Supplementary table S1. Database search formulas

Data base	Search terms for query
Pubmed	
#1	Rheumatoid arthritis
#2	(((exercise training) OR progressive resistance training) OR strength training) OR physical activity
#3	(((((skeletal muscle mass) OR lean body mass) OR fat free mass) OR appendicular lean mass) OR body composition)
#4	((((muscle morphology) OR muscle architecture) OR muscle ((thickness) OR cross section area) OR muscle CSA) OR muscle hypertrophy)
#5	(#3) OR #4
#6	(Randomized controlled trial) OR Randomization
#7	#1 AND #2 AND #5 AND #6
Physiotherapy Evidence Database (PEDro)	
	Method: clinical trial
	Abstract & Title:
#1	rheumatoid arthritis
#2	exercise training
#3	resistance training
#4	strength training
#5	physical activity
#6	lean body mass
#7	fat free mass
#8	skeletal muscle mass
#8	appendicular lean mass
#9	body composition
#10	muscle thickness
#11	muscle cross-sectional area
#12	muscle architecture
#13	muscle morphology
#14	muscle hypertrophy

(continued)

Supplementary table S1. (continued)

Data base	Search terms for query
Excerpta Medica dataBASE (EMBASE)	
#1	rheumatoid arthritis
#2	exercise training
#3	resistance training
#4	strength training
#5	physical activity
#6	lean body mass
#7	fat free mass
#8	skeletal muscle mass
#9	muscle cross sectional area
#10	muscle thickness
#11	muscle hypertrophy
#12	muscle morphology
#13	muscle architecture
#14	body composition
#15	#2 OR #3 OR #4 OR #5
#16	#6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14
#17	#1 AND #15 AND #16 AND ([systematic review]/lim OR [meta analysis]/lim OR [randomized controlled trial]/lim) AND [humans]/lim
Cochrane Library Database	
#1	rheumatoid arthritis
#2	exercise training
#3	resistance training
#4	strength training
#5	physical activity
#6	lean body mass
#7	fat free mass
#8	muscle cross sectional area
#9	muscle thickness
#10	muscle hypertrophy
#11	body composition
#12	#2 OR #3 OR #4 OR #5
#13	#6 OR #7 OR #8 OR #9 OR #10 OR #11
#14	randomized controlled trial
#15	#1 AND #12 AND #13 AND #14

(continued)

Supplementary table S1. (continued)

Data base	Search terms for query
China knowledge resource integrated database	
#1	rheumatoid arthritis
#2	(((exercise training) OR progressive resistance training) OR strength training) OR physical activity
#3	(((((skeletal muscle mass) OR lean body mass) OR fat free mass) OR appendicular lean mass) OR body composition)
#4	((((muscle morphology) OR muscle architecture) OR muscle ((thickness) OR cross section area) OR muscle CSA) OR muscle hypertrophy)
#5	randomized controlled trial
#6	#1 AND #2 AND #3 AND #4 AND #5
Google Scholar	
#1	allintitle: rheumatoid arthritis
#2	allintitle: “exercise training” OR “resistance training” OR “strengthening exercise” OR “physical activity”
#3	allintitle: “skeletal muscle mass” OR “lean body mass” OR “fat free mass” OR “appendicular lean mass” OR “body composition”
#4	allintitle: “muscle morphology” OR “muscle cross sectional area” OR “muscle thickness” OR “muscle hypertrophy”
#5	allintitle: randomized controlled trial

Supplementary table S2. Summary of exercise training protocols in the included studies

Study	Experimental group								Control group
	Flexibility/ROM/ stretching exercises	Muscle strengthening (progressive RET)				Training time (min/session)	Frequency (session/w)	Intervention duration (wk)	
		Training part	Resistance set	Intensity	Training volume				
Häkkinen 1994	None	Upper and lower extremity, and trunk (9 different exercises).	Individually designed; Elastic (rubber) bands	40%–80% 1RM	3 sets of 10–30 repetitions	30	2–3	6	Maintained habitual physical activities which are not related to strength training (walking, biking, and swimming; 3–4 session/week, 50–60 min/session).
Lemmey 2009; 2012	10-min warm up and 10-min cooling down (low-intensity ROM exercises)	Upper and lower extremity	Multi-stack machine exercises: leg press, chest press, leg extension, seated rowing, leg curl, triceps extension, standing calf raises, and bicep curl.	60%–80% 1RM	1–3 sets of 8–15 repetitions (1–2 minutes of rest between sets)	60[a]	2	6	Maintained habitual physical activity levels and diet during the experimental period; home-based, low-intensity range of movement (ROM) exercise
Piva 2019	5-min warm up (stationary cycling; 1–2 bouts of 30-sec quadriceps stretching).	Lower extremity (targeted mainly the bilateral quadriceps muscles)	Respective machines: leg extension and leg press exercises.	40%–80% 1RM	1–3 sets of 8–15 repetitions (2-sec concentric load, 2-sec eccentric load, and 3-sec interval between each contraction); 1–2 minutes of rest between sets.	60[a]	2–3	16	NMES (frequency: 75 pulses/s; pulse duration: 450 ms; stimulus on/off time (1-min cycle) was 12-sec on (3-sec ramp up, 6-sec full contraction, 3-sec ramp down), and 48-sec off.
Prioreschi 2016	None	Lower limbs	Whole body vibration training (standing on a vertical synchronous vibration plate)	Vibration was set at 3 mm amplitude and a frequency of 30 Hz.	10 repetitions	15	2	12	Maintained normal daily activities during the experimental period
Rodrigues 2020	None	Lower limbs (Bilateral)	Leg press and knee extension exercises	50%–70% 1RM	4–5 sets of 10 repetitions (1-minute rest interval between each set)	NR	2	12	Maintained habitual daily living activities
	None	Lower limbs (Bilateral)	BFRT with an air cuff (leg press; knee extension exercises)	20%–30% 1RM	4–5 sets of 15 repetitions (1-minute rest interval between each set)	NR	2	12	Maintained habitual daily living activities
Sandstad 2015	Warm-up for 10 min (70 % of HR_{max})	Lower limbs	High intensity interval training	85–95 % of HR_{max}	4 sets: 4-minute interval of training period (85–90% HR_{max}); 3-min recovery period (70 % HR_{max}).	35	2	10	Maintained habitual daily living activities

Continued.

Supplementary table S2. Continued

Study	Experimental group							Control group
	Flexibility/ROM/stretching exercises	Muscle strengthening (progressive RET)				Training time (min/session)	Frequency (session/w)	Intervention duration (wk)	
		Training part	Resistance set	Intensity	Training volume				
Siqueira 2017	Warm up: 5-min walk (the plantar flexion of knees and hips was restricted to a maximum of 90 degrees); 15–30 min lower-limb exercises.	Lower extremity	Aquatic exercise (water-based aerobic training); the weight of the lower limbs was the training load. An adaptation period was provided to adapt to the environment (water or land) and learn the sequence and level of effort for the 11 movements as needed to provide body control in the use of the chair.	Borg CR-10: 5–8 (60%–85% 1RM)[a]	2–4 sets (each set comprised 11 series of 30 seconds)	30–60	3	16	Maintained habitual daily living activities
	Warm up: 5-min walk (the plantar flexion of knees and hips was restricted to a maximum of 90 degrees); 15–30 min lower-limb exercises.	Lower extremity	Land-based exercise; the weight of the lower limbs was the training load. An adaptation period was provided to adapt to the environment (water or land) and learn the sequence and level of effort for the 11 movements as needed to provide body control in the use of the chair.	Borg CR-10: 5–8 (60%–85% 1RM)[a]	2–4 sets (each set comprised 11 series of 30 seconds)	30–60	3	16	Maintained habitual daily living activities
Strasser 2011	Warm-up (10 min, stretching exercise)	Upper extremity (bench press, chest cross, shoulder press); trunk (pull downs, bicep curls); Lower extremity (leg press)	NR	70% 1RM	2–4 sets of 10–15 repetitions	NR	2	24	Maintained recreational physical activity; stretching exercises to maintain their joint mobility.
		Lower extremity	Cycle ergometer	Endurance training: 60% of VO_{2max} (75% of HR_{max})[a]	In combination with RET	15–80	2	24	

[a]Data is estimated.

1RM, one repetition maximum; BFRT, blood-flow restriction training; Borg CR-10, Borg's category ratio-scale (0 extremely easy to 10 extremely hard); HR_{max}, maximal heart rate; NMES, neuromuscular electrical stimulation; RET, resistance exercise training; ROM, range of motion; VO_{2max}, maximal oxygen consumption.

Supplementary table S3. Summary of methodological quality based on the PEDro classification scale*

Study author (year)	Overal†	Eligibility criteria‡	1	2	3	4	5	6	7	8	9	10
Häkkinen, 1994	5/10		*X*		*X*				*X*		*X*	*X*
Lemmey, 2009	5/10	*X*	*X*		*X*					*X*	*X*	*X*
Lemmey, 2012	4/10		*X*		*X*						*X*	*X*
Piva, 2019	8/10	*X*	*X*	*X*	*X*			*X*	*X*	*X*	*X*	*X*
Prioreschi, 2016	6/10	*X*	*X*		*X*			*X*		*X*	*X*	*X*
Rodrigues, 2020	7/10		*X*		*X*			*X*	*X*	*X*	*X*	*X*
Sandstad, 2015	6/10	*X*	*X*		*X*				*X*	*X*	*X*	*X*
Siqueira, 2017	8/10	*X*	*X*	*X*	*X*			*X*	*X*	*X*	*X*	*X*
Strasser, 2011	6/10	*X*	*X*		*X*				*X*	*X*	*X*	*X*
Summary§		6	9	2	9	0	0	4	6	7	9	9

*PEDro = Physiotherapy Evidence Database. Guidelines of the PEDro scale is available from the PEDro database (https://www.pedro.org.au/english/downloads/pedro-scale/).

†Points of methodological quality were "*X*" when a criterion was fulfilled. Methodological quality: high, ≥7/10; medium, 4–6/10 points; low, ≤3/10 points.

‡Not used to calculate the total score.

§This was calculated as the number of studies satisfied.

PEDro classification scale: 1 = random allocation, 2 = concealed allocation, 3 = similarity at the baseline, 4 = subject blinding, 5 = therapist blinding, 6 = assessor blinding, 7 = more than 85% follow-up for at least one key outcome, 8 = intention-to-treat analysis, 9 = between-group statistical comparison for at least one key outcome, 10 = point and variability measures for at least one key outcome.

Supplementary table S4. Summary of the results of subgroup analyses for muscle mass

Subgroups	Comparison, *n* (reference)	SMD(95% CI)	*P* value	I^2 (%)
Methodology quality				
High (PEDro score ≥7)	3 [18, 20, 22]	0.62 (−0.52, 1.76)‡	n.s.	92
Medium (PEDro score 4−6)	6 [16, 17, 19, 21, 39, 40]	0.88 (0.56, 1.19)†	<0.00001	0
Subgroup difference			n.s.	0
Control type				
Exercise	4 [19, 20, 39, 40]	0.54 (−0.16, 1.24)‡	n.s.	72
Regular care	5 [16-18, 21, 22]	0.95 (0.27, 1.63)‡	0.006	81
Subgroup difference			n.s.	0
Exercise type				
RET	6 [16, 18, 20, 22, 39, 40]	0.66 (0.06, 1.26)‡	0.03	77
Non-RET	5 [17-19, 21, 22]	0.87 (−0.08, 1.83)‡	n.s.	89
Subgroup difference			n.s.	0
Usage of steroid				
Use	6 [16-18, 21, 39, 40]	1.05 (0.55, 1.55)‡	<0.0001	60
No use	3 [19, 20, 22]	0.29 (−0.36, 0.93)‡	n.s.	75
Subgroup difference			n.s.	70.4

†Fixed-model effect

‡Random-model effect

SMD, standard mean difference; I^2, heterogeneity; n.s., statistically nonsignificant ($P > 0.05$); PEDro, Physiotherapy Evidence Database; RET, resistance exercise training.

Supplementary table S5. Summary of meta-regression analyses results

Covariate	Effect size of changes in muscle mass						
	Comparison (N)	Coefficient	(95% CI)	τ^2	R^2 (%)	I^2 (%)	*P* value
Age, years	12	−0.013	(−0.038, 0.012)	0.089	0	27.67	0.282
BMI, kg/m^2	11	−0.059	(−0.127, 0.007)	0.039	46.23	16.69	0.075
Sex rate (women, %)	12	−0.003	(−0.032, 0.026)	0.096	0	40.14	0.845
Disease duration, mo	12	−0.006	(−0.009, −0.003)	0.022	69.69	9.71	0.005
Intervention duration, mo	12	0.110	(−0.101, 0.321)	0.112	0	38.61	0.272
Follow-up duration, mo	12	0.007	(−0.197, 0.212)	0.118	0	34.61	0.938

BMI, body mass index.

Supplementary table S6. Summary of withdraw and adverse events in the included trials

Study author (year)	Exercise type	Training intensity	EG (events or patients/group sample)		CG (events or patients/group sample)	
			Related to exercise	Unrelated to exercise	Related to exercise	Unrelated to exercise
Withdraw (drop out)[a]						
RET						
Häkkinen, 1994	RET	40%-80% 1RM	N	X (2/21)	N	X (2/18)
Lemmey, 2009; 2012	RET	60%-80% 1RM	N	X (9/18)[c]	N	X (9/18)[c]
Piva, 2019	RET	40%-80% 1RM	X (1/28)	X (1/28)	X (6/31)	X (1/31)
Rodrigues, 2020	HI-RET	50%-70% 1RM	X (1/16)	N	N	X (1/16)
Siqueira, 2017	LB-ET	Borg CR-10: 5–8 (60%-85% 1RM)[b]	X (8/33)	X (1/33)	N	X (2/34)
Non-RET						
Prioreschi, 2016	WBV		N	X (5/20)[c]	N	X (7/19)[c]
Rodrigues, 2020	BFR, LI-RET	20%-30% 1RM	N	X (1/16)	N	X (1/16)
Sandstad, 2015	HIIT, 1st session	85–95 % of HR_{max}	N	X (3/9)[c]	N	X (2/9)[c]
	HIIT, 2nd session	85–95 % of HR_{max}	N	X (1/7)[c]	N	X (1/6)[c]
Siqueira, 2017	AQ-ET	Borg CR-10: 5–8 (60%-85% 1RM)[b]	X (6/33)	N	N	X (2/34)
Strasser, 2011	MET	70% 1RM for RET; 60% of VO2max (75% of HRmax)[b] for AET	N	X (5/20)	N	N (0/20)
Summary, No. of trials (No. of patient)			3 (16/110)	7 (29/172)	1 (6/31)	7 (24/165)
Adverse events[a]						
RET						
Häkkinen, 1994	RET	40%-80% 1RM	X (1/21)	X (6/21)	X (1/18)	X (5/18)
Lemmey, 2009; 2012	RET	60%-80% 1RM	N	N	N	N
Piva, 2019	RET	40%-80% 1RM	X (NR)	N	X (NR)	N
Siqueira, 2017	RET, LB-ET	Borg CR-10: 5–8 (60%-85% 1RM)[b]	X (8/33)	X (7/33)	X (21/34)	X (12/34)
Rodrigues, 2020	RET, HI-RET	50%-70% 1RM	X (1/16)	N	N	X (1/16)
Non-RET						
Prioreschi, 2016	WBV		NR	NR	NR	NR
Sandstad, 2015	HIIT, 1st session	85–95 % of HR_{max}	NR	NR	NR	NR
	HIIT, 2nd session	85–95 % of HR_{max}	NR	NR	NR	NR
Siqueira, 2017	AQ-ET	Borg CR-10: 5–8 (60%-85% 1RM)[b]	N	X (3/33)	X (21/34)	X (12/34)
Rodrigues, 2020	BFR, LI-RET	20%-30% 1RM	N	X (1/16)	N	X (1/16)
Strasser, 2011	MET	70% 1RM for RET; 60% of VO_{2max} (75% of HRmax)[b] for AET	NR	NR	NR	NR
Summary, No. of trials (No. of event)			4 (15/70)	3 (12/103)	3 (26/52)	3 (14/68)

[a]The occurrence of adverse events is denoted as "X" with the number of events. N = the trial reported no complication event; NA = data of the complications or adverse events were not available

[b]Data is estimated.

[c]The events did not occur during exercise periods.

1RM, one-repetition maximum; AET, aerobic exercise training; AQ-ET, aquatic exercise training; Borg CR-10, Borg's category ratio-scale (0 extremely easy to 10 extremely hard); CG, control group; EG, experimental group; HIIT, high-intensity interval training; HI-ET, high intensity exercise training; HR_{max}, maximal heart rate; LB-ET, land-based exercise training; LI-ET, low intensity exercise training; MET, multicomponent exercise training; NR, not reported; RET, resistance exercise training; VO_{2max}, maximal oxygen consumption; WBV, whole body vibration.

Supplementary figure S1

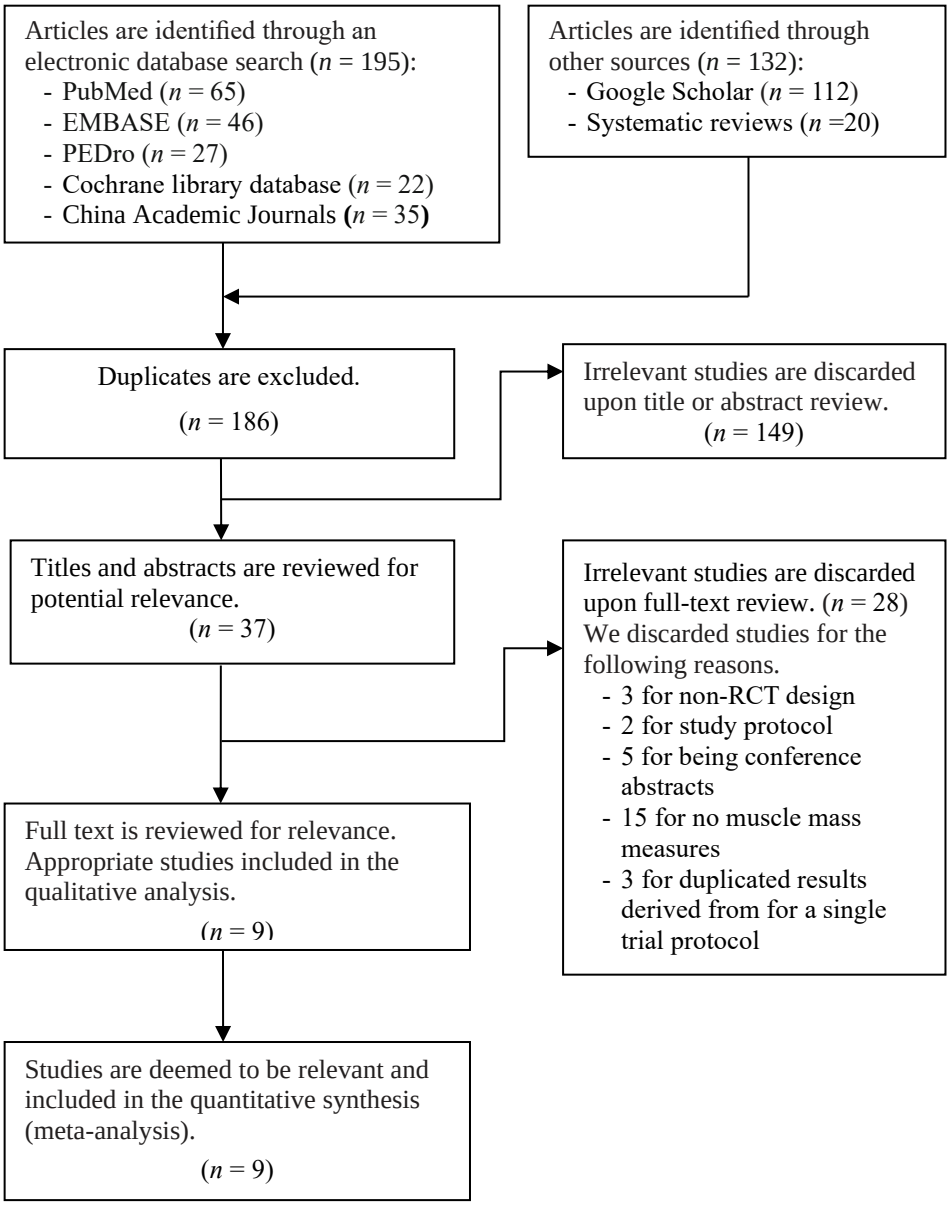

Figure S1. PRISMA flowchart of study selection.

Supplementary figure S2

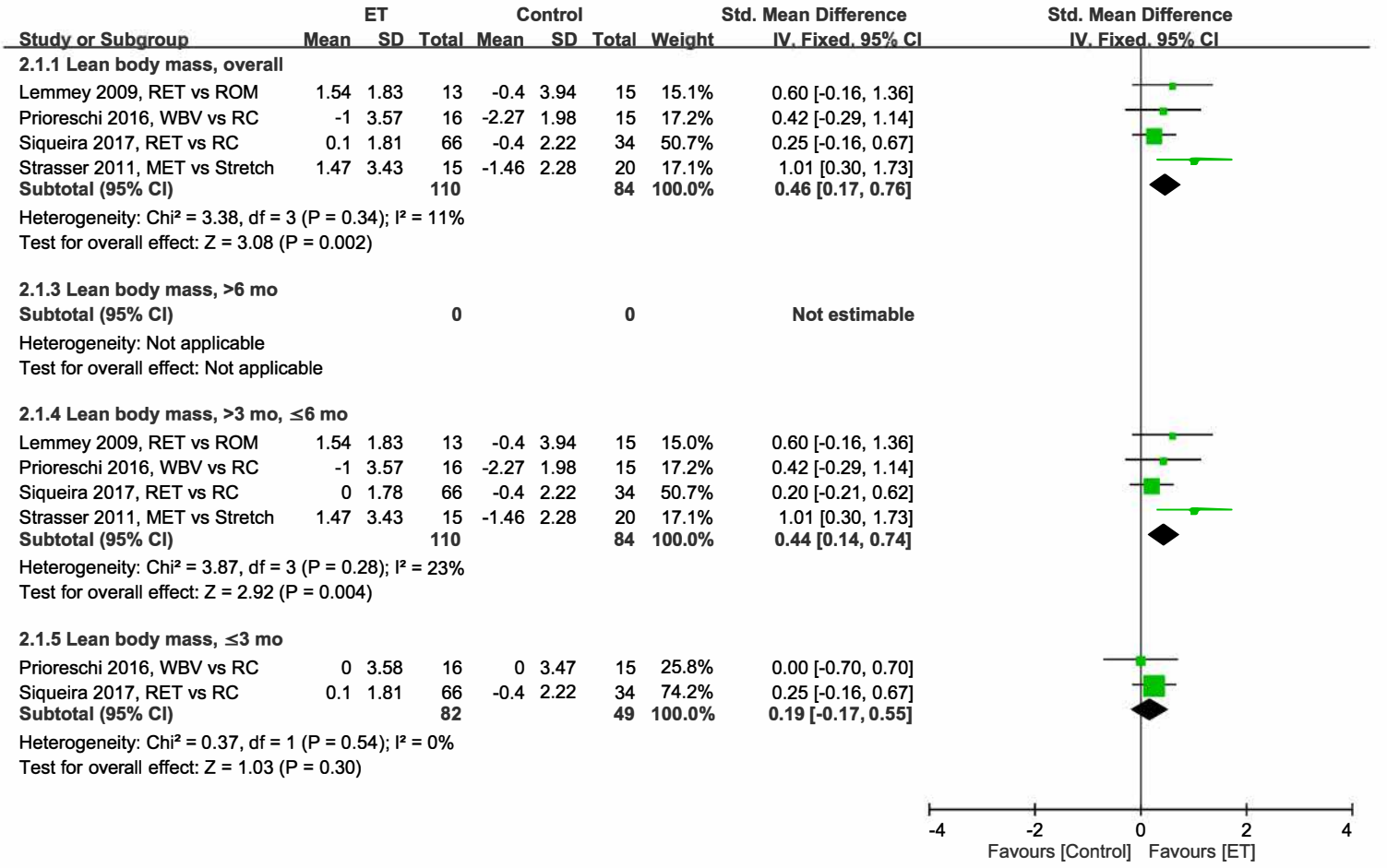

Figure S2. Forest plot summarizing effects ofexercisetherapy(ET) on leanbody mass at an overall duration and each follow-up time point. The horizontal line links the lower and upper limits of the 95% CI of this effect. The combined effects are plotted using black diamonds.

95% CI = 95% confidence interval; Std. = standard; IV = inverse variance; MET, multicomponent exercise training; RC, regular care; RET, resistance exercise training; ROM, range of motion exercise; WBV, whole body vibration.

Supplementary figure S3

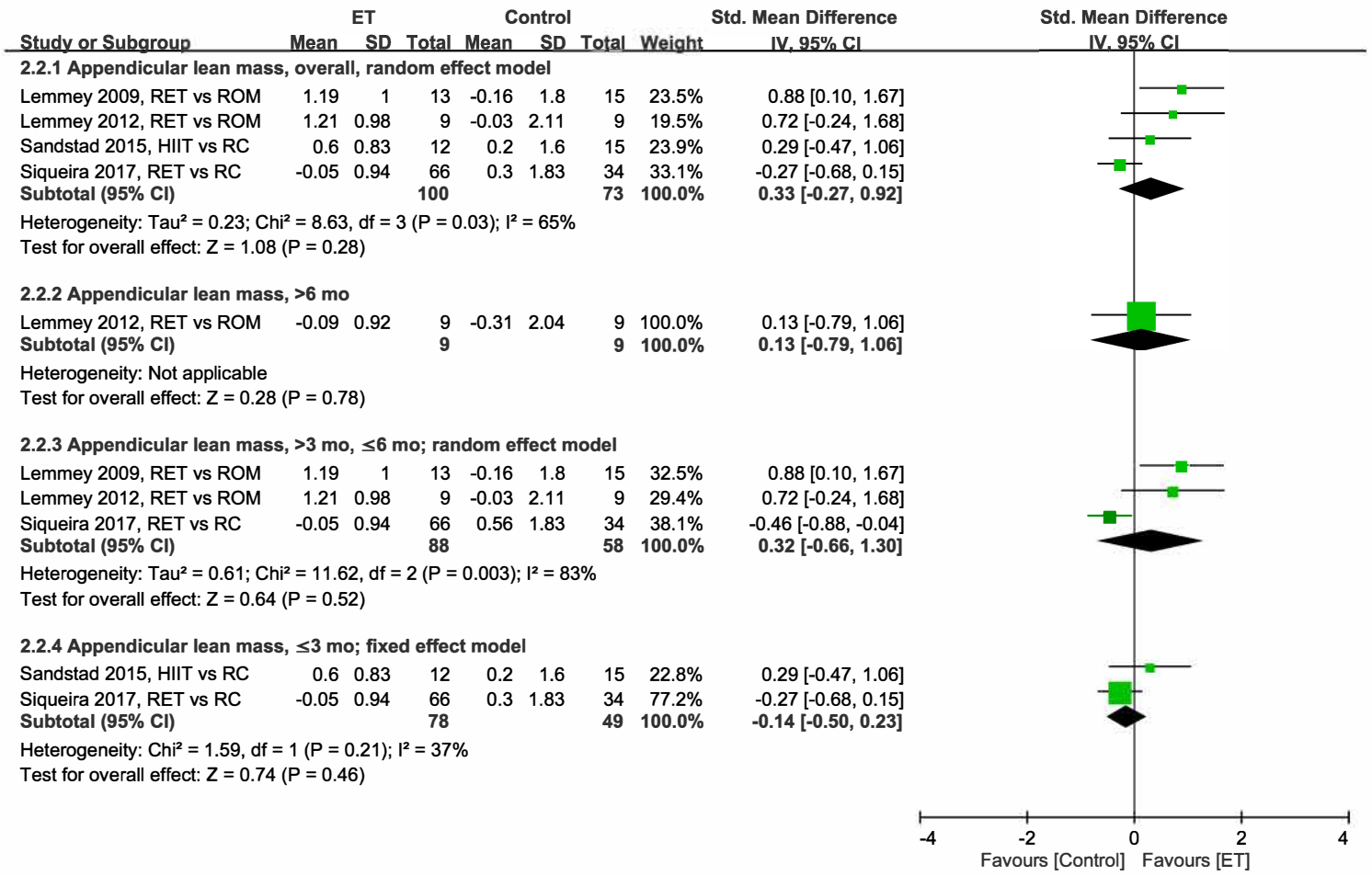

Figure S3. Forest plot summarizing effects ofexercisetherapy(ET) on appendicular lean mass at anoverall duration and each follow-up time point. The horizontal line links the lower and upper limits of the 95% CI of this effect. The combined effects are plotted using black diamonds.

95% CI = 95% confidence interval; Std. = standard; IV = inverse variance; HIIT = high-intensity interval training; RC, regular care; RET, resistance exercise training; ROM, range of motion exercise.

Supplementary figure S4

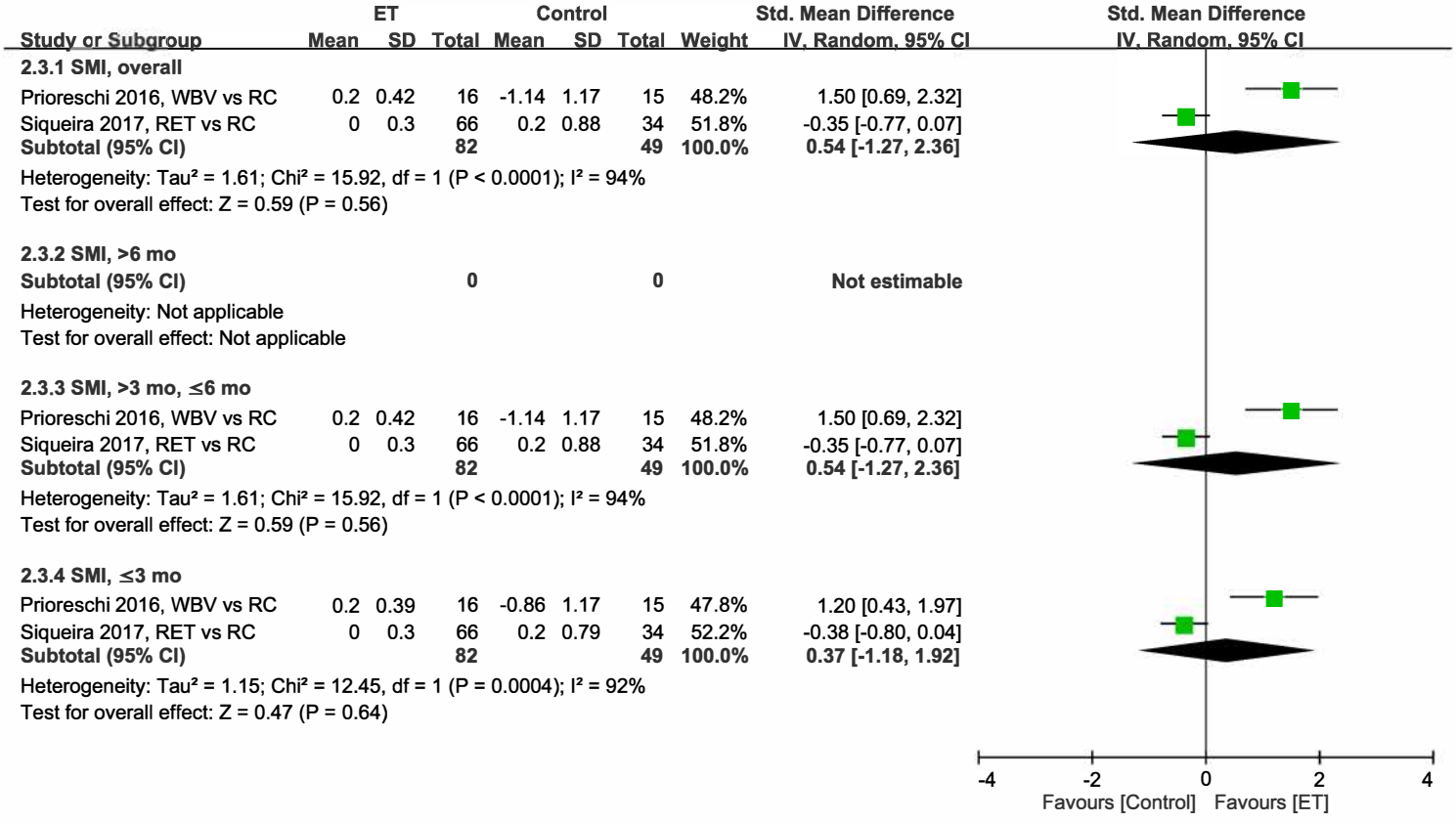

Figure S4. Forest plot summarizing effects ofexercisetherapy(ET)onskeletal musclemass index (SMI)at anoverall duration and each follow-up time point. The horizontal line links the lower and upper limits of the 95% CI of this effect. The combined effects are plotted using black diamonds.

95% CI = 95% confidence interval; Std. = standard; IV = inverse variance; RC, regular care; RET, resistance exercise training; WBV, whole body vibration.

Supplementary figure S5

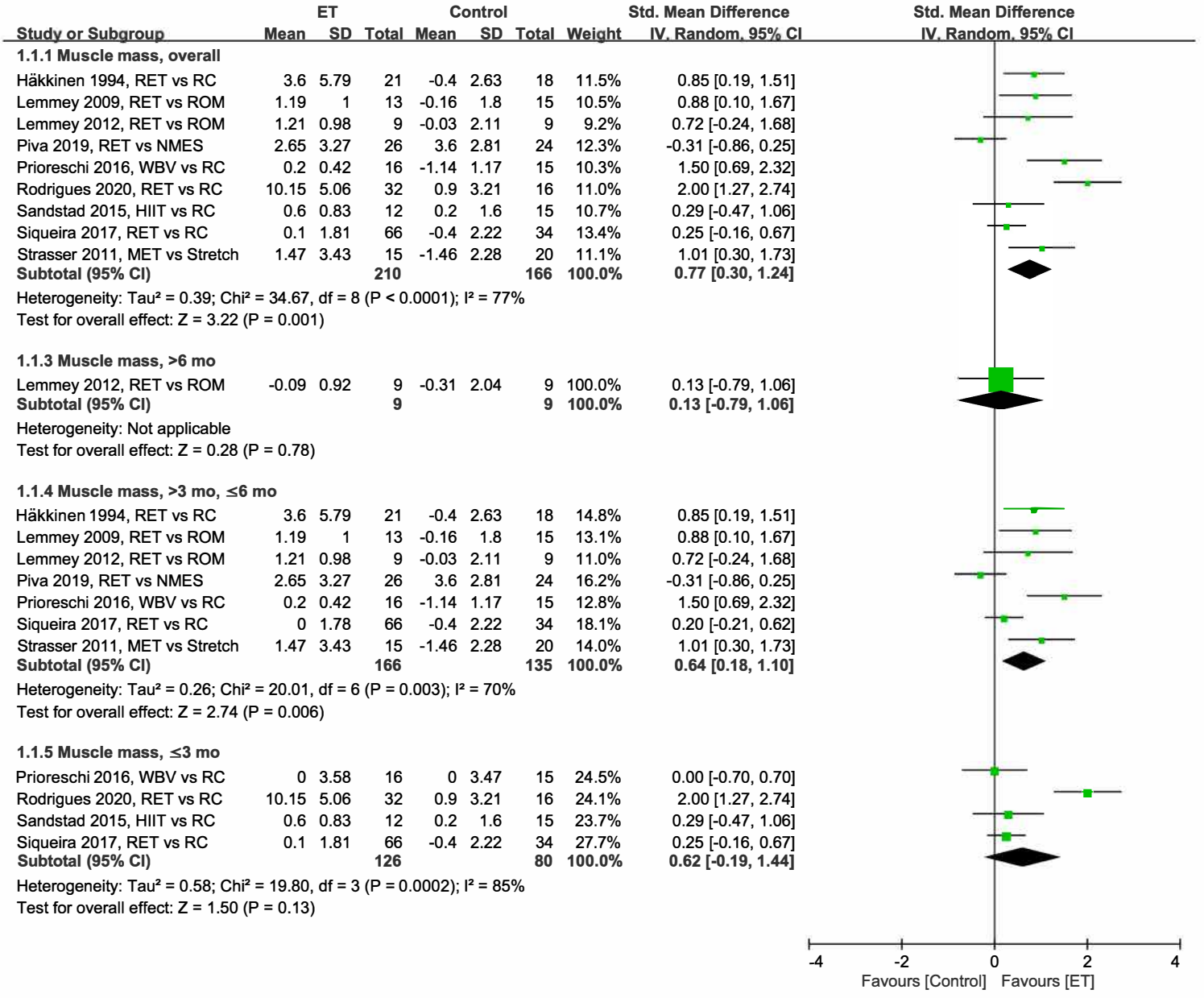

Figure S5. Forest plot summarizing effects ofexercisetherapy(ET)on pooled muscle mass measuresat anoverall duration and each follow-up time point. The horizontal line links the lower and upper limits of the 95% CI of this effect. The combined effects are plotted using black diamonds.

95% CI = 95% confidence interval; Std. = standard; IV = inverse variance; HIIT = high-intensity interval training; MET, multicomponent exercise training; RC, regular care; RET, resistance exercise training; ROM, range of motion exercise; WBV, whole body vibration.

Supplementary figure S6

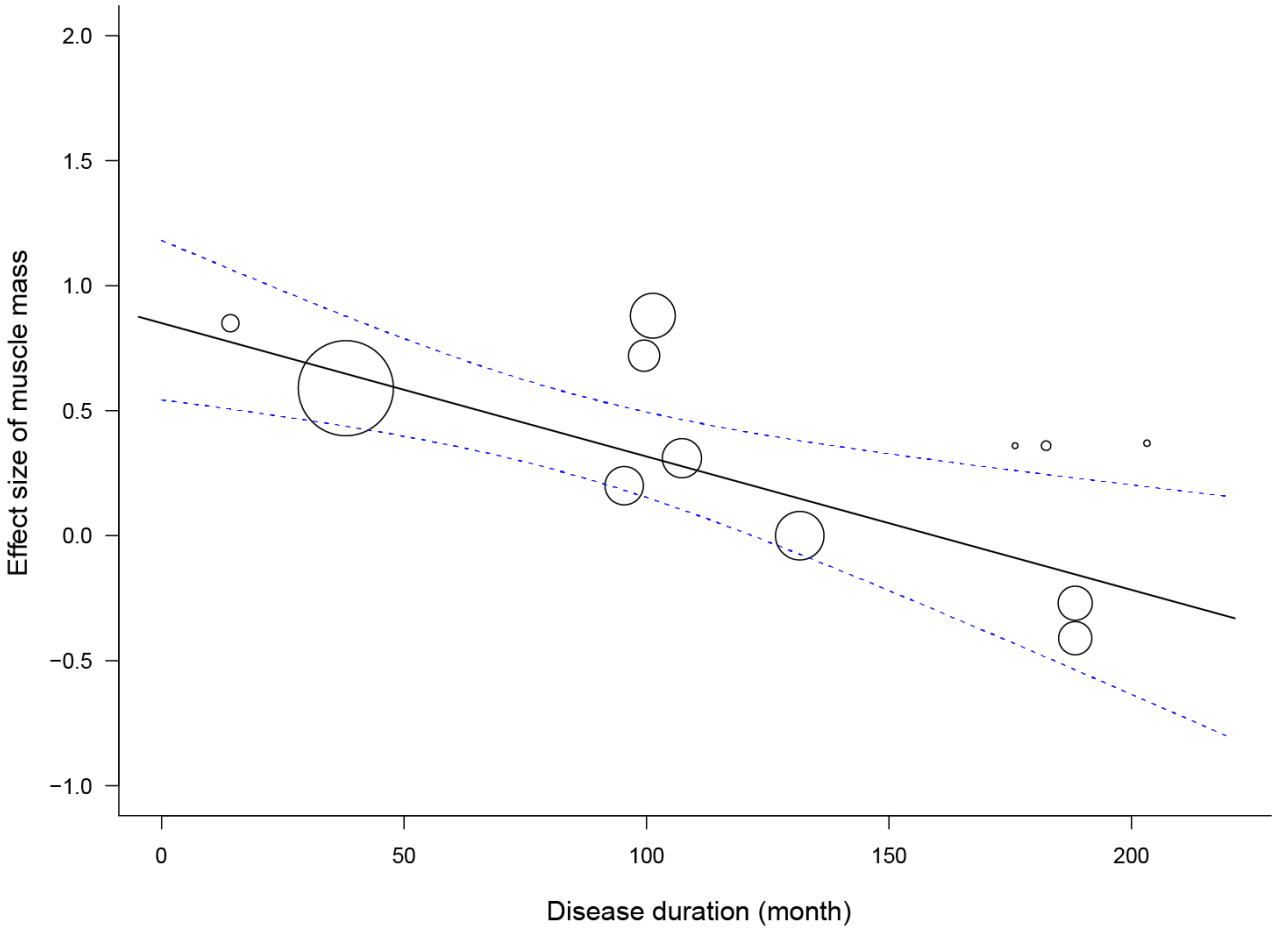

Figure S6. Univariate meta-regression between effect size of change in muscle mass and disease duration. Each circle represents an independent comparison. The size of each circle is proportional to that study's weight (inverse variance weighted). The effect size of change in muscle mass predicted by the regression model is represented by a solid line. Dotted lines represent the 95% CI.

Supplementary figure S7

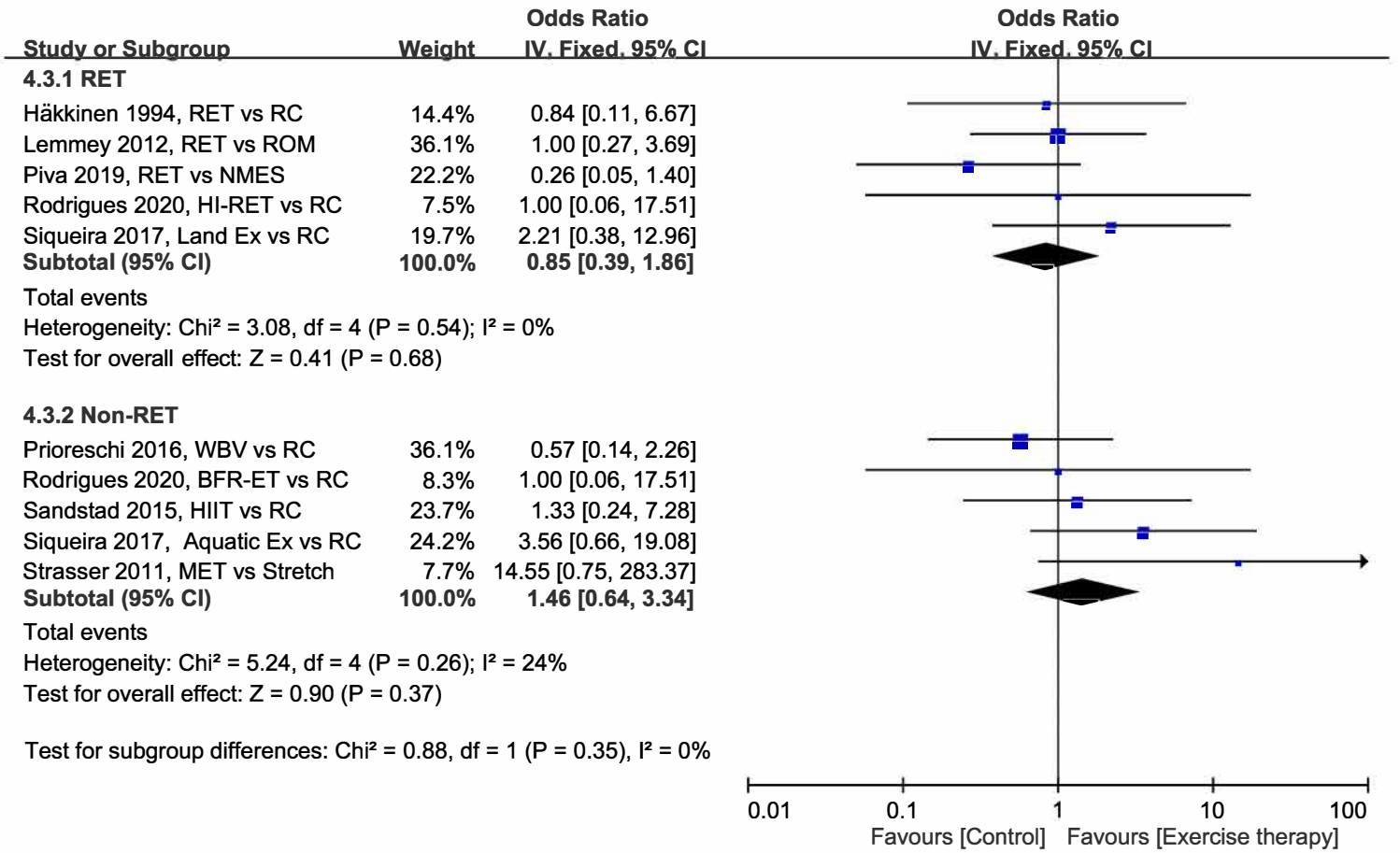

Figure S7. Compliance of resistance exercise training (RET) and non-RET therapy. The horizontal line links the lower and upper limits of the 95% CI of this effect. The combined effects are plotted using black diamonds.

95% CI, 95% confidence interval; IV, inverse variance; BFR-ET, blood-flow restriction exercise training; HIIT, high-intensity interval training; HI-RET, high-intensity resistance exercise training; MET, multicomponent exercise training; NMES, neuromuscular electrical stimulation; RC, regular control; RET, resistance exercise training; ROM, range of motion exercise; WBV, whole body vibration.

Supplementary figure S8

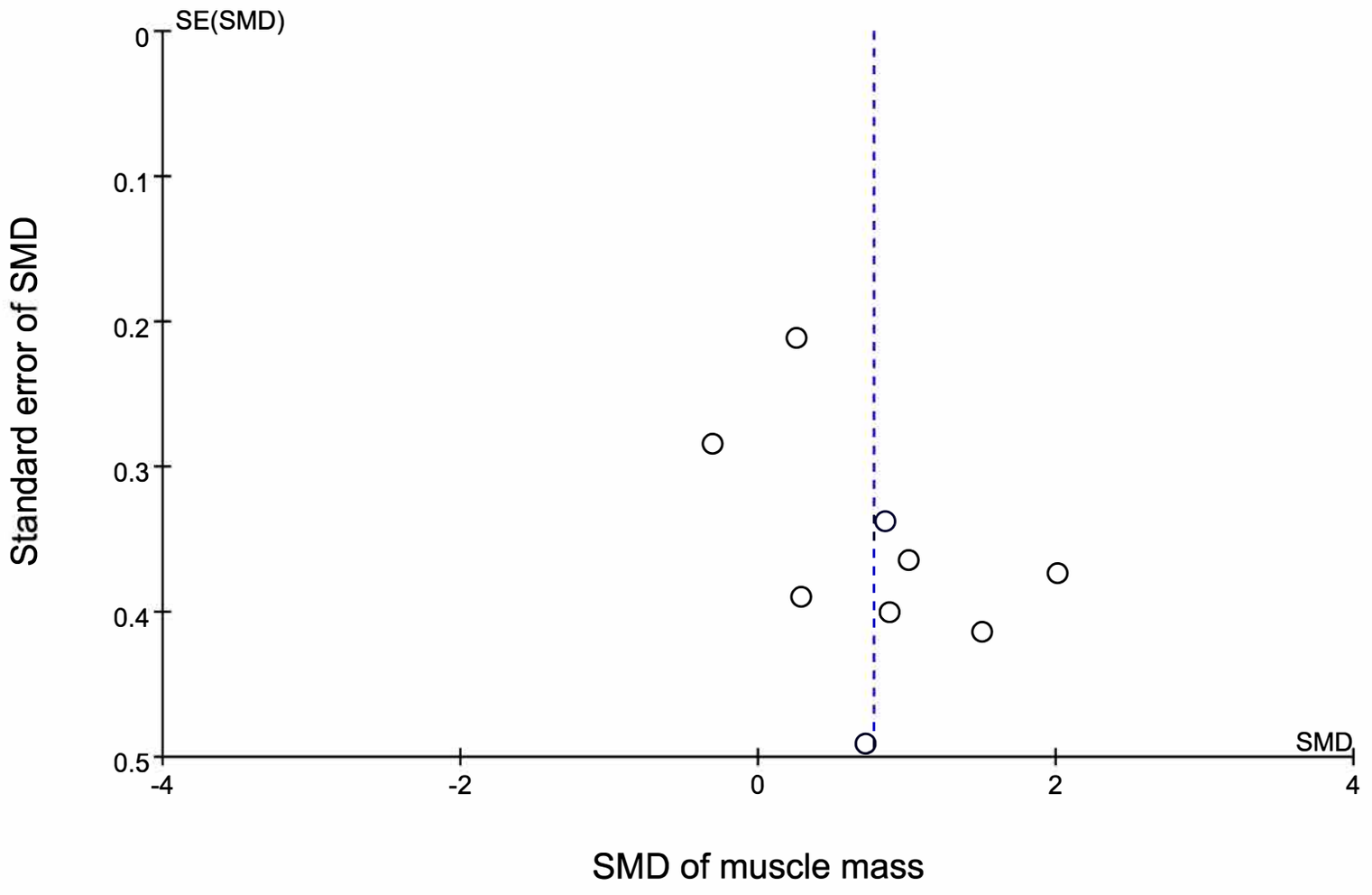

Figure S8. Funnel plots of exercise intervention effects for muscle mass. Each circle represents an independent comparison, with the X-axis representing a standard mean difference (SMD) over control comparisons and the Y-axis showing the standard error (SE) of SMD. The vertical dotted line indicates the SMD of the combined effect for each outcome measure.