ORIGINAL RESEARCH

The Acute and Chronic Effect of Endurance Versus Resistance Exercise on Circulating Irisin: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Exercise-induced release of irisin is associated with various improved health outcomes. However, the most effective exercise mode(s) to stimulate irisin release remain unclear. In this systematic review, we separately examine potential differences in (i) resting irisin concentrations (chronic change) after resistance (RT) and endurance training (ET) and (ii) the concentrations of irisin after a single bout (acute change) of resistance (RE) and endurance exercise (EE).

Methods: Searching was completed February 2022 in PubMed, CINAHL, Web of Science, Cochrane Library, SCOPUS, and SportDiscus. Studies were included by consensus of 2 reviewers, if they were randomized controlled trials (RCTs) or comparison studies with adults over 18 years and compared chronic change after RT and ET for any intervention duration or acute change after RE and EE. Risk of bias and quality of findings were independently assessed using PEDRo and GRADE, respectively. Irisin post means and standard deviations were extracted to calculate standardized mean differences (SMDs) and 95% confidence intervals using a random effect model.

Results: Of 174 studies screened, 8 chronic and 4 acute studies were included in the analysis, comprising a total of 332 participants. No difference between RT or ET for chronic irisin response was found ($P = 0.380$, SMD = 0.17, n = 248); however, there tended to be greater acute increases in circulating irisin after RE than EE ($P < 0.001$, SMD = 0.93, n = 56).

Conclusions: A greater effect of RE on irisin concentrations than EE was found in acute studies. Future research requires larger sample sizes and matched intensities.

Keywords: myokines, resistance training, FNDC5, endurance training

INTRODUCTION

Exercise improves outcomes in various chronic diseases, such as dementia (1) and type 2 diabetes (2), though the mechanisms underpinning these remain unclear. One promising area attracting the attention of researchers is the role of exercise-induced release of myokines on health outcomes. Myokines are molecules released from active skeletal tissue that regulate various metabolic processes through autocrine, paracrine, and endocrine signaling pathways (3,4). Recently, a role for the myokine irisin has been implicated in several chronic diseases including obesity (5), type 2 diabetes (2), and cognitive decline (6).

Irisin was initially identified as a peroxisome proliferator-activated receptor γ coactivator-1α (PGC1α)-dependent

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myokine with the potential to induce brown-fat-like development of white adipose tissue (7). Irisin responds to increased energy expenditure during exercise via PGC1α, Cyclic adenosine monophosphate (cAMP), and cytokine pathways (8) to induce mitochondrial biogenesis (9) and increase Adenosine triphosphate (ATP) production (8) and glucose uptake along with insulin stimulation (8).

However, reported changes in resting irisin concentrations in response to training are inconsistent (10–18), with no overall effect reported in a systematic review of these studies (19). A potential role for mode in explaining this inconstancy was highlighted in a systematic review of resistance training (RT) studies (20). Although, no effect of training was detected, subgroup analyses found chronic increases in resting irisin concentrations in older adults and when RT was demanding and progressive in terms of intensity. Given these findings, further exploration of the effect of mode on the response of irisin to chronic exercise is warranted.

Less inconsistency is found in the response of irisin to exercise when acute studies are considered, with a 15% increase in postexercise irisin concentrations reported overall (21). However, authors of 4 studies included in this systematic review reported no significant change (16,22–24). Although variability in the study outcomes was not explained by exercise mode, this systematic review was not designed to compare the effect of mode specifically, including studies in which authors did not directly compare resistance exercise (RE) and endurance exercise (EE) in a single cohort (21). Nonetheless, authors of studies directly comparing exercise modes showed that postexercise irisin concentrations tended to be higher after RE than EE (25,26). Therefore, with further investigation through a systematic review and meta-analysis of these studies, we may explain the inconsistencies in the literature.

The purpose of this systematic review and meta-analyses was therefore to (a) compare chronic changes in resting irisin concentrations after endurance training (ET) and RT interventions and (b) compare acute changes in postexercise irisin concentrations after a single bout of EE and RE, including only studies in which authors directly compared these modes.

MATERIALS AND METHODS

This systematic review was completed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta Analyses statement (27). This protocol was reviewed and registered by Open Science Framework (https://doi.org/10.17605/OSF.IO/HTQSR), and searching occurred during March 2020, May 2021, and again Feb 2022, using the following 6 databases: PubMed, CINAHL, Web of Science, Cochrane Library, SCOPUS, and SportDiscus. The text words "irisin" or "FNDC5" were combined using AND with the text words "weight training" OR "resistance training" OR "resistance exercise" OR "strength training" OR "strength exercise" in all databases. Due to the small number of papers, it was decided to broaden the search by not including endurance terms or adults to capture as many studies as possible. Database searches were conducted without the use of external limiters to reduce the incidence of neglecting articles because of incomplete indexing.

Inclusion criteria for studies were (a) random controlled trials and quasiexperimental trials directly comparing chronic RE and EE; (b) men and/or women aged 18 years and older; (c) comparison of both RE and EE (specifying type, intensity, repetition maximum, frequency, and session duration), for any intervention duration, including preacute and postacute studies; and (d) report of both preintervention and postintervention resting concentrations of irisin in chronic studies and pre-exercise to postexercise acute circulating irisin concentrations in acute studies. Exclusion criteria were (a) noninterventions (neither chronic or acute) studies; (b) theoretical articles or descriptions of treatment approaches; (c) review articles; (d) unpublished studies, abstracts, or dissertations; (e) articles without adequate specification of interventions and/or comparisons; (f) non-peer-reviewed articles and book chapters; (g) animal studies; or (h) non-English-language articles.

After the search, full-text articles were independently assessed by 2 reviewers (JN and MS) for eligibility (28). Corresponding authors were contacted in the instance where full texts were not available. Extraction of data relating to the study population, outcome measures, and exercise program was completed (JN) using a standardized data extraction sheet; extracted data included sample size, sample characteristics (age, sex, body mass index [BMI], $\dot{V}O_{2max}$, and % body fat), authors and publication year, details of the intervention (exercise form, intensity, and duration), the methods for irisin measurement, and timing after the intervention for blood sampling. Before and after means (based on the peak postmeasurements) and standard deviations of irisin concentration were recorded for each intervention group in both (a) chronic and (b) acute interventions, to calculate the within- and between-groups effect sizes (ESs) and respective standard errors. The standardized difference in means was also calculated to determine the ES, expressed as Cohen's d, for each study. The data for determining Cohen's d included the sample sizes, means, and standard deviations (SDs) of circulating irisin in the 2 exercise conditions as well as confidence level.

In studies in which authors used more than 1 comparator intervention, the intervention with the endurance intensity (based on $\dot{V}O_{2max}$) closest to the resistance intensity (based on 1 repetition maximum [1RM]) was chosen to reduce the confounding effect of intensity. Means and SDs were derived from figures in several studies using Web plot digitizer software (12,16,18,25,26). Authors of 2 studies (13,14) only reported percentage change. In another study, baseline data for healthy participants and those with metabolic syndrome were collated (29). These authors also reported baseline data in quartiles, so SD was calculated according to the method reported by Hozo et al. (30). Where standard error was reported, it was converted to SD (25,26,31).

Two authors (JN and MS) independently assessed the risk of bias using the PEDRo scale (32). In the current review, 2 of the 11 criteria (blinding of the trainers and blinding of the participants) were not appropriate for the type of interventions and were excluded (33). Both reviewers rated the

eligible articles on each of the 9 items of the scale and provided a total score between 0 and 9 for each article. All criteria were equally rated using *yes* (1 point) or *no* or *unclear* (0 points) on a standardized spreadsheet, and a quality score was generated as a percentage of the maximum score for each study. Any discrepancies between reviewer scores were identified and discussed before consensus was reached.

Included studies were categorized for synthesis in 2 separate meta-analyses, namely, chronic training interventions—multiple exercise sessions with blood sampled before and >3 h after the intervention—and acute interventions—blood was sampled before and <60 min after completion of a single exercise bout. Due to the baseline data being skewed in both analyses, we adopted a conservative approach to minimize the influence of these data where only the postexercise means were compared. Initially, a within-groups ES was calculated to estimate the mean difference from baseline in each group. To incorporate a correction for paired data, we assumed a correlation of 0.5 measured within each group to estimate the SD of changes from baseline in each group (21). The within-groups ESs were used in our primary analyses to calculate a standardized between-groups pooled ES of chronic/acute RE compared with EE. Thus, an ES > 0 indicated that the change in irisin concentration was higher/lower in the resistance than in the endurance group. Pooled ESs and 95% confidence intervals (CIs) were calculated using random effect meta-analyses with inverse variance.

Data were tabulated separately into chronic and acute studies to display before and after means with SDs for each study, and separate forest plots for training and single-bout studies displayed studies in random order with standardized mean differences (SMDs) and 95% CIs. Heterogeneity was first examined with a forest plot visual inspection and then statistically tested using the χ^2 test, with $P \leq 0.1$ taken as significant (34). The magnitude of inconsistency across the findings of studies was quantified using the I^2 statistic, with values <25% indicating low, 25%–50% moderate, and >50% indicating high heterogeneity (34). Due to a small-pooled sample size, it was not possible to meaningfully explore possible causes of heterogeneity among study results. As a measure of sensitivity, analysis of influence was used to investigate the influence of each individual study on the overall meta-analysis summary estimate. The meta-analysis was re-estimated omitting each study in turn, and the usual, full meta-analysis (omitting none of the studies) was given as the combined results. Publication bias was visually assessed by funnel plots by plotting the ES on each study against its standard error (35). The quality of the evidence was assessed by 2 authors (JN, GM) as implemented and described in the Cochrane Consumers and Communication (36) using the GRADE criteria. The quality of the evidence for each outcome on each of the following domains was assessed: risk of bias, inconsistency, imprecision, indirectness, and publication bias. All analyses were conducted using STATA v16.1 (StataCorp. Stata Statistical Software, College Station, TX).

RESULTS

Search Results

Thirty publications were initially identified as potentially suitable for inclusion. Of these, 12 met all the inclusion criteria; 8 were chronic studies assessing potential changes in resting irisin concentrations pretraining and posttraining, and 4 were acute interventions, including single bouts of exercise with measurement of pre-exercise and post-exercise irisin concentrations (Figure 1). Tables 1 and 2 summarize the methodological characteristics of the individual studies assessed. Studies were of moderate quality with an average score of 64.3 ± 12% for training studies and 75 ± 4.8% for single-bout studies.

Description of Irisin Measurement

Irisin was measured using a variety of commercially available enzyme-linked immunosorbent assay immunoassay kits; authors of 5 studies measured serum irisin (18,37–40), authors of 6 measured plasma irisin (12,13,31,41–43), and authors of 1 study did not report the sample type (25). For the chronic interventions, blood was sampled from 3 h to 2 d after the final training session. For the acute studies, blood was sampled at 0, 1, 3, 24, 48, and 72 h (24); 0 and 1 h (25); 0, 1, 2, 4, 6, and 24 h (31); and 0, 0.5, 1, 2, 3, 4, 6, and 24 h (26). Peak irisin concentrations were reached within 1 h after exercise in all single-bout studies, except in the study by He et al. (24) (<3 h). In all cases, peak irisin concentrations were used as the postexercise value for the meta-analysis.

Description of Chronic Study Participants

The median sample size was 26 (range = 18–75). Participants were aged 39.0 ± 13 years (n = 276), with BMI of 27.9 ± 3.2 $kg \cdot m^{-2}$ (n = 276), $\dot{V}O_{2max}$ of 31.2 ± 4.4 $mL \cdot kg^{-1} \cdot min^{-1}$ (n = 92), and percentage body fat of 28.9 ± 4.9% (n = 181; Table 3).

Description of Chronic Interventions

ET involved continuous moderate exercise: treadmill running/walking (12,14,40–42), treadmill running/mountain climber (12), Nordic walking (44), bicycle ergometer (38), and rhythmic aerobic step training and running (18). The average duration of the chronic interventions was 13.6 ± 6.5 weeks; participants trained, on average, 3.0 ± 0.8 times per week, and each training session averaged 57 ± 7.0 min. Exercise intensity was generally moderate and assessed via heart rate reserve (50%–80%) (14,42), $\dot{V}O_{2max}$ (65%–85%) (12,40), heart rate max (60%–75%) (18,41), and heart rate (below anaerobic threshold with 5–10 min bouts above) (38). In the 8 RT studies assessed, participants completed 2–3 sets of 8–15 repetitions of machine-based exercises targeting major muscle groups with an average intensity of 63.9 ± 4.5% 1RM. Further details of the interventions are provided in Table 1.

Meta-Analysis of Chronic Studies

There was low quality of evidence in the chronic studies indicating that neither mode was favored regarding their

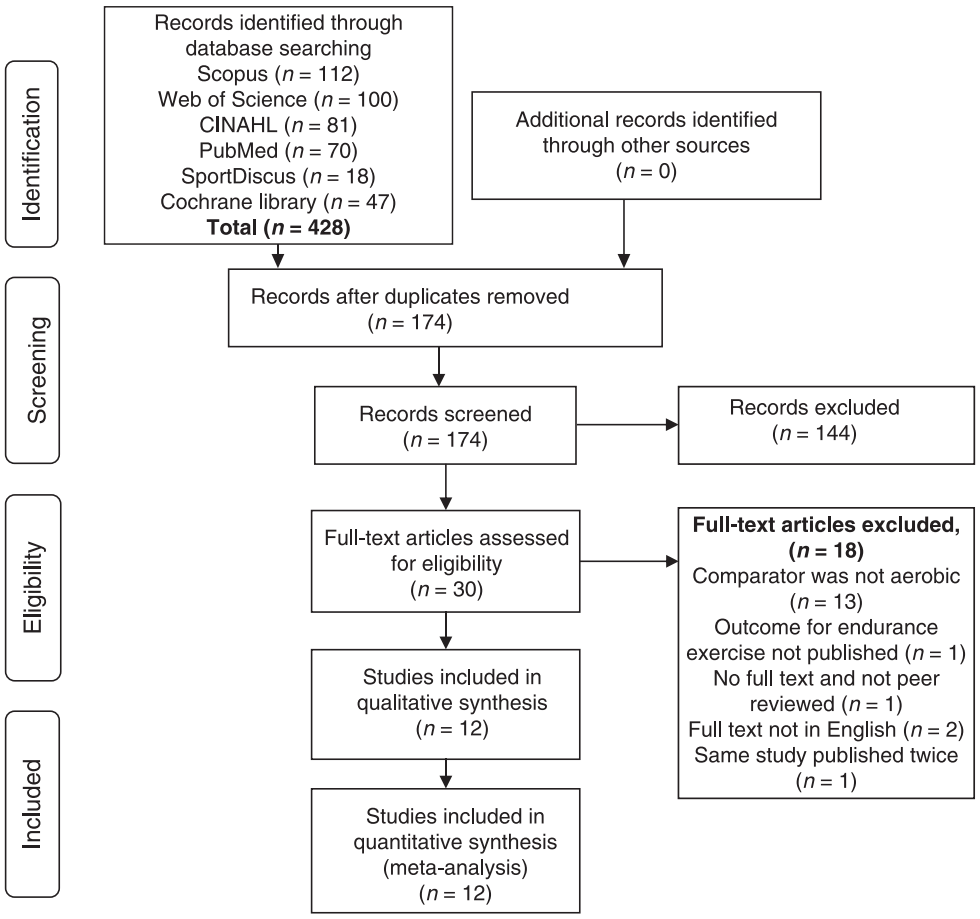

FIGURE 1. PRISMA flow chart of the selection of both chronic and acute studies included in the meta-analysis.

effect on resting irisin concentrations (n = 248, P = 0.380, SMD = 0.17; 95% CI, −0.20, 0.54). The quality of the evidence was downgraded to low quality due to the studies having an unclear risk of bias-allocation concealment (lack of blinding of outcome assessors, and measures of at least 1 key outcome were only obtained from >85% of participants in 5 of the 8 studies) due to imprecision caused by the small number of studies and that many studies within the meta-analysis had 95% CIs crossing zero. Examination of Figure 2 suggests high heterogeneity between research findings, and this is supported by a high statistically significant heterogeneity observed between research findings (χ^2 = 14.65, df = 7, P = 0.041), with an I^2 value of 52.2%. Due to the small number of studies assessed, it was not possible to complete a meaningful subgroup analysis for chronic studies to determine the source of heterogeneity. Sensitivity analysis of the meta-analysis to the removal of each study indicated that no individual study overly influenced the outcome (combined estimate = 0.165; 95% CI, −0.204, 0.535). Bias was examined with a funnel plot, and no asymmetry was detected, indicating no publication bias.

Description of Acute Study Participants

The median sample size for the acute studies was 13.5 (range = 9–20). Participants averaged 30.0 ± 7.8 years (n = 56), with BMI of 24.6 ± 2.5 kg·m^{-2} (n = 56), $\dot{V}O_{2max}$ of 44.7 ± 6.7 mL·kg^{-1}·min^{-1} (n = 46), and percentage body fat of 23.3 ± 0.5% (n = 39; Table 3).

Description of Acute Study Protocols

Some variation was found in exercise type, intensity, and duration across the acute studies. Of the 4 studies included, authors of 3 used high-intensity interval exercise (treadmill) (24,25,31), and 1 involved continuous moderate exercise cycle ergometry (26). EE duration averaged 53.8 ± 6.5 min, and exercise intensity was assessed using $\dot{V}O_{2max}$ (range = 65%–90% $\dot{V}O_{2max}$) (24,26), heart rate max (65%) (25), and/or rating of perceived exertion (RPE) (18 on the Borg 6–20 scale) (31). All 4 acute studies included RE studies involving 3–4 sets of 8–12 repetitions of machine-based exercises targeting major muscle groups. The average session duration was 51 ± 10 min, and intensity averaged 71.9 ± 4.5% 1RM (24–26,31) (Table 3).

Meta-Analysis of Acute Studies

RE resulted in significantly greater acute increases in irisin concentration postexercise than EE, with a large ES (P < 0.001; n = 56, SMD = 0.93; 95% CI, 0.44, 1.43). The evidence was classified as low quality due to the small number of studies, thus decreasing statistical precision. Examination

TABLE 1. Description of training studies included in the meta-analysis.

Studies	n[a]	Age[b]	BMI[c]	Period[d]	Mode	Frequency[e]	Intensity	Duration[f]	Sets and Reps	Sample Timing[g]	*P*
Pekkala et al. 2013 (16)	9/0	57 ± 7.0	24 ± 2	21	Concurrent, cycle	2	40%–80% 1RM	60–90	3 × 15–30	3	ns
Comparison trial					HIIT, cycle	2	80–100 HRmax	45	-		ns
Hecksteden et al. 2013 (14)	64/38	48 ± 9.9	24.24 ± 4.7	26	Concurrent	3	100% 20RM	-	2 × 15	48–168	ns
Comparison trial					Walking/running	3	60% HHR	45			ns
Kim et al. 2016 (12)	7/3	26.4 ± 2.9	27.0 ± 3.4	8	RT	5	65%–80% 1RM	60	3 × 10–12	48	↑0.002
RCT, obese	6/4	25.7 ± 4.1	26.4 ± 2.4		Cycling, treadmill, mountain climber	5	65%–80% HR_{max}	60	-		ns
Shabani et al. 2018 (18)	0/37	25.3 ± 5.6	24.7 ± 6.3	8	RT	3	65%–75% 1RM	65	3–4 × 8–12	48	ns
RCT					Rhythmic aerobic step	3	60%–75% HR_{max}	65	-		ns
Korkmaz et al. 2019 (13)	144/0	54.6 ± 1.3	29.6 ± 0.3	12	RT	3	50%–85% 1RM	60	-	48	ns
RCT					Nordic walking	3	55%-87% HRR	60	-		↑0.014
Amanat et al. 2020 (41)	0/42	54.50 ± 6.9	29.0 ± 3.0	12	RT, whole body	2-3	60%–80%1RM	60	2 × 8–10	12	ns
RCT, obese, metabolic syndrome			29.3 ± 4.0		CME, treadmill walking, bicycle ergometer	3	60%–75% HRmax	30–60	-		↑>0.001
Poutafkand et al. 2020 (42)	0/25	49.0 ± 5.4	32.3 ± 1.4	8	RT, whole body	3	50%–80% 1RM	60	3 × 10–15	48	ns
RCT, obese		49.5 ± 5.9	32.4 ± 2.3		CME, out-door running	3	50%–80% HRR	60	-	48	ns
Rezaeeshirazi et al. 2021 (40)	14/0	21.3 ± 1.9	32.6 ± 1.7	8	Circuit training, whole body	4	50%–70%1RM	45	2–3 × 8–15	10	ns
Type 2 diabetes, obese	13/0	21.1 ± 2.4	32.0 ± 1.3		CME, treadmill	4	60%–90% $\dot{V}O_{2max}$	45	-		ns

↑ = increase; 1RM = 1 repetition maximum; BMI = body mass index; CME = continuous moderate exercise; HIIT = high-intensity interval training; HRR = heart rate reserve, $kg \cdot m^2$; HR_{max} = maximum heart rate; ns = nonsignificant; RCT = randomized controlled trial; RT = resistance training; $\dot{V}O_{2max}$ = maximal oxygen consumption ($mL \cdot kg^{-1} \cdot min^{-1}$)

[a]n; men/women

[b]Age (y)

[c]BMI ($kg \cdot m^{-2}$)

[d]Intervention length (wk)

[e]Frequency (sessions per wk)

[f]Duration (min)

[g]Blood sampling timing (h)

TABLE 2. Description of single-bout studies.

Studies	n[a]	Age[b]	BMI[c]	Mode	Intensity	Duration[d]	Sets and Reps	Blood Sampling[e]	*P*
Nygaard et al. 2015 (49)	7/2	32 ± 9	24.5 ± 2.4	RE, whole body	10–12 RM	60	3 × 10–12	0, 1, 2, 4, 6, 24	↑0.001
Random crossover design				HIIT	6 × 5 min, 18 (Borg scale)	60	-		↑0.037
Huh et al. 2015 (25)		Healthy		RE, whole body	75%–80% 1RM	45	3 × 8–12	0, 1	↑0.05[f]
	14/0	41.1 ± 6.7	28.1 ± 4.2	HIIT, treadmill	4 × 4 min, 90% HR_{max}	36	-		↑<0.05
Random crossover design		Metabolic syndrome							
	6/0	4.5 ± 8.5	30.1 ± 3.7						
Tsuchiya et al. 2015 (26)	10/0	23 ± 1	23.7	RE, whole body	65% 1RM	45	3–4 × 12	0, 0.5, 1, 2, 3, 4, 6, 24	↑0.05
Random crossover design				Cycle ergometer	65% $\dot{V}O_{2max}$	60	-		ns
He et al. 2018 (24)	17/0	23 ± 3	22 ± 2	RE, whole body	70%–75% 1RM	~50	4 × 8–10	0, 1, 3, 24, 48, 72	ns 0.54
Random crossover design				HIIT, treadmill running	5 × 4, 90%, 50% $\dot{V}O_{2max}$	45–60	-		ns 0.54

↑ = increase; 1RM = 1 repetition maximum; BMI = body mass index; HIIT = high-intensity interval training; HR_{max} = maximum heart rate; ns = nonsignificant; RE = resistance exercise; $\dot{V}O_{2max}$ = maximal oxygen consumption ($mL \cdot kg^{-1} \cdot min^{-1}$)
[a]n = men/women
[b]Age (y)
[c]BMI ($kg \cdot m^{-2}$)
[d]Duration (min)
[e]Blood sampling timing (h)
[f]Greater than other modes

TABLE 3. Subject characteristics single-bout, and training studies.

	Single-Bout Studies	n	Training Studies	n
Sample size (range)	22.4 (20–19)	56	26 (18–75)	276
Age (y)	30 ± 7.8	56	39.0 ± 13	276
BMI ($kg \cdot m^{-2}$)	24.6 ± 2.5	56	27.9 ± 3.2	276
$\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	44.7 ± 6.7	39	31.2 ± 4.4	92
Body fat (%)	20.7 ± 3.9	46	28.9 ± 4.9	181

BMI = body mass index; $\dot{V}O_{2max}$ = maximal oxygen consumption

of Figure 2 suggests a lack of heterogeneity between research findings. In that respect, no statistically significant heterogeneity was observed between research findings ($\chi^2 = 4.61$, df = 3, $P = 0.203$), with an I^2 value of 34.9%. Again, due to the small number of studies, it was not possible to complete a meaningful subgroup analysis for acute studies. Sensitivity analysis indicated that no individual study overly influenced the outcome (combined estimate = 0.935; 95% CI, 0.437, 1.433). Bias was examined with a funnel plot, and no asymmetry was detected, indicating no publication bias.

DISCUSSION

In this study, we attempted to explain variability in the responses of irisin to exercise and training by directly comparing the effect of mode (RE or EE) on both chronic and acute changes in irisin concentrations in 2 separate meta-analyses. No apparent effect of exercise mode on chronic (resting) irisin concentrations was found; however, acute increases in irisin tended to be greater after RE than EE. Therefore, mode of exercise may explain some variability in the acute response.

Authors of previous reviews of chronic training studies have found increases in resting irisin after completing RT in some groups (older adults and at higher exercise intensity) (20) but no response when including all exercise modes (19). The present findings show that variability in chronic study outcomes do not appear to be explained by exercise mode; this is supported by several studies (14–16,18,40) with authors of only 1 published study reporting greater irisin concentrations after RT (12).

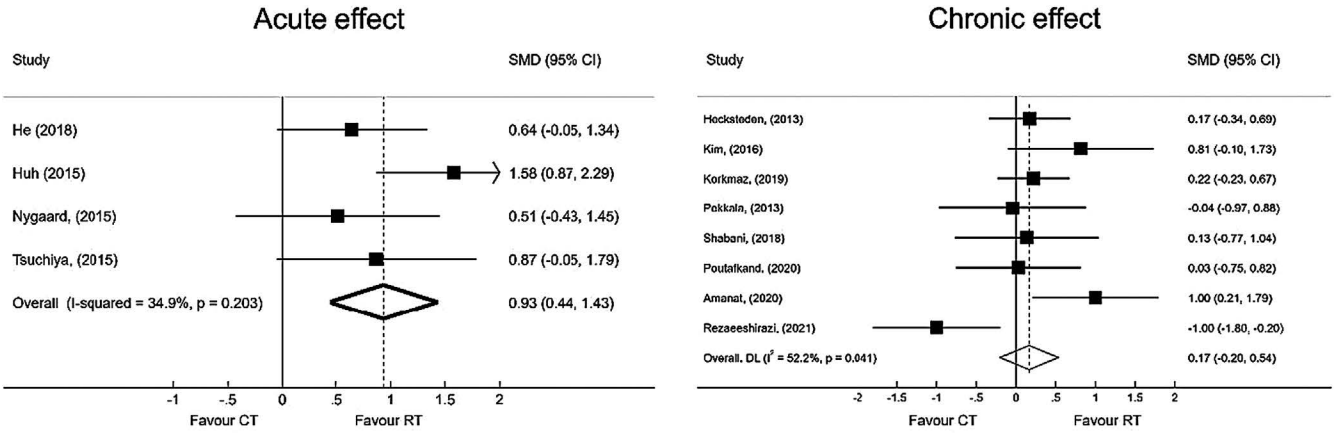

FIGURE 2. Forest plots demonstrating the impact of acute resistance exercise compared with acute endurance exercise on irisin concentration and chronic resistance training compared with endurance training on irisin concentration. CT = endurance; RT = resistance; SMD = standard mean difference; CI = confidence interval; ♦ = overall weighted mean treatment effect.

One potential explanation for variability in previous findings may be the intensity of exercise. A qualitative review of included studies implicated a potential association between exercise intensity and increased irisin resting concentrations after training in both modes, a finding supported by the systematic review by Cosio et al. (20). Kim et al. (12), the only authors that reported a significant increase in resting irisin concentrations after RT ($P = 0.002$), employed a higher %1RM (average 72%) (12) than other studies (averages ranging from 60% to 67.5% 1RM) (13,14,16,18,42). Therefore, some evidence suggests the effect of exercise intensity and not exercise mode better explains variability in resting irisin after training. However, in the present review, it was not possible to statistically analyze the potential causes of variability in the response due to the small sample size. A need for larger, higher-quality studies in which authors explore the effect of exercise intensity on the chronic response of irisin is implicated by our findings.

In contrast, variability in the acute studies appears to be explained, in part, by exercise mode. Irisin concentrations were significantly higher after RE than EE in our pooled dataset. However, the small number of studies, decreasing precision of the statistical outcome, highlights the need for larger, higher-quality studies in which authors investigate the acute irisin response to exercise. Although authors of 3 of the 4 acute studies included in this meta-analysis reported a significant increase in circulating irisin after acute RE (25,26,31), only Huh et al. (25) reported a significantly greater response to RE than EE ($P < 0.05$). In addition, authors of a recent meta-analysis (21) investigating the transient response of irisin to acute exercise did not support the present finding. However, this study was limited by the inclusion of studies that did not directly compare exercise mode, which increases heterogeneity (21). A strength of the present review is that only studies in which authors directly compared acute EE and RE responses were included; thus, an effect of exercise mode could be investigated specifically.

Exercise intensity may also explain the variation in postexercise irisin concentrations in acute exercise studies. For example, Huh et al. (25), who reported the greatest difference in intensity between the 2 exercise modes (RE: 77.5% 1RM, EE: 65% HRmax) as well as the greatest resistance intensity (77.5%1RM compared with an average of 70 ± 3.5%1RM), also showed the greatest change in irisin concentrations after RE. This finding is supported by Daskalopoulou et al. (45), who reported the greatest increase in irisin postexercise after a maximal workload ($\dot{V}O_{2max}$; $P < 0.004$). Given that irisin responds to increased energy expenditure by stimulating mitochondrial biogenesis (46), glucose uptake, and PGC1α (8) and is positively correlated with resting energy expenditure (47,48), an important role of exercise intensity is likely. This may also explain the greater response to RE, especially at higher intensities. Future studies in which authors measure the effect of well-differentiated intensities of RE and EE in larger samples would better inform the effect of intensity and mode on the acute irisin response to exercise.

A strength of the present meta-analysis was the inclusion of studies in which authors only compared RT/RE and ET/EE. This allowed for the assessment of exercise mode on irisin concentrations with greater certainty. However, the small number of studies, all with small sample sizes contributing to a small-pooled sample, limited our ability to capture the true effect of these interventions within the general population. The small-pooled sample also prevented a meaningful subgroup comparison, and therefore, we were unable to statistically investigate the effect of intensity on outcomes. Due to the limitations of present studies, future studies in which authors compare the effect of mode in single-bout exercise will require larger sample sizes with matched intensities and energy expenditures.

CONCLUSIONS

In the present study, we found no difference in the effect of mode of exercise on irisin in chronic studies; however, for acute studies, higher concentrations of irisin immediately after RE was detected. Overall, these meta-analyses demonstrate

that future studies in which authors compare the effect of mode in acute and chronic exercise studies require larger sample sizes with matched intensities and energy expenditures to fully elucidate the effect of exercise mode on irisin concentrations. Given the importance of irisin as a myokine implicated in human health and chronic disease risk, exercise recommendations to maximize health outcomes are essential.

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