和 Rustaden, A. M.等[37]三篇文献明确写到有使用双盲以外，其余文献在参与人员和试验人员的施盲评估上大部分未提及盲法的使用情况，这可能因为 RT 不易进行盲法，因此均在该项给出“不确定风险偏移(Unclear risk of bias)”。

Table 1. Basic information of included research articles
表 1. 纳入研究文献基本信息

序号	文献来源	被试年龄(岁)	样本量 RTG/CG	结果指标(为 mean ± SD/SE)
1	Bonganha, V.等 2012 [19]	RTG: 58 ± 4.6 CG: 53 ± 6.3	16/16	FM
2	Colado, J. C.等 2012 [20]	RTG: 53.9 ± 1.87 CG: 54.14 ± 2.89	21/10	FM/FFM
3	Colado, J. C.等 2008 [21]	51~57	21/10	FF/FFM
4	Cunha, P. M.等 2018 [22]	68.0 ± 4.3	20/21	BF%/MM
5	Fjeldstad, C.等 2009 [23]	60~75	22/12	FM /BF%
6	Franklin, N. C.等 2015 [24]	18~40	10/8	BF%
7	Kerksick, C. M.等 2010 [25]	38.7 ± 8.0	5/9	FM/FFM
8	Klimentidis, Y. C.等 2015 [26]	30~65	84/64	FM/BF%/FFM
9	Lee, S. J.等 2013 [27]	12~18	14/8	FM/MM/BF%
10	Liao, C. D.等 2017 [28]	60~80	25/21	FM/FFM/BF%
11	Nichols, D. L.等 2001 [29]	14~17	5/11	FM/BF%

Continued

12	Olson, T. P.等 2006 [30]	24~44	15/15	FM/FFM/BF%
13	MELODY D. PHILLIPS 等 2012 [31]	60~70	11/12	FM/FFM/BF%
14	Poehlman, E. T.等 2002 [32]	18~35	16/19	FM/FFM
15	Poehlman, E. T.等 2000 [33]	18~35	17/20	FM/FFM
16	Prabhakaran, B.等 1999 [34]	27 ± 7	12/12	BF%
17	Rana, S. R.等 2008 [35]	21.1 ± 2.7	10/8	FM/FFM/BF%
18	Raso, V.等 2007 [36]	60~77	21/21	FFM/BF%
19	Rustaden, A. M.等 2017 [37]	18~65	25/21	BF%/FM/MM
20	Socha, M.等 2016 [38]	62.5 ± 5.8	13/19	BF%
21	Teixeira, P. J.等 2003 [39]	40~66	59/55	BF%/FFM/FM
22	Tomeleri, C. M.等 2016 [40]	68.2 ± 4.2	19/19	BF%/MM
23	Verschueren, S. M.等 2004 [41]	60~70	22/23	MM/FM

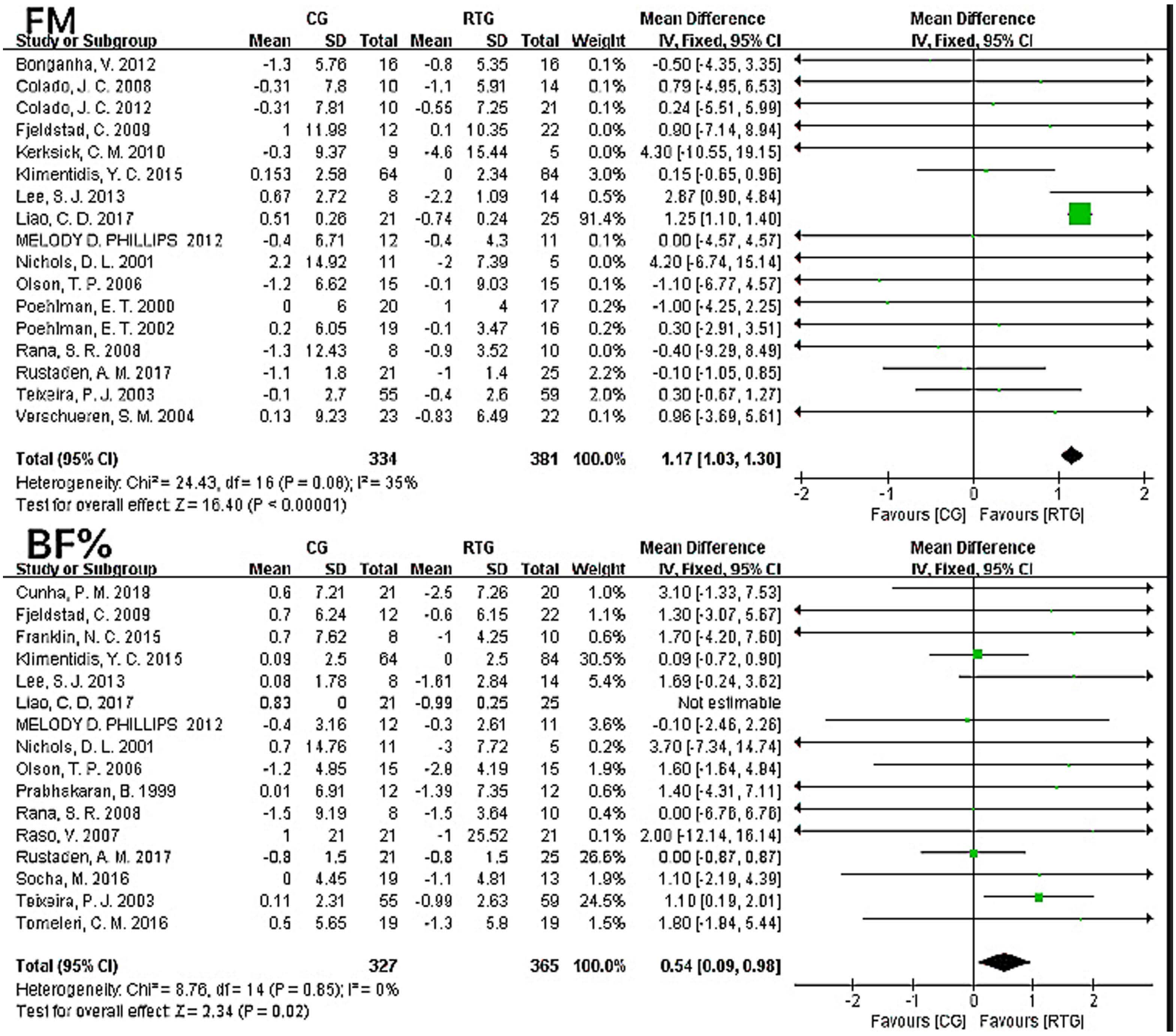
注：RTG，抗阻训练组；CG，对照组；Y，是；N，否；B，同时都有；FM，体脂量；BF%，体脂百分比；FFM，去脂体重；MM，肌肉量。

Table 2. Total time, frequency, number of sets, repetitions and intensity of exercise intervention
表 2. 运动干预总时间、频率、组数、重复次数及强度

文献序号	干预时长(周)	频率(次/周)	组数(组)	重复次数(次)	强度(RM)
1	16	3	(3 + 3)	1	70%~80% 1-RM
2	10	2	(2 + 1)~(2 + 2)~(3 + 3)	1	
3	10	2	(2 + 1)~(2 + 2)~(3 + 3)	1	20 RM
4	12	3	3	10~15	10~15 RM
5	32	3	3	10	80% 1-RM
6	8	2	4~6	10	80%~90% 10 RM
7	14	3	3	1	80% 1 RM
8	48	3	2	6~8	70%~80% 1 RM
9	12	3	2	8~12	60% 1 RM
10	12	3	3	10	
11	60	3	1~3	9~14	10 RM
12	48	2	3	8~10	
13	12	3	3	10	8 RM
14	24	3	1	10	60%~80% 1 RM
15	24	3	3	10	80% 1 RM
16	14	3	2	8~12	85% 1 RM
17	6	2~3	3	6~10	6~10 RM
18	48	3	3	10	60% of 1 RM
19	12	3	2~4	3~15	40%~75%~85% 1 RM
20	8	2	2	25	
21	48	3	2	6~8	70%~80% 1 RM
22	8	3	3	10~15	10~15 RM
23	24	3	1~3	8~20	8~20 RM

3.2. Meta 分析结果

RT 影响所有纳入文献中的女性身体成分的 Meta 分析结果见图 3。有 17 篇文献报告了 RT 对女性 FM 影响的结果，共涉及 715 名参与者(RTG 381 名和 CG 334 名)；异质性检验结果 Chi2 = 24.43，df = 1.6 (P = 0.08)，I2 = 35%，文献间不存在异质性；RTG 的女性 FM 明显低于 CG 女性的 FM (WMD：1.17；95%CI：1.03，1.30；总效应值 Z = 16.40；P < 0.00001)。共有 16 篇文献报告了 RT 对女性 BF%影响的结果，共涉及 682 名参与者(RTG 365 名和 CG 327 名)；异质性检验结果 Chi2 = 8.76，df = 14 (P = 0.85)，I2 = 0%，文献间不存在异质性；与 CG 相比，RTG 女性的 BF%显著性低于 CG (WMD：0.54；95%CI：0.09，0.98；总效应值 Z = 2.34；P = 0.02)。共有 12 篇报告了 RT 对女性 FFM 影响的结果，涉及 536 名参与者(RTG282 名和 CG254 名)；异质性检验结果 Chi2 = 8.99，df = 11 (P = 0.62)，I2 = 0% ，文献间不存在异质性；与 CG 相比，RT 能非常明显地增加女性的 FFM (WMD：−0.81；95%CI：−0.93，−0.69；总效应值 Z = 13.44；P < 0.00001)。仅有 5 篇文献报告了 RT 对女性 MM 的影响，共涉及 192 名参与者(RTG100 名和 CG92 名)；异质性检验结果 Chi2 = 2.69，df = 4 (P = 0.61)，I2 = 0%，文献间不存在异质性；与 CG 相比，RT 对增加女性的 MM 无显著性差异(WMD：−0.20；95%CI：−0.59，0.19；总效应值 Z = 0.99；P = 0.32)。



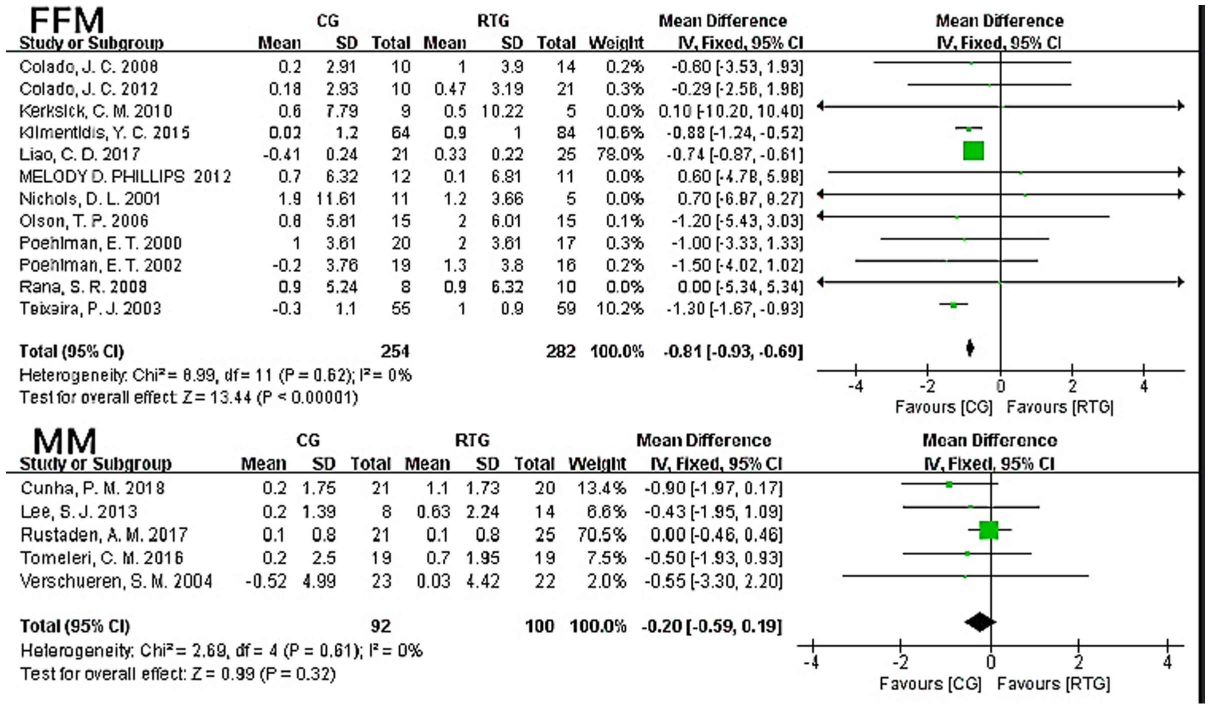


Figure 3. Forest graph of the effect of RT on the FM, BF%, FFM and MM of female
图 3. RT 对女性 FM、BF%、FFM、MM 影响的森林图

4. 讨论与分析

本研究电子检索了 PubMed 和 Web of science 两大数据库，搜索到相关文献共 1157 篇，而最终纳入 Meta 分析的文章仅 23 篇，约占搜索总文献的 1.98%。剔除的文献将从实验设计、结局指标及研究对象等方面进行分析。在实验设计上，CG 有干预的占比约 30.33%，搜索到较多文献中其 CG 有摄入亮氨酸、肌酸或使用苹果、牛奶蛋白等作为补充剂；或是 CG 也有运动或饮食上与 RTG 有不同的干预。因此目前单独研究抗阻力训练对身体成分的影响且要求对照组为无干预的文献较少。在阅读了 162 篇全文的基础上，剔除了约 28.4%无相关结局指标数据的文献。由于本次分析的纳入及排除标准较多且严苛，为了避免纳入文献过少，则对结局指标的选择上有 FM、BF%、FFM 或 MM 之一即可。在研究对象上，本文只选取了女性被试者，并扩大了年龄范围以研究 RT 对所有年龄段女性的增肌减脂作用。另也剔除了患有其它疾病(除肥胖外)约 13.49%的文献，这是为了避免除肥胖以外的其余疾病，如：糖尿病、高血脂、冠心病等对 meta 分析结果产生影响。

本研究发现，RT 对降低女性的 FM 和 BF%有明显的效果。FM 是体重的组成部分，主要是反映人体内脂肪含量的多少，是判定肥胖最重要的指标之一[42]；BF%是指脂肪重量在人体总体重中所占的比例，它排除了肌肉、骨骼发达，浮肿等情况造成的体重超出正常值的现象[43]。本研究结果与大多数 RT 对照试验研究结果一致，都表明 RT 对降低受试者 BF%效果显著，如：Willis, L. H.等[44]对 44 名久坐肥胖成年人进行了为期 8 个月的 RT (3 天/周，3 组/天，8~12 次重复/组)，结果显示 RT 前后 BF%有显著性差异；Straight, C. R.等[45]也对超重和肥胖的 95 名老年人执行了为期 8 周的 RT (2 天/周，3 组/天，8~12 次重复/组)，结果显示 RT 后受试者的 BF%显著性降低。Padilha, C. S.等[46]对 14 篇关于 RT 影响癌症患者的 FFM 和 FM 的文献进行了 Meta 分析，发现 RT 对于接受术前和术后治疗的癌症患者的 FFM 增加和 FM 降低均有效；Collins, H.等[47]的 meta 分析发现 RT 对降低 8~16 岁青少年的 BF%有显著性影响。

RT 也能明显增加女性的 FFM，但对其 MM 的增加效果不明显。FFM 指除脂肪以外的身体其他成分的重量，骨骼、肌肉是其主要部分[48]；MM 为骨骼肌的质量[49]。本研究结果发现 RT 无助于女性 MM 的提升，那么 FFM 的增加更可能出现在骨骼质量的增加上，已有研究发现 RT 有助于保持妇女腰椎的骨矿密度，保持和增加绝经后妇女股骨和桡骨的骨矿密度[16]。因本研究中纳入关于 FFM 的文献中，绝经后女性对象就有 6 篇(占该指标文献总数的 50%)，因此本研究中 RTG 的女性 FFM 增加很可能是绝经后女性骨量增加的结果。有单个研究证实，9 周高负荷 RT 后，女性肌肉增长量低于男性[50]，说明 RT 增长肌肉的效果还存在性别差异；另外在本研究的被纳入文献中，有 MM 结果指标的文献仅有 5 篇，涉及的参与者也只有 192 名，样本量的不足也可能会降低结果的精确性[51]；鉴于 50 岁以后久坐不动的个体骨骼肌萎缩的发生率过高，相比青年人，运动锻炼更不易使其 MM 明显增加[13]，而本研究中纳入的关于绝经后女性对象 MM 的文献共 3 篇(占该指标文献总数的 75%)。因此，年龄、性别和样本量大小等因素，都可能是 RT 不能有效提升女性 MM 的原因。另有研究显示，RT 的机制似乎可以在不增加 MM 的情况下提高肌肉力量[52]。而大多数研究结果证明，RT 对增加 FFM 和肌肉力量有显著性效果[6] [7] [8] [9] [53]，但并未提到其增加 MM 的作用，也许 RT 的“增肌”效果更多是指肌肉力量而非 MM 的增加。

本研究的局限性在于：纳入文献中提到研究对象在进行 RT 干预时均不改变其饮食习惯，因此饮食的不统一性可能会导致研究分析结果有一定的误差；另外在运动干预的总时间上为 6~60 周不等，干预的频率，强度等也有一定的差异，所以各项结果指标也会因训练时间的不同而出现效果上的差异。

5. 结论

本研究结果证实单纯的 RT 可以有效降低女性的 FM 和 BF%、明显增加她们的 FFM，但 RT 不能促使女性 MM 的增长。因此，单纯的 RT 不能作为女性以增长 MM 为主要目的的训练方式。

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