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REVIEW

Effect of exercise on concentrations of irisin in overweight individuals: A systematic review

L'effet de l'exercice physique sur les concentrations d'irisine chez les individus à poids excessif : une revue systématique

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Myokine;
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Summary
Introduction. — Irisin myokine whose secretion is induced by exercise is associated with an increase in thermogenesis. However, the effect of acute and chronic exercise on the production and release of irisin in overweight individuals is controversial.
Objective. — To evaluate whether acute and chronic exercise affects irisin concentrations in overweight individuals.
Methods. — The Medline/PubMed and Science Direct databases were used. The data search included clinical trials with humans that assessed the effect of acute or chronic exercise on irisin concentrations in overweight or obese individuals. The search terms used were: ''irisin'' AND ''exercise'' OR ''acute exercise'' OR chronic exercise ''OR'' endurance exercise ''OR'' aerobic exercise ''OR'' strength exercise ''OR'' resistance exercise ''OR'' obesity''.
Results. — Nine articles performed in healthy and diabetic subjects were found. The irisin concentrations in individuals with excess weight increased with acute exercise and remained the same with chronic exercise. The maximum concentration of irisin occurred between 1 and 2 hours after the exercise was completed. The protocols of resistance and high-intensity training were more effective.

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Conclusion. — The increase in irisin concentrations after exercise is transient. Further research is needed to assess whether this change has a cumulative effect and actually acts on thermogenesis.

MOTS CLÉS
Myokine ;
FNDC5 ;
Entraînement ;
Exercice physique ;
Exercice aigu ;
Exercice chronique ;
Obésité

Résumé
Introduction. — L'irisine est une myokine induite par l'exercice et qui est associée à une hausse de la thermogenèse. Cependant, l'effet des interventions sur la production et la libération de l'irisine, ainsi que son potentiel thérapeutique dans les maladies liées au surpoids, est controversé.
Objectif. — Évaluer si les exercices aigus et chroniques ont un effet sur les concentrations d'irisine chez les personnes en surpoids.
Méthodologie. — Les bases de données utilisées étaient Medline/PubMed et Science Direct. La recherche comprenait des essais cliniques sur des humains qui évaluaient l'effet de l'exercice physique aigu ou chronique sur les concentrations d'irisine chez les personnes en surpoids ou obèses. Les termes de recherche utilisés étaient : « irisin » AND « exercise » OR « acute exercise » OR « chronic exercise » OR « endurance exercise » OR « aerobic exercise » OR « strength exercise » OR « resistance exercise » OR « obesity ».
Résultats. — Sept articles ont été inclus. L'exercice aigu a augmenté, et l'exercice chronique a maintenu les concentrations d'irisine chez les individus à poids excessif. La concentration maximale d'irisine s'est produite entre 1 h et 2 h après la fin de l'exercice physique. Les protocoles d'entraînement de résistance et de haute intensité étaient plus effectifs.
Conclusion. — L'augmentation des concentrations d'irisine après l'exercice est transitoire. Des recherches supplémentaires sont nécessaires pour évaluer si ce changement a un effet cumulatif et agit effectivement sur la thermogenèse.

1. Introduction

The overweight condition is characterized by increased body fat and metabolic disturbances [1,2]. In this context, it contributes to the development of diseases such as hypertension, diabetes mellitus, osteoarthritis, among others. Currently, over one billion adults worldwide are overweight [2].

Exercise is a strategy to prevent and treat overweight [1], as it contributes to the improvement of body composition and the increase of energy expenditure [2]. Skeletal muscle has an endocrine function and its exercise-induced contractions stimulate myokine secretion, including interleukin-6 (IL-6), interleukin-8 (IL-8) and brain-derived neurotrophic factor (BDNF).

Irisin is a myokine induced by exercise, which aroused the interest of the scientific community due to its potential thermogenic effect [3]. The mechanism involved in this process is due to overexpression of the peroxisome proliferator-activated receptor-γ co-activator (PGC-1α) induced by exercise. This, in turn, stimulates the expression of type I transmembrane fibronectin protein (FNDC5), which upon being cleaved is released as irisin [3—5]. This myokine increases the expression of the mitochondrial uncoupling protein UCP-1 [3,5], allowing white adipose tissue to acquire characteristics of brown adipose tissue, a process known as browning [5]. Brown adipose tissue is more vascularized and has a larger number of mitochondria, which makes it metabolically more active than white adipose tissue, resulting in increased thermogenesis [6]. Thus, exercise-induced irisin may have a therapeutic effect on overweight [7]. Thus, the mechanisms related to this myokine are widely studied in animal models, but the effects of exercise on the production and release of irisin are controversial, especially in humans [8—11]. Therefore, the objective of this systematic review was to evaluate whether acute and chronic exercise have an impact on the circulating concentrations of irisin in overweight individuals.

2. Method

This is a systematic review based on the analysis of articles in English available in Medline/PubMed and Science Direct databases published up until April/2017. It included clinical trials with humans that which evaluated the effect of acute or chronic exercise on circulating concentrations of irisin in overweight (overweight or obese) individuals of any age. The search terms used were ''irisin'' and ''exercise'' or ''acute exercise'' or ''chronic exercise'' or ''endurance exercise'' or ''aerobic exercise'' or ''strength exercise'' or ''resistance exercise'' or ''obesity''.

The identified studies were initially selected by reading the titles and, subsequently, reading the abstracts and the article in its entirety, adopting as inclusion criterion: intervention studies in which the effect of exercise on the circulating concentrations of irisin in individuals classified as being overweight or obese as a function of body mass index (BMI). Then, the studies must include at least one group of individuals with BMI > 25 kg/m^2. Exclusion criteria were: absence of intervention with exercise, animal or in vivo studies, meta-analyses, reviews, books, book chapters, editorials and letters to the editor.

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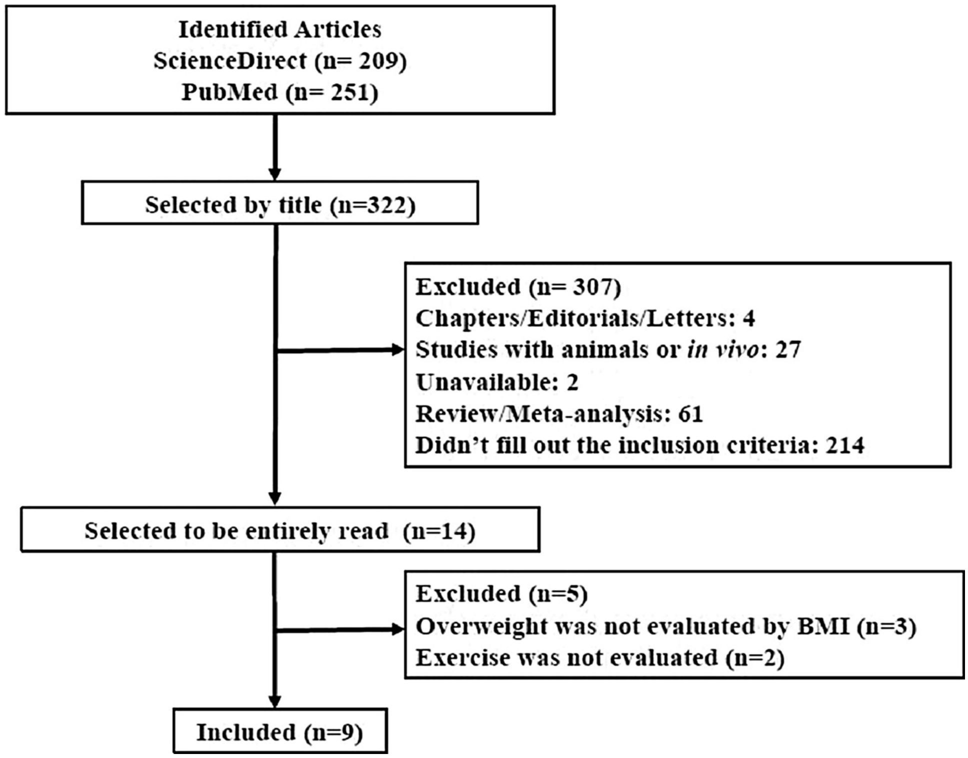

Figure 1 Flowchart of the article selection process. BMI: body mass index.

Two researchers carried out the selection of articles according to the eligibility criteria from September 2016 to April 2017. In case of disagreement between the evaluators, differences were discussed and a decision was made by consensus. The steps for selection of the articles are represented in the flowchart (Fig. 1). The following information was extracted from the studies: author(s), sample characteristics, BMI, intervention, sample and testing, collection time and main results. The data are grouped into two tables related to acute exercise (Table 1) and chronic exercise (Table 2).

The studies' quality was evaluated according to the method proposed by Downs and Black [12]. This method consists of 27 questions related to quality of reporting, external validity, internal validity (bias and confounding), and statistical power. Thus, each study's quality was classified as low (< 9/20), intermediate (9—13/20) and (> 14/20) good quality, according to the adaptation of the cut-off points proposed by Fernando et al. [13] (Table 3).

3. Results

From the nine selected studies, four dealt with acute exercise, two with chronic and three with both. All studies included in this review demonstrated good quality according to the evaluation criteria proposed by Downs and Black (Table 3).

3.1. Effects of acute exercise

Most of the studies in which acute exercise protocols were applied (Table 1) involved the participation of adult individuals [8,13—16]; only one study involved children and adolescents [11]. Most of the studies had both obese and overweight groups [8,13—16] and some evaluated groups with comorbidities: metabolic syndrome [15] and pre-diabetes [13].

All the studies used aerobic exercise as intervention [8,10,13—16] and two also used resistance exercise [8,15]. The exercise protocols were different in all. When comparing types of exercise, irisin concentrations were higher in subjects submitted to resistance exercise compared to aerobic exercise [15]. However, one study demonstrated maintenance in the circulating concentrations of irisin after resistance exercise [8].

Regarding the sample, serum irisin concentrations [10], plasma [13,15,16] and saliva [14] increased after the intervention. The most commonly used kit for evaluating irisin concentrations was the enzyme-linked immunosorbent assay (Elisa) EK 067-52 for both plasma [13,15] and serum [10,14]. Only one study used the Enzyme Immunoassay (EIA) kit [8] and another used the EK067-29 Elisa kit [16]. In all studies, the collection of samples for analysis of irisin concentrations occurred before the intervention, but only one specified the pre-exercise collection time (1 hour) [15]. After the intervention, the time of collection varied between zero [10,13,15,16] and three hours [8,16], and one study did not define the time of the post-exercise analysis [14]. Almost all irisin concentrations remained elevated after the intervention [10,13,15,16] except in two studies in which they remained similar to pre-exercise [8,14].

3.2. Effects of chronic exercise

The adult age group was predominant in chronic intervention studies [8,11,13,16,17], but two studies involved the

Table 1 Characteristics of studies in which the effect of acute exercise on irisin concentrations was evaluated.

Study	Sample	BMI (kg/m^2 or *Z*-score*)	Age (years)	Intervention	Sample, testing	Collecting time	Main results
Aydin et al., 2013 [14]	*n* = 7 Obese *n* = 7 Overweight *n* = 6 Obese control	35.67 ± 4.53 26.62 ± 5.98 34.23 ± 3.52	40.50 ± 6.53 44.14 ± 6.77 —	AE: 5.5 km/45 min (7.3 km/h) of moderate intensity outdoor racing (obese and eutrophic group). Obese control: no exercise	Serum and saliva Elisa EK-067-52	Pre- and Post-exercise	↑ Circulating concentrations of irisin in the pre-exercise saliva of obese individuals compared to serum irisin concentrations ↓ Circulating concentrations of irisin in pre-exercise serum and saliva of obese subjects compared to overweight ↑ Circulating concentrations of irisin in post-exercise saliva in obese individuals ↔ Concentrations of post-exercise serum irisin in obese subjects compared to obese controls ↑ Circulating concentrations of irisin in post-exercise saliva in obese subjects compared to obese controls
Huh et al., 2015 [15]	*n* = 14 M Healthy overweight *n* = 6 Overweight with metabolic syndrome	28.1 ± 4.2 30.1 ± 3.7	41.1 ± 6.7 44.5 ± 8.5	Control: Resting HIIE: 5 sets of 4-minute walk alternating with 4 sets of 4-minute run at 90% MHR (36 min) CME: 36 minutes of walking/treadmill running at 65% of MHR RE: 3 sets of 8—12 repetitions at 75—80% of 1-MR for different muscle groups (45 min)	Plasma, Elisa EK 067-52	1 h before, 0 h to 1 h after exercise	↑ Circulating concentrations of irisin after 1 hour in three exercise protocols ↔ Circulating concentrations of irisin in subjects with metabolic syndrome compared to healthy individuals Circulating concentrations of irisin after 1 hour were higher in the RE protocol compared to the HIIE and CME protocols
Norhein et al., 2014 [13]	*n* = 13 M Normoglicemic eutrophic *n* = 13 M Pre-diabetic overweight	23,5 ± 2,0 29,0 ± 2,4	40—65	AE: Exercise on a stationary bicycle at 70% of the VO_2max for 45 min	Plasma, Elisa EK-067-52	Pre, 0 h, 2 h post-exercise	↑ In the circulating concentrations of irisin up to 2 h after exercise in normoglycemic eutrophic ↑ In circulating concentrations of irisin after exercise in overweight pre-diabetic subjects
Pekkala et al., 2013 [8]	*n* = 17 Overweight *n* = 14	27 ± 4 26 ± 2	53 ± 4 34 ± 7	LIAE: ergometric exercise for 1 h at 50% of VO_2max RE: 5 sets of 10 MR of bilateral knee extension	Serum, EIA kit	Pre- and up to 3 h post-exercise	↔ Circulating concentrations of irisin 1 h after the LIAE protocol ↔ Circulating concentrations of irisin 1 min, 15 min and 30 min after the RE protocol

Table 1 (*Continued*)

Study	Sample	BMI (kg/m^2 or *Z*-score*)	Age (years)	Intervention	Sample, testing	Collecting time	Main results
Löffler et al., 2015 [10]	*n* = 29 Eutrophic (11 M/8 W) Obese (2 M/8F) *n* = 28 Eutrophic (7 M/7 W) Obese (7 M/7 W)	−0.32 ± 0.86* 2.59 ± 0.57* 24.14 ± 2.97 25.8 ± 5.27	8–21 21.29 ± 1.39 38.23 ± 5.88	15 min of maximal spiroergometry test 30 min (10 min of running, 10 min of gymnastics and 10 min-sprint)	Serum Elisa EK-067-52	Pre- and 0 h post-exercise	↑ Circulating concentrations of irisin in all subjects after maximal effort test No change in results after stratification of sex and obesity ↑ Circulating concentrations of irisin at time 0 h in lean adult men and obese women with 30 minute-acute exercise
Winn et al., 2017 [16]	*n* = 11 Obese	37.3 ± 2.1	24.3 ± 1.4	1st intervention — no exercise 2nd intervention — CME: 55 minutes of walking at 55% VO2peak on a treadmill 3rd intervention — HIIE: 4 minutes of high intensity at 80% VO_2peak with 3-minute intervals of active recovery (50% VO2peak) for 55 minutes on treadmill	Plasma Elisa EK-067-29	Pre-; 30, 50, 80 and 190 min	↔ Circulating concentrations of irisin in the control intervention Peak irisin increase occurred at time 50 min for CME and HIIE ↑ Circulating concentrations of irisin throughout CME ↑ Circulating concentrations of irisin during HIIE with return to basal levels after 15 min of exercise Irisin concentrations tend to remain ↑ for more than 2 hours after CME

PA: physical activity; M: man; W: woman; VO_2max: maximum oxygen consumption; AE: aerobic exercise; ML: maximum load; RL: relative load; AL: absolute load; RE: resistance exercise; HIIE: high-intensity intermittent exercise; CME: continuous moderate exercise; LIAE: low intensity aerobic exercise; HIAE: high-intensity aerobic exercise; MHR: maximum heart rate; MR: maximal repetition; Elisa: enzyme-linked immunosorbent assay; EIA: enzyme immunoassay.

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Table 2 Characteristics of the studies in which the effect of chronic exercise on irisin concentrations was evaluated.

Study	Sample	BMI (kg/m^2 or Z-score*)	Age (years)	Intervention	Sample, testing	Collection time	Main results
Bluher et al., 2014 [9]	*n* = 65 (54% W) Overweight	28.5 ± 0.5	7—18	39 exercise sessions per year, 150 minutes per week, 90 minutes with professional supervision and 60 minutes using free and independent sports facilities, adapted to three age groups	Serum, Elisa EK-067-52	Pre and post-intervention	↑ of 12% in the circulating concentrations of irisin after the intervention ↔ circulating concentrations of irisin between sex and age
Pekkala et al., 2013 [8]	*n* = 14 Overweight	26 ± 2	26 ± 2	HIIT: 21 weeks of training, 2 sessions per week, 60—90 min on exercise bicycle CT: 21 weeks of training, 2 aerobic sessions and 2 resistance sessions per week with duration of 60—90 min	Serum, EIA kit	Pre-, 3 h post-intervention	↔ circulating concentrations of irisin after 21 weeks of training
Norhein et al., 2014 [13]	*n* = 13 M Normoglicemic eutrophic *n* = 13 M Pre-diabetic overweight	23,5 ± 2,0 29,0 ± 2,4	40—65	CT: 12 weeks of combined aerobic and resistance training, 2 sessions of exercise on the bicycle (60 min) and 2 sessions of resistance exercise (60 min) per week	Plasma, Elisa EK-067-52	Pre-, 0 h and 2 h after last training session	↓ circulating irisin concentrations after 12 weeks of training in both groups ↑ circulating concentrations of irisin before and after 12 weeks of pre-diabetic training compared to normoglycemic
Kurdiova et al., 2014 [11]	*n* = 6 W *n* = 10 M Obese	31,8 ± 0,6	36,5 ± 1,1	CT: 12 weeks, 3 times per week, 1 hour per day of circuit exercise, combining strength training and aerobic activities. Strength training at 50—60% of 1-MR with an addition of 2.5% 1-MR every week. One exercise session corresponded to 75% of maximal capacity	Plasma Irisin RIA kit (RK-067-16)	Pre- and post-intervention	↔ circulating concentrations of irisin after 12 weeks of training
Löffler et al., 2015 [10]	*n* = 58 Obese (23 M/35 W)	2.42 ± 0.41*	12.7 ± 2.28	4—6 weeks of daily physical activity, nutritional and psychological counseling	Serum Elisa EK-067-52	Pre- and post-intervention	↔ circulating concentrations of irisin after 4—6 weeks of intervention
Fukushima et al., 2016 [17]	22 obese (5 M/17 W)	36.9 ± 5.0	46.1 ± 16.0	CT: 30 minutes (bicycle or treadmill) + 40 minutes of RE with body weight, 3 × a week	Elisa EK-067-29	Pre; after 6 months	↔ circulating concentrations of irisin in most participants

PA: physical activity; M: man; W: woman; C: control; T: trained; RHR: reserve heart rate; MR: maximal repetition; HIIT: high-intensity interval training; CT: combined training; Elisa: enzyme-linked immunosorbent assay; EIA: enzyme immunoassay; RIA: radioimmunoassay.

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Table 3 Quality of the articles included in the review according to the Downs and Black method (1988).

Questions	Aydin et al., 2013 [14]	Pekkala et al., 2013 [8]	Bluher et al., 2014 [9]	Norhein et al., 2014 [13]	Kurdiova et al., 2014 [11]	Löffler et al., 2015 [10]	Huh et al., 2015 [15]	Fukushima et al., 2016	Winn et al., 2017
1	1	0	1	1	1	1	1	1	1
2	0	1	0	1	1	1	0	1	1
3	1	1	1	1	1	0	1	1	1
4	1	1	0	1	1	1	1	1	1
5	0	0	0	1	0	1	1	0	0
6	1	1	1	1	1	1	1	1	1
7	1	1	0	1	1	1	1	1	1
8	0	0	1	1	0	0	1	0	0
9	1	0	1	1	0	1	1	1	1
10	1	1	1	1	1	1	1	1	1
11	ND	ND	ND	ND	ND	ND	ND	ND	ND
12	ND	ND	ND	ND	ND	ND	ND	ND	ND
13	ND	ND	ND	ND	ND	ND	ND	ND	ND
14	ND	ND	ND	ND	ND	ND	ND	ND	ND
15	ND	ND	ND	ND	ND	ND	ND	ND	ND
16	1	1	1	1	1	1	1	0	1
17	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1
21	ND	ND	ND	ND	ND	ND	ND	1	ND
22	ND	ND	ND	ND	ND	ND	ND	0	1
23	0	ND	0	ND	ND	ND	1	0	1
24	0	ND	0	ND	ND	0	ND	0	0
25	0	0	0	0	0	1	1	1	0
26	0	ND	0	ND	ND	0	ND	1	ND
27	4	5	5	5	3	5	3	4	5
Total score	16	16	16	20	15	19	19	19	20
Quality	Good	Good	Good	Good	Good	Good	Good	Good	Good

I: irrelevant (study design does not include this component); ND: not determined.

participation of children and adolescents [9,10]. Regarding the BMI of the participants, the studies are heterogeneous, presenting overweight groups [8,9], obese groups [10,11,16,17] and both [13]. Only one study with prediabetic subjects was identified [13]. The types of intervention applied in the studies differed. Four studies with adults used combined training (resistance and aerobic), two for 12 weeks [11,13], one for 21 weeks [7] and one for 6 months [17]. In the interventions with children, the studies used 39 sessions of exercise for one year [9] and 4—6 weeks of physical activity [10]. The most commonly used kit for evaluating irisin concentrations was Elisa EK 067-52 [9,10,13]. Other kits used were EIA [8] and Radioimmunoassay (RIA) (RK-067-16) [11]. In addition, serum was the most frequently used sample [8,9]. All studies analyzed irisin concentrations prior to intervention; post-exercise collection ranged from immediate [13] to three [8] hours after. For a majority of the studies, circulating irisin concentrations remained unchanged after the intervention [8,10,11], except for one study in which a decrease was observed [13] and in another, an increase [9].

4. Discussion

Irisin concentrations increased with acute exercise in most studies [10,13,15,16]. On the other hand, in studies with chronic exercise, the maintenance of irisin concentrations after weeks of exercise training was verified [8,10,11,17]. The increase in irisin occurred in both eutrophic and overweight individuals, but this appears to be transient [10,13,15]. During [16] and immediately after exercise (time zero) it was already possible to observe an increase in irisin concentrations [13,16]. However, about 2—3 hours after exercise was completed, the irisin was reduced to levels similar to or lower than the baseline state [13,16].

These results indicate that the irisin is a myokine induced by exercise, whose maximum concentration can be observed between 1 h and 3 h after its end [13,15,16]. On the other hand, in two studies irisin concentrations were maintained after resistance and aerobic exercise of moderate to low intensity [8,14]. Increased irisin concentrations in the body during exercise, even temporary, may have beneficial effects on muscle strength and function, and the longer-term prevents muscle deterioration [18]. Therefore, it is possible that the temporary increase of irisin during exercise exerts a cumulative and beneficial effect on the body.

Regarding the studies that did not find increase in irisin concentrations even during exercise, it is possible that methodological differences may have caused this result. While the EIA kit was used in one study [8], the Elisa kit EK-067-52 was used in the others [13,19,20]. It should be noted, however, that the Elisa kit appears to be the most suitable for detecting increased irisin blood concentrations [15]. Moreover, in one article, the precise information about blood collection time was not reported by the authors [14].

Since irisin concentrations may vary during, immediately after and in the hours after exercise, the lack of this information may influence the interpretation of the results. As for the intervention strategy, the irisin increase was more pronounced after high-intensity exercise [10,15] than low intensity exercise [8,13,14], but returned to basal levels after 15 minutes of high-intensity interval exercise, while it remained elevated for up to 3 hours after intervention in moderate, continuous exercise [16].

Other factors such as gender, nutritional status and fitness do not seem to influence the irisin response to exercise [10,19]. In addition, resistance exercise seems to increase irisin concentrations more than aerobic, even when both are high intensity [10,15]. This fact may be related to the greater muscle damage resulting from resistance exercise, since the irisin concentrations present a positive correlation with the production of lactate and creatine kinase, biochemical markers of muscle damage [15]. The irisin concentration was maintained after low intensity aerobic exercise and after resistance exercise in a study [8]. However, we believe that this result is due to methodological differences in the irisin measurement technique.

In one study, higher concentrations of irisin were observed in eutrophic individuals than in individuals who were overweight before exercise [14]. The concentrations of irisin have been positively correlated with body fat in children and adults [14,19,21,22]. As it similarly occurs with leptin and insulin, overweight individuals may present resistance to irisin, so their secretion is increased due to a compensatory mechanism to increase thermogenesis and reduce weight gain [23,24].

Acute exercise was able to increase irisin levels in both normoglycemic and pre-diabetic subjects [13]. In diabetics, the lower concentrations of irisin compared to normoglycemics and pre-diabetics are due to the reduction in PGC1α which may be related to chronic low-grade inflammation characteristic of these individuals [25,26]. It is believed that diabetes induces changes in the pathway that regulates the expression of this protein and is dependent on exercise, which explains the lower response of diabetics to exercise training [27]. Thus, we believe that in this study [13], glycemic alteration may have been insufficient to cause abnormalities in the PGC1α pathway of pre-diabetics after acute exercise.

One group of adults underwent combined training three times a week in addition to receiving nutritional orientation and psychological counseling. After 6 months, subjects who experienced increased circulation of irisin concentrations showed more significant metabolic improvement than those who experienced reduced irisin concentrations [17]. One of the parameters evaluated was HOMA-IR, which indicates that the increase in circulating irisin may aid in the improvement of insulin resistance and control of diabetes.

The concentrations of irisin in saliva and serum samples vary. While in the saliva sample the irisin concentrations increased after an aerobic exercise session, in the serum the concentrations before and after the exercise session were the same [14]. This was the only study in which irisin concentrations were evaluated in saliva. This fact makes it difficult to compare the results obtained between the studies. Thus, although saliva is easy to collect and non-invasive [14], serum or plasma samples remain the most suitable for Elisa kits.

Regarding chronic exercise, only one study observed a 12% increase in irisin concentrations after 39 exercise sessions during one year [9]. The characteristics of the

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population, duration, intensity and frequency of exercise may have influenced the observed results. The irisin concentrations remained constant in studies lasting 4—21 weeks [8,10,11,13]. It is noteworthy that the study in which a reduction in irisin concentrations after 12 weeks of intervention was observed had an older population with subjects aged 40—65 years [13], indicating that the age group of the population may have influenced the results and led to reduced concentrations of irisin. Other authors have detected a negative correlation between age and irisin concentration [28], suggesting that the lower muscle mass in the elderly would induce lower irisin production and release, since skeletal muscle is the main tissue responsible for its production.

Given the results, resistance and high-intensity exercises may be more effective in raising irisin concentrations. However, the literature on this effect is scarce and intervention strategies diverge among studies, which limits the recommendation of a more adequate protocol. Thus, exercise has a therapeutic potential in the treatment of obesity and one of the mechanisms associated to this effect may be related to the increase in irisin production and thermogenesis.

5. Conclusion

The increase in irisin concentrations after exercise is transitory in overweight individuals, and this remains unchanged after chronic exercise. The protocols of resistance and high-intensity exercise are more effective in this sense. Studies with longer periods of exercise training and different interventions are required to verify the effect on irisin concentrations. In addition, new investigations can assess whether the transient increase in irisin exerts a cumulative effect and actually acts on thermogenesis.

Disclosure of interest

The authors declare that they have no competing interest.

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