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P u b l i s h e r s

Irisin serum increasing pattern is higher at moderate-intensity continuous exercise than at moderate-intensity interval exercise in obese females

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RESEARCH ARTICLE

Abstract

Lifestyle, unhealthy eating patterns, and low physical activity become trigger factors of obesity. Therefore, lifestyle modification with an exercise-based nonpharmacological approach is one of the strategies for combat obesity. This study aims to analyse the response of moderate-intensity interval and continuous exercise to irisin level increasing pattern on the obese female. A total of 21 obese females were enrolled in this study and given moderate-intensity interval exercise (MIIE) and moderate-intensity continuous exercise (MICE). ELISA was used to quantify the serum level of irisin in all samples. Statistical analysis was performed using one way-ANOVA and Tukey's honestly significant difference (HSD) post hoc test. Mean irisin levels of pre-exercise at control (CON), MIIE, and MICE were 3.26±1.28l, 3.44±0.56 and 3.89±1.08 ng/ml, respectively (*P*=0.519). The mean irisin level of 10 min post-exercise was 2.99±0.86 ng/ml at CON, 4.82±1.01 ng/ml at MIIE, and 5.99±1.27 ng/ml at MICE (*P*=0.000). The mean irisin levels of 6 h post-exercise were 3.04±0.60, 4.56±0.87, and 5.73±1.02 ng/ml at CON, MIIE, and MICE, respectively (*P*=0.000). The mean irisin level of 24 h post-exercise was 3.04±0.91 ng/ml at CON, 4.64±0.69 ng/ml at MIIE, and 5.69±1.53 ng/ml at MICE (*P*=0.002). We conclude that the post-exercise serum irisin level increased in both MICE and MIIE subjects, and the post-exercise serum irisin level maintained higher in the MICE than in the MIIE in the obese female subjects.

Keywords: obesity, interval exercise, continuous exercise, treadmill, irisin pattern

1. Introduction

Obesity prevalence in 2015 reached 12% or equal to 603.7 million adults around the world (The Global Burden of Disease (GBD) 2015 Obesity Collaborators, 2017). The Southeast Asia prevalence was counted 1.7% in 1980 and increased to 6.2% in 2015 (Chooi *et al.*, 2019), while Riset Kesehatan Dasar (Riskesdas) 2018 showed that the prevalence of obesity over 18 years old in Indonesia was 21.8%. This data was higher than that of 2013 (14.8%) and 2007 (10.5%) (Riskesdas, 2018). It is estimated that in 2030 prevalence will reach 57.8% of the world's population (Kelly *et al.*, 2008). Obesity prevalence tends to increase both

in developed and developing countries (Ng *et al.*, 2014; Norheim *et al.*, 2014) and becomes a serious threat to the world health (Akter *et al.*, 2014; Chooi *et al.*, 2019; Gadde *et al.*, 2018; Peterson *et al.*, 2014; Tsuchiya *et al.*, 2014).

Obesity is a disease with a high risk of complications, disability and early death (Akter *et al.*, 2014; Rosella *et al.*, 2019). Moreover, obesity increases the risk of cardiovascular disease (Ng *et al.*, 2014), type 2 Diabetes mellitus (Gadde *et al.*, 2018) and some cancers (Nimptsch *et al.*, 2019), hypertension, stroke (Agofure, 2017), gallstones, osteoarthritis (Bales and Buhr, 2008), dyslipidaemia, non-alcoholic fatty liver disease (NAFLD) (Moreno-Navarrete and Fernández-Real, 2019),

cerebrovascular disease, respiratory disease, gastrointestinal system, chronic kidney disease (Malnick and Knobler, 2006), and low life expectancy (Nimptsch *et al.*, 2019). Life style, unhealthy eating patterns, and low physical activity become trigger factors of obesity (Bautista *et al.*, 2019; Norheim *et al.*, 2014). Therefore, lifestyle modification with an exercise-based nonpharmacological approach is the right strategy (Murawska-Cialowicz *et al.*, 2015). Exercise is considered a very effective and efficient method of preventing obesity prevalence increment (Boström *et al.*, 2012; Huh *et al.*, 2014).

Exercise has increased the energy expenditure which is mediated by the irisin hormone (Tsuchiya *et al.*, 2014). Exercise induces irisin by activating peroxisome proliferation-activated receptor γ coactivator-1α (PGC-1α) (Boström *et al.*, 2012). PGC-1α activation stimulates fibronectin type III domain-containing protein 5 (FNDC-5) expression (Fatouros, 2018) which induces irisin release to the blood circulation (Moreno-Navarrete *et al.*, 2013). The release of irisin will trigger a browning process on white adipose tissue by stimulating uncoupling protein-1 (UCP-1) gene expression via p38 mitogen-activated protein kinase (p38-MAPK) signalling, and increasing energy expenditure and decreasing lipid accumulation (Boström *et al.*, 2012; Fatouros, 2018; Perakakis *et al.*, 2017). Some studies have reported different results, due to irisin increment which did not occur at the same time and depending on the intensity of exercise (Huh *et al.*, 2014; Tsuchiya *et al.*, 2014; Winn *et al.*, 2017). The research by Huh *et al.* (2014) concluded that high-intensity interval training (HIIT) may lead to increases of acute response of plasma irisin levels 5 min post-intervention, more than continuous moderate-intensity exercise (CME) of males and females with a normal body mass index (BMI). Research by Tsuchiya *et al.* (2014) has shown that high-intensity exercise (HIE) causes an increase of irisin response after 6 and 19 h post-intervention compared to low-intensity exercise (LIE) on normal BMI males. The study by Winn *et al.* (2017) described that moderate-intensity continuous aerobic exercise (ModEx) increases irisin level during intervention and 190 min post-recovery compared to high-intensity aerobic interval exercise (IntEx) on female subjects with a BMI over 30 kg/m². According to those studies, no one has yet studied irisin secretion increment as a result of moderate-intensity interval exercise (MIIE) and moderate-intensity continuous exercise (MICE) conducted in the morning by female teenagers aged 18-23 years with a BMI of 25-35 kg/m² and percentage body fat (PBF) over 30%. These results on irisin secretion pattern and exercise intensity are important to support future exercise intervention strategies against obesity.

The aim of this study was to determine the effect of MICE and MIIE on irisin levels in obese females. We hypothesised that the greater metabolic stress induced by MICE would enhance higher peak serum irisin levels compared with MICE.

2. Materials and methods

Experimental design

This study was a true experiment using a basic time series design. The subjects were 21 obese females aged 18-23 years with a BMI of 25-35 kg/m², PBF over 30%, normal blood pressure, normal resting heart rate (RHR), normal oxygen saturation (SpO_2) of 95-100%, fasting blood glucose (FBG) under 100 mg/dl and normal haemoglobin (Hb). They were randomly divided into three groups, CON (n=7, control group without intervention), MIIE (n=7), and MICE (n=7). All subjects received verbal or written information about the research. Subjects filled out and signed an informed consent before participating in the study. All procedures were approved by The Health Research Ethics Committee Faculty of Medicine Universitas Airlangga Surabaya no. 309/EC/KEPK/FKUA/2019.

Exercise protocol

MIIE intervention was performed by using a moderate-intensity treadmill with 60-70% HR_{max} for 45 min, which is divided into 5 min warming up (50-60% HR_{max}), 35 min core exercise (5 min workout (60-70% HR_{max}) inserted by an active recovery above treadmill tool for 2.5 min (50-60% HR_{max}), repeated 5 times) and 5 min cooling down (50-60% HR_{max}). Moderate-intensity continuous exercise (MICE) intervention was done by running on a treadmill tool with 60-70% HR_{max} intensity for 40 min, which was divided into 5 min warming up (50-60% HR_{max}), 30 min core exercise continuously (60-70% HR_{max}) and 5 min cooling down (50-60% HR_{max}) (Dias *et al.*, 2018; Garber *et al.*, 2011; Tew *et al.*, 2019; Wewege *et al.*, 2017). This experiment was performed between 07:00-09:00 AM by using a treadmill (Richter Treadmill Semi-Commercial Evolution (4.0HP DC); Richter Fitness, Taipei, Taiwan). Further information about the duration and intensity scheme of MIIE and MICE is shown in Figure 1.

Blood collection

Blood samples were obtained from a cubital vein of 4 ml (Daskalopoulou *et al.*, 2014). It was taken four times (pre-exercise, 10 min, 6 h, and 24 h post-exercise). The blood samples were centrifuged for 15 min at a speed of 3,000 rpm. The serum was separated and saved at -80 °C until analysis on the next day (Daskalopoulou *et al.*, 2014; Tsuchiya *et al.*, 2014, 2015).

Blood analysis

Irisin level was measured by a commercial ELISA kit (EK-067-29; Phoenix Pharmaceuticals, Inc., Burlingame, CA, USA) with a standard curve range of 1.9-1000 ng/ml and irisin sensitivity level of 1.9 ng/ml. FBG was measured in
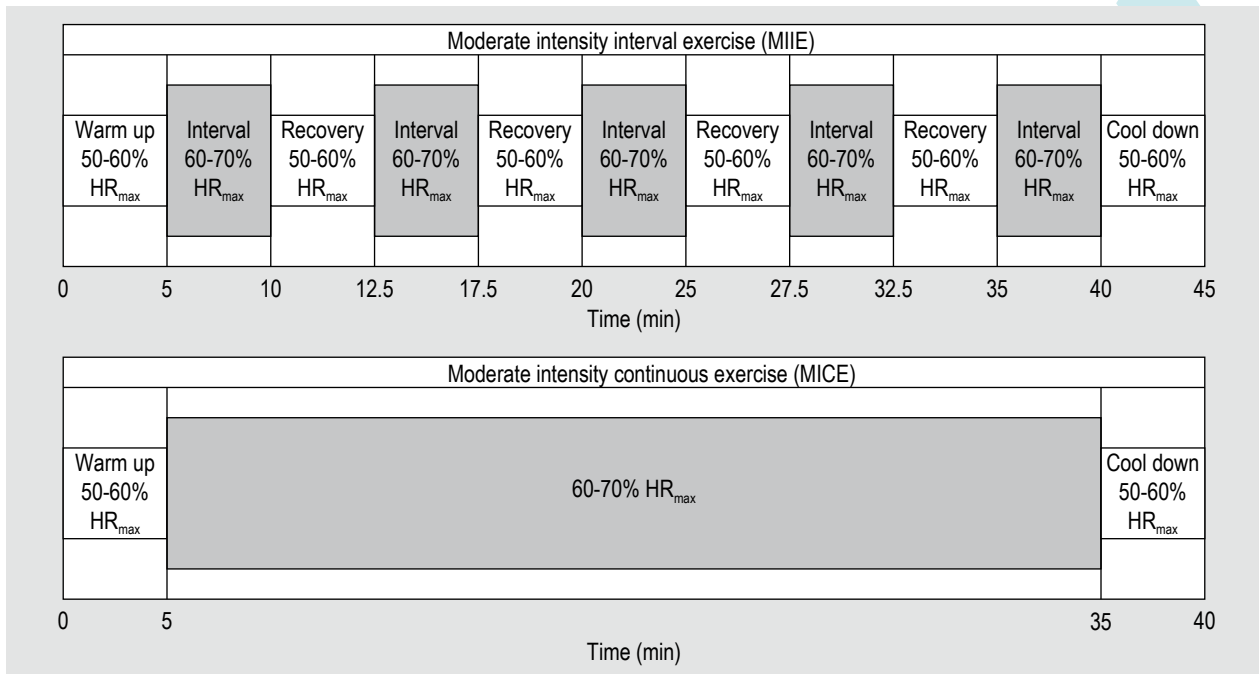
Figure 1. Scheme of detailed duration and intensity of moderate-intensity interval exercise (MIIE) and moderate-intensity continuous exercise (MICE). HR_{max} = maximum heart rate.

mg/dl using an Accu-Chek Performa (Roche, Mannheim, Germany), while Hb was measured g/dl by Easy Touch GCHb (Easy Touch, Hsinchu, Taiwan).

Body composition analysis

The body height of the subject was measured using a stadiometer (SECA, Chino, CA, USA). Body composition includes of body weight, BMI, PBF, fat mass, free fat mass, muscle mass, total body water, bone mass and basal metabolic rate were measured by bio-impedance analysis using a TANITA Body Composition Analyzer DC3607601(2)-1604 FA (TANITA Corporation of America, Inc., Arlington Heights, IL, USA). Waist circumference (WC) was measured by wrapping anthropometric tape measure circularly on the middle between the lower rib and iliac which was parallel to the midaxillary line, whereas hip circumference (HC) was measured by wrapping anthropometric tape measure circularly on great trochanter (Vatier *et al.*, 2014). Waist to hip ratio (WHR) was counted WC divided by HC. This body composition measurement was done at 24 h pre-intervention.

Maximal oxygen volume test

Measurement of maximal oxygen volume (VO_{2max}) by the Astrand 6-min cycle test method was performed by using a Monark 828 E Version 1010 ergo cycle (Monark, Vansbro, Sweden). The heart rate was monitored by a Polar H10 Heart Rate Sensor (Polar Electric, Inc., Bethpage, NY, USA), while oxygen saturation (SpO_2) was evaluated by using a

Beurer Pulse Oximeter (PO 30 Pulse Oximeter, Beurer North America LP, Hallandale Beach, FL, USA). Blood pressure was measured using an OMRON automated device (OMRON Model HEM-7130 L, Omron Co., Osaka, Japan) at the nondominant arm 3 times consecutively with a 1-2 min interval between two measurements while participants were in a seated position.

Statistical analysis

Data were analysed using SPSS for Windows, version 16 (SPSS Inc., Chicago, IL, USA). The normality of data was tested using Shapiro-Wilk, whereas homogeneity was checked using the Levene test. A comparison test was done using one-way ANOVA, two-way ANOVA and continued by Tukey's honestly significant difference (HSD) post hoc test. All data were presented as mean ± standard deviation (SD) and $P<0.05$ was considered significant.

3. Results

Descriptive analysis of subjects' characteristics (anthropometry, physical and physiological condition) in each group is presented in Table 1. The result of the one-way ANOVA test concluded that there was no differences in the subjects' characteristics on all variables from each group ($P>0.05$). Analysis result of pre-exercise, 10 min post-exercise, 6 h post-exercise, and 24 h post-exercise irisin level is shown in Table 2. It shows that the irisin level of MICE is higher than that of MIIE and CON in all-time recorded post-exercise.

Table 1. Subject baseline characteristics.[1]

Variable	CON (n=7)	MIIE (n=7)	MICE (n=7)	ANOVA *P*-values
Anthropometry				
Age (years)	20.67±1.03	21.29±1.49	20.71±0.76	0.551
Body weight (kg)	75.23±6.74	73.26±8.83	72.60±7.89	0.829
Body height (m)	1.59±0.05	1.58±0.07	1.57±0.05	0.942
Body mass index (kg/m^2)	29.85±1.60	28.97±1.85	29.11±1.47	0.606
Percentage body fat (%)	45.47±3.16	43.79±2.43	44.29±2.68	0.546
Fat mass (kg)	34.18±4.14	32.24±4.89	32.33±5.09	0.720
Free fat mass (kg)	40.92±4.25	41.20±4.74	40.33±3.21	0.922
Muscle mass (kg)	38.52±3.89	38.76±4.33	37.96±2.93	0.921
Total body water (kg)	30.20±4.33	31.01±3.86	30.67±2.32	0.919
Total body water (%)	40.15±3.50	42.30±2.24	42.41±2.86	0.315
Bone mass (kg)	2.40±0.35	2.44±0.40	2.37±0.28	0.929
Basal metabolic rate (kcal)	1,366.17±136.62	1,363.29±154.79	1,342.86±108.48	0.942
Waist circumference (cm)	88.17±6.49	85.86±8.33	87.29±10.34	0.888
Hip circumference (cm)	109.33±3.56	107.29±7.89	107.86±6.62	0.843
Waist to hip ratio	0.81±0.03	0.79±0.04	0.80±0.05	0.771
Physical condition				
Resting heart rate (bpm)	76.33±11.27	85.14±10.91	77.86±8.99	0.278
Maximum heart rate (bpm)	199.33±1.03	199.29±1.38	199.43±0.79	0.970
VO$_{2max}$ (ml/kg/min)	27.41±2.37	26.17±1.04	27.51±1.27	0.260
Physiological condition				
Systolic blood pressure (mmHg)	113.33±5.16	112.86±4.88	111.43±3.78	0.739
Diastolic blood pressure (mmHg)	76.67±5.16	75.71±5.34	74.29±5.34	0.719
Oxygen saturation (%)	98.17±0.75	97.86±0.89	98.00±0.82	0.801
Body temperature (°C)	36.32±0.69	36.23±0.49	35.93±0.75	0.537
Fasting blood glucose (mg/dl)	91.67±4.55	89.57±6.13	89.57±8.16	0.809
Hemoglobin (g/dl)	15.32±1.99	15.21±1.01	14.53±1.11	0.544

[1] Data are represented as Mean ± standard deviation. CON = control group; MIIE = moderate-intensity interval exercise group; MICE = moderate-intensity continuous exercise group.

Table 2. Irisin level in each group based on time blood samples.[1,2]

Time	n	CON (ng/ml)	MIIE (ng/ml)	MICE (ng/ml)	ANOVA *P*-values
Pre-exercise	7	3.26±1.28	3.44±0.56	3.89±1.08	0.519
10 min post-exercise	7	2.99±0.86	4.82±1.01*	5.99±1.27*	0.000
6 h post-exercise	7	3.04±0.60	4.56±0.87*	5.73±1.02*†	0.000
24 h post-exercise	7	3.04±0.91	4.64±0.69*	5.69±1.53*	0.002

[1] Data are represented as Mean ± standard deviation. CON = control group; MIIE = moderate-intensity interval exercise group; MICE = moderate-intensity continuous exercise group. *P*-values were obtained using one-way ANOVA.

[2] Tukey's HSD post hoc test was used to compare irisin levels between groups. 10 min post-exercise (*) significant vs CON ($P \le 0.05$). 6 h post-exercise (*) significant vs CON ($P \le 0.05$) and (†) significant vs MIIE ($P \le 0.05$). 24 h post-exercise (*) significant vs CON ($P \le 0.05$).

According to the one-way ANOVA test, the pre-exercise mean irisin level in all groups is not significantly different (*P*=0.519), whereas at 10 min post-exercise the mean irisin level showed a significant difference (*P*=0.000). There are also significant differences at 6 h (*P*=0.000) and 24 h post-exercise (*P*=0.002). Based on the Tukey's HSD post hoc test, there is a significant difference of 10 min post-

exercise irisin level between MIIE and CON (*P*=0.018), MICE and CON (*P*=0.000), while MIIE and MICE are not significantly different (*P*=0.131). At 6 h post-exercise, the irisin level was significantly different between MIIE and CON (*P*=0.014), MICE and CON (*P*=0.000), and MICE and MIIE (*P*=0.042). A significant difference is also found at 24 h post-exercise between MIIE and CON (*P*=0.048),

MICE and CON (*P*=0.001), but not between MIIE and MICE (*P*=0.211).

Figures 2-4 provide a graphical representation of the mean irisin level in each group. Figure 2 shows the result of the two-way ANOVA test indicating there is no significant difference in irisin level based on time samples taken in CON (*P*>0.05), whereas MIIE and MICE shows a significant difference in irisin level based on time samples (*P*<0.05) (Figure 3 and 4). Tukey HSD post hoc test of MIIE shows a significant difference in irisin level between 10 min post-exercise and pre-exercise (*P*=0.018), between 6 h post-exercise and pre-exercise (*P*=0.047), also between 24 h post-exercise and pre-exercise (*P*=0.046). Meanwhile, there are no significant differences between 10 min post-exercise and 6 h post-exercise (*P*=0.929), 10 min post-exercise and 24 h post-exercise (*P*=0.974), as well as 6 h post-exercise and 24 h post-exercise (*P*=0.998) (Figure 3). Based on Tukey HSD post hoc test MICE showed a significant difference in irisin level between 10 min post-exercise and pre-exercise (*P*=0.020), 6 h post-exercise and pre-exercise (*P*=0.038), and 24 h post-exercise and pre-exercise (*P*=0.045). Conversely, there are no significant differences in irisin level between 10 min post-exercise and 6 h post-exercise (*P*=0.979), 10 min post-exercise and 24 h post-exercise (*P*=0.968), as well as 6 h post-exercise and 24 h post-exercise (*P*=1.000) (Figure 4).

4. Discussion

This study was conducted to analyse the response of MIIE and MICE to the increment of irisin levels in females with obesity. According to the one-way ANOVA test, the subjects' characteristics (anthropometry, physical and physiological condition) in all groups were similar (*P*>0.05). Therefore, the three groups were in the same starting point of pre-intervention.

The female subjects were selected based on the risk level of obesity. Females have a higher risk level of overweight and obesity by 1.76 and 3.43 times, respectively, than males (Sudikno *et al.*, 2015). The diagnosis used to determine

Figure 3. Mean irisin level of the moderate-intensity interval exercise group. Data are shown as mean ± standard deviation. *P*-values were obtained using two-way ANOVA to compare 10 min, 6 h, 24 h post-exercise with pre-exercise irisin levels. * Significant vs pre-exercise (*P*≤0.05).

Figure 2. Mean irisin level of the control group. Data are shown as mean ± standard deviation. *P*-values were obtained using two-way ANOVA to compare 10 min, 6 h, 24 h post-exercise with pre-exercise irisin levels.
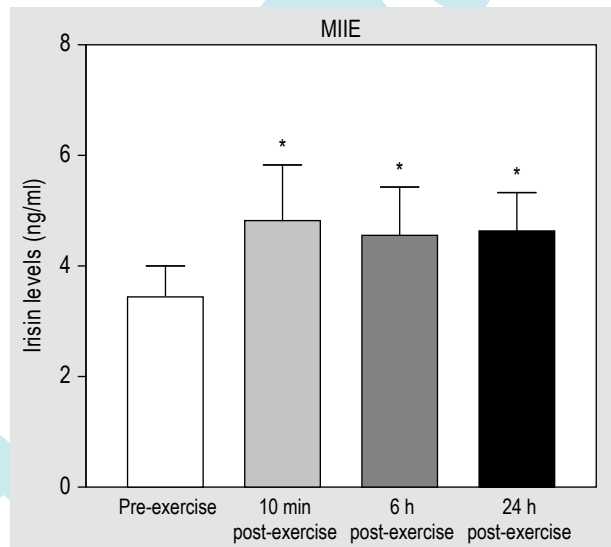
Figure 4. Mean irisin level of the moderate-intensity continuous exercise group. Data are shown as mean ± standard deviation. *P*-values were obtained using two-way ANOVA to compare 10 min, 6 h, 24 h post-exercise with pre-exercise irisin levels. * Significant vs pre-exercise (*P*≤0.05).
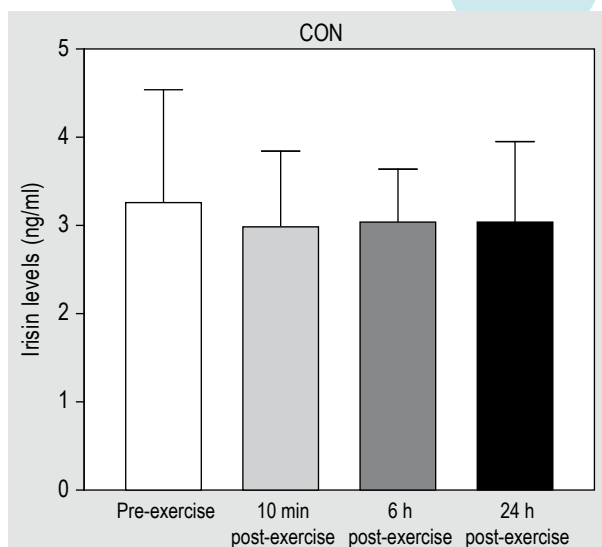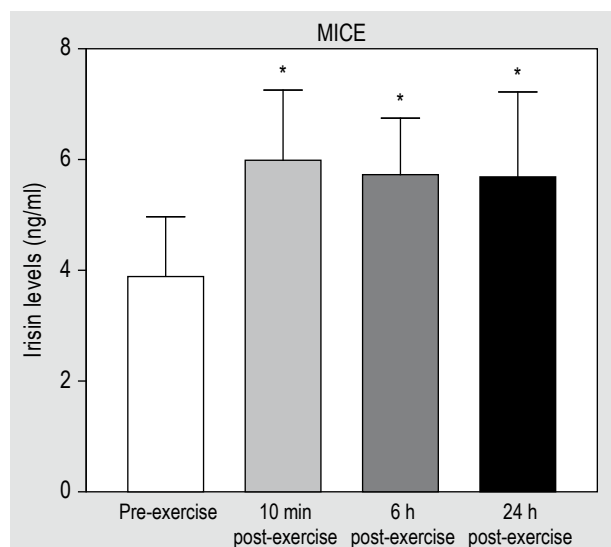
obesity was by anthropometric methods (Sudargo *et al.*, 2016), such as BMI, skinfold thickness, WHR, bioelectrical impedance analysis (BIA) and dual-energy x-ray absorptiometry (DEXA) (Beechy *et al.*, 2012; Da Silvia *et al.*, 2016; Sudargo *et al.*, 2016; Visscher *et al.*, 2010; Zeng *et al.*, 2012). However, this study only used the BMI and PBF parameters to describe body composition in diagnosing obesity. BMI is a parameter used to detect obesity and measure body weight over time (Beechy *et al.*, 2012). However, BMI has low accuracy caused by the inability to describe human composition, such as free fatty mass, fat mass and body fat distribution (Akpinar *et al.*, 2007). Besides, BMI cannot distinguish between fat mass and muscle mass (Nimptsch *et al.*, 2019). Therefore, only using BMI as measurement of body composition to determine the obesity level is not recommended, as it will inhibit obesity prevention and control in the future (Beechy *et al.*, 2012; Chooi *et al.*, 2019). PBF is a body component beside bone mass, muscle mass and body water. PBF represents the body fat mass proportion in body weight (Zeng *et al.*, 2012). Females possess a natural higher PBF than males (Blaak, 2001); they tend to have a 10% higher PBF than that of males in the same BMI class (Jackson *et al.*, 2002). An individual can be classified as obese if the PBF ≥25% (males) or ≥30% (females), according to the Asian BMI criteria (Wen *et al.*, 2009); thus a PBF over 30% was used to classify obesity in this study.

There was a significant difference in irisin level at 10 min, 6 h dan 24 post-exercise in the three groups. We found that both MIIE and MICE had increasing irisin levels at all recorded post-exercise times compared to pre-exercise in each group. During exercise, there was an increase in energy demand for muscle contraction, thus the energy reserved in the muscle decreased, and consequently, increased the release of irisin into the blood to maintain energy balance during exercise. Huh *et al.* (2012) stated that irisin levels significantly increased when muscle ATP decreases. Previous studies conducted on healthy human subjects suggested that irisin and lactate concentrations were positively correlated with increasing exercise load (Daskalopoulou *et al.*, 2014). Our result is similar to the previous researcher's hypothesis that increment of irisin release correlates with energy demands of the muscle during contraction (Daskalopoulou *et al.*, 2014). Our result indicates that the increase in muscle contraction and decrease in ATP during exercise becomes one of marking factors in the increment of irisin release to the blood circulation (Maalouf and Khoury, 2019). Exercise induces irisin release via peroxisome proliferator-activated receptor-γ (PPAR-γ) and PGC-1α (Spiegelman, 2013). PPAR-γ and PGC-1α are multispecific transcriptional co-activators that regulate genes as a response to the nutritional and physiological signals of the tissue. PPAR-γ and PGC-1α are expressed in skeletal muscle, brown adipose tissue, liver and heart (Gizaw *et al.*, 2017; Moreno-Navarrete *et al.*,

2013; Norheim *et al.*, 2014; Xu, 2013). Moderate-intensity exercise increases PGC-1α activation, especially in the heart and skeletal muscle, and also increases some metabolic parameters, such as insulin sensitivity and signalling, and supports AMPK activation, PGC-1α phosphorylation and FNDC5 production; this is followed by FNDC5 division to produce irisin, which will be released into the blood (Moreno-Navarrete *et al.*, 2013; Norheim *et al.*, 2014; Xu, 2013).

According to the analysis, the irisin level increase in MICE was higher than in MIIE and CON. This is similar to the study conducted by Winn *et al.* (2017) using female subjects aged 18-35 years with a BMI over 30 kg/m^2 performing moderate-intensity aerobic exercise (ModEx). The study showed that ModEx significantly increased irisin levels, both during intervention and 190 min post-recovery. It is similar to the study conducted by Kraemer *et al.* (2014) using female and male teenager subjects, who had been instructed to do MICE (60% VO$_{2max}$) using a treadmill. Their results showed that MICE significantly increased irisin levels about 20.4% for males and 24.6% for females. The study by Huh *et al.* (2014) reported that moderate-intensity exercise (CME) significantly increased irisin levels in healthy males. Irisin level increment in MICE is caused by a higher energy requirement than MIIE, thus PGC-1α is activated. PGC-1α activation triggers FNDC-5 expression (Fatouros, 2018) and induces proteolytic cleavage of the FNDC-5 membrane protein in skeletal muscle. Consequently, irisin will be released to the blood circulation (Moreno-Navarrete *et al.*, 2013). The release of irisin into the blood stimulates the browning process in white adipose tissue by triggering UCP-1 expression via p38-MAPK signalling. The process causes an increase of energy expenditure and a decrease of lipid accumulation (Boström *et al.*, 2012; Fatouros, 2018; Perakakis *et al.*, 2017).

Irisin is a hormone that modulates the effect of exercise by regulating energy expenditure and lipid oxidation (Boström *et al.*, 2012). Irisin may act as a muscle-derived energy-expenditure signal that directly communicates with adipose tissue and induces the browning process (Pardo *et al.*, 2014). This effect may improve the white adipose tissue metabolic profile and enhance whole-body energy expenditure, making irisin a potential new target for the treatment of metabolic diseases, including obesity (Benedini *et al.*, 2017; Pardo *et al.*, 2014). Although irisin is known as an exercise-induced myokine, many studies showed inconsistent results. Moreover, highly controversial results concerning the effects of exercise on irisin have been also reported. Based on the systematic review conducted by Dinas *et al.* (2017), thirteen studies showed that acute exercise increased circulating irisin in healthy individuals, while five studies showed no effect of acute exercise on circulating irisin. The study by Huh *et al.* (2012) reported a significant difference in irisin level by acute exercise in

a healthy male, whereas Kurdiova *et al.* (2014) reported that exercise, in an acute form applied to either sedentary or trained individuals, was not effective in modulating the irisin circulating levels and skeletal muscle FNDC5 gene expression. Khodadadi *et al.* (2014) reported that high-intensity interval acute exercise increased irisin (33%, P=0.039) in overweight females. Löffler *et al.* (2015) also reported that acute exercise increased irisin levels in both adults (P=0.006) and children (P<0.001). However, Aydin *et al.* (2013) reported no changes in serum irisin after acute exercise in obese and normal weight males. Moienneia and Hosseini (2016) also found an unchanged irisin level after acute exercise for both low- and high-intensity exercise in sedentary young healthy females. These differences might be the result of a different set-up of the studies compared to our experiments, such as (1) the subjects (they recruited sedentary young healthy females, whereas we recruited young obese females), (2) the intensity of exercise (they applied low-intensity and high-intensity resistance training, whereas we applied MIIE and MICE with treadmill). Therefore, further studies are necessary to evaluate the effects of MIIE and MICE against increase irisin levels on an obese female with a similar study design.

Moreover, highly controversial results obtained with different ELISA kits in exercise studies have been reported. For instance, the research by Huh *et al.* (2015) which compared the resistance exercise results, showed the most dynamic irisin changes (measured using the EK-067-52 kit, Phoenix Pharmaceuticals), with our results using the EK-067-29 kit. Results with the EK-067-52 kit showed approximately 10-fold higher irisin levels than with the EK-067-29 kit, and there was a low correlation between the results from the two kits (r=0.233, P=0.191). Furthermore, Kurdiova *et al.* (2014) reported poor agreement between ELISA kit RK-067-16 (Phoenix Pharmaceuticals) and EK-067-29. Similarly, Montes-Nieto *et al.* (2016) analysed human irisin using two different lots (604824 and 605835) of the EK-067-29 ELISA kit and reported that serum irisin levels determined by lot 604824 were higher in patients with weight excess when compared with lean subjects, but this difference was not found when assaying irisin with lot 605835. Finally, Albrecht *et al.* (2015) also reported that irisin circulating in the blood is largely based on commercial ELISA kits which are based on polyclonal antibodies (pAbs) not previously tested for cross-reacting serum proteins. Albrecht *et al.* (2015) analysed four commercial pAbs by Western blotting, which revealed prominent cross-reactivity with non-specific proteins in human and animal sera. Using recombinant glycosylated and non-glycosylated irisin as positive controls, they found no immune-reactive bands of the expected size in any biological samples. A FNDC5 signature was identified at 20 kDa by mass spectrometry in human serum, but was not detected by the commercial pAbs tested (Albrecht *et al.*, 2015).

Limitations to this current study include (1) small sample size, (2) high drop-out rate, (3) analysis of body composition by BIA, (4) only one parameter measured, (5) lack of evidence of browning markers, and (6) this study only conducted an acute exercise. Firstly, in this study we only used a small sample size with the total number of subjects 21 obese females. Therefore, a future study should include a larger number of female obese subjects. Secondly, the high drop-out rate in each group was as one for the control group, three for MIIE and 5 for the MICE group. The high drop-out rate was due to the inability of the subject to follow the treadmill rhythm; thus the intervention was stopped and the subject was declared a failure in our study methods (dropout). Another subject was also found to be unable to continue to the blood sampling process, due to sickness with physical diagnosis of shortness of breath, pale face, dizziness, and a body temperature above 37.5 °C. Thirdly, although previous studies have reported that BIA has similarity with DEXA in measuring free fat mass, fat mass, PBF, and muscle mass (Fox *et al.*, 1996, Pratley *et al.*, 2000), BIA could not provide conclusive information of body composition that DEXA could have provided (Kim *et al.*, 2016). Fourthly, we only used one parameter to measure irisin levels, whereas other parameters, such as PGC-1α and FNDC-5 would have provided information on irisin levels as well. Fifthly, we were unable to estimate browning markers, such as UCP1, PR domain containing 16 (PRDM16), and other cytokines that might be related to circulating irisin levels, such as interleukin 6. Lastly, this study only conducted an acute intervention (exercise), thus further studies are required to find out the effect of a chronic intervention (training) in obese females. Besides, irisin measurements should be done in more than 24 h (e.g. 36, 48, and 72 h post-exercise). The results are expected to be useful for stabilising an optimal exercise frequency in obesity management in the future.

5. Conclusions

Based on the results of this study it can be concluded that the post-exercise serum irisin levels increased both in MICE and MIIE, and post-exercise serum irisin level were maintained at a higher level in MICE compared to MIIE in obese females. These results suggest that MICE is more effective to increase serum irisin levels than MIIE.

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Conflict of interest

The authors declare that they have no competing interests.

References

Agofure, O., 2017. Prevalence of obesity among adults in Issele-Uku, Delta State Nigeria. Alexandria Journal of Medicine 54: 463-468. https://doi.org/10.1016/j.ajme.2017.10.005

Akpinar, E., Bashan, I., Bozdemir, N. and Saatci, E., 2007. Which is the best anthropometric technique to identify obesity: body mass index, waist circumference or waist-hip ratio? Collegium Antropologicum 31: 387-393.

Akter, S., Rahman, M.M., Abe, S.K. and Sultana, P., 2014. Prevalence of diabetes and prediabetes and their risk factors among Bangladeshi adults: a nationwide survey. Bulletin of the World Health Organization 92: 204-213. https://doi.org/10.2471/BLT.13.128371

Albrecht, E., Norheim, F., Thiede, B., Holen, T., Ohashi, T., Schering, L., Lee, S., Brenmoehl, J., Thomas, S., Drevon, C.A., Erickson, H.P. and Maak, S., 2015. Irisin – a myth rather than an exercise-inducible myokine. Scientific Reports 5: 8889. https://doi.org/10.1038/srep08889

Aydin, S., Aydin, S., Kuloglu, T., Yilmaz, M., Kalayci, M., Sahin, I. and Cicek, D. 2013. Alterations of irisin concentrations in saliva and serum of obese and normal-weight subjects, before and after 45 min of a Turkish bath or running. Peptides 50: 13-18. https://doi.org/10.1016/j.peptides.2013.09.011

Bales, C.W. and Buhr G., 2008. Is obesity bad for older persons? A systematic review of the pros and cons of weight reduction in later life. Journal of the American Medical Directors Association 9: 302-312. https://doi.org/10.1016/j.jamda.2008.01.006

Basic Health Research (Riskesdas). 2018. National report on basic health research. Ministry of Health, Jakarta, Indonesia. Available at: http://www.kesmas.kemkes.go.id

Bautista, R.J.H. Mahmoud, A.M., Königsberg, M. and Guerrero, N.E.L.D., 2019. Obesity: pathophysiology, monosodium glutamate-induced model and anti-obesity medicinal plants. Biomedicine and Pharmacotherapy. 111: 503-516. https://doi.org/10.1016/j.biopha.2018.12.108

Beechy, L., Galpern, J., Petrone, A. and Das, S.K., 2012. Assessment tools in obesity – psychological measures, diet, activity, and body composition. Physiology and Behavior 107: 154-171. https://doi.org/10.1016/j.physbeh.2012.04.013

Benedini, S., Dozio, E., Invernizzi, P.L., Vianello, E., Banfi, G., Terruzzi, I., Luzi, L. and Romanelli, M.M., 2017. Irisin: a potential link between physical exercise and metabolism – an observational study in differently trained subjects, from elite athletes to sedentary people. Journal of Diabetes Research 2017: 1039161. https://doi.org/10.1155/2017/1039161

Blaak, E., 2001. Gender differences in fat metabolism. Current Opinion in Clinical Nutrition and Metabolic Care 4: 499-502. https://doi.org/10.1097/00075197-200111000-00006

Boström, P., Wu, J., Jedrychowski, M.P., Korde, A., Ye, L., Lo, J.C., Rasbach, K.A., Boström, E.A., Choi, J.H., Long, J.Z., Kajimura, S., Zingaretti, M.C., Vind, B.F., Tu, H., Cinti, S., Hojlund, K., Gygi, S.P. and Spiegelman, B.M., 2012. A PGC1α-dependent myokine that drives browning of white fat and thermogenesis. Nature 481: 463-468. https://doi.org/10.1038/nature10777.A

Chooi, Y.C., Ding, C. and Magkos, F., 2019. The epidemiology of obesity. Metabolism: Clinical and Experimental 92: 6-10. https://doi.org/10.1016/j.metabol.2018.09.005

Da Silva, A.P., Matos, A., Valente, A., Gil, A., Alonso, I., Ribeiro, R. and Gorjão-Clara, J., 2016. Body composition assessment and nutritional status evaluation in men and women Portuguese centenarians. Journal of Nutrition, Health and Aging 20: 256-266. https://doi.org/10.1007/s12603-015-0566-0

Daskalopoulou, S.S., Cooke, A.B., Gomez, Y.H., Mutter, A.F., Filippaios, A., Mesfum, E.T. and Mantzoros, C.S., 2014. Plasma irisin levels progressively increase in response to increasing exercise workloads in young, healthy, active subjects. European Journal of Endocrinology 171: 343-352. https://doi.org/10.1530/EJE-14-0204

Dias, K.A., Ingul, C.B., Tjonna, A.E., Keating, S.E., Gomersall, S.R., Follestad, T., Hosseini, M.S., Hollekim-Strand, S.M., Ro, T.B., Haram, M., Huuse, E.M., Davies, P.S.W., Cain, P.A., Leong, G.M. and Coombes, J.S., 2018. Effect of high-intensity interval training on fitness, fat mass and cardiometabolic biomarkers in children with obesity: a randomised controlled trial. Sports Medicine 48: 733-746. https://doi.org/10.1007/s40279-017-0777-0

Dinas, P.C., Lahart, I.M., Timmons, J.A., Svensson, P.-A., Koutedakis, Y., Flouris, A.D. and Metsios, G.S., 2017. Effects of physical activity on the link between PGC-1a and FNDC5 in muscle, circulating irisin and UCP1 of white adipocytes in humans: a systematic review. F1000 Research 6: 286. https://doi.org/10.12688/f1000research.11107.2

Fatouros, I.G., 2018. Is irisin the new player in exercise-induced adaptations or not? A 2017 update. Clinical Chemistry and Laboratory Medicine 56: 525-548. https://doi.org/10.1515/cclm-2017-0674

Fox, A.A., Thompson, J.L., Butterfield, G.E., Gylfadottir, U., Moynihan, S. and Spiller, G., 1996. Effects of diet and exercise on common cardiovascular disease risk factors in moderately obese older women. American Journal of Clinical Nutrition 63: 225-233. https://doi.org/10.1093/ajcn/63.2.225

Gadde, K.M., Martin, C.K., Berthoud, H.R. and Heymsfield, S.B., 2018. Obesity: pathophysiology and management. Journal of the American College of Cardiology 71: 69-84. https://doi.org/10.1016/j.jacc.2017.11.011

Garber, C.E., Blissmer, B., Deschenes, M.R., Franklin, B.A., Lamonte, M.J., Lee, I.M., Nieman, D.C. and Swain, D.P., 2011. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Medicine and Science in Sports and Exercise 43: 1334-1359. https://doi.org/10.1249/MSS.0b013e318213fefb

Gizaw, M., Anandakumar, P. and Debela T., 2017. A review on the role of irisin in insulin resistance and type 2 diabetes mellitus. Journal of Pharmacopuncture 20: 235-242. https://doi.org/10.3831/KPI.2017.20.029

Huh, J.Y., Mougios, V., Kabasakalis, A., Fatourus, I., Siopi, A., Douroudos, I.I., Filippaios, A., Panagiotou, G., Park, K.H. and Mantzoros, C.S., 2014. Exercise-induced irisin secretion is independent of age or fitness level and increased irisin may directly modulate muscle metabolism through AMPK activation. Journal of Clinical Endocrinology and Metabolism 99: E2154-E2161. https://doi.org/10.1210/jc.2014-1437

Huh, J.Y., Panagiotou, G., Mougios, V., Brinkoetter, M., Vamvini, M.T., Schneider, B.E. and Mantzoros, C.S., 2012. FNDC5 and irisin in humans: I. Predictors of circulating concentrations in serum and plasma and II. mRNA expression and circulating concentrations in response to weight loss and exercise. Metabolism: Clinical and Experimental 61: 1725-1738. https://doi.org/10.1016/j.metabol.2012.09.002

Jackson, A.S., Stanforth, P.R., Gagnon, J., Rankinen, T., Leon, A.S., Rao, D.C., Skinner, J.S., Bouchard, C. and Wilmore, J.H., 2002. The effect of sex, age and race on estimating percentage body fat from body mass index: the heritage family study. International Journal of Obesity 26: 789-796. https://doi.org/10.1038/sj.ijo.0802006.

Kelly, T., Yang, W., Chen, C.S., Reynolds, K. and He J., 2008. Global burden of obesity in 2005 and projections to 2030. International Journal of Obesity 32: 1431-1437. https://doi.org/10.1038/ijo.2008.102

Khodadadi, H., Rajabi, H., Attarzadeh, S.R.S.R. and Abbasian, S., 2014. The effect of high intensity interval training (HIIT) and pilates on levels of irisin and insulin resistance in overweight women. Iranian Journal of Endocrinology and Metabolism 16: 190-196.

Kim, H.-J., Lee, H.-J., So, B., Son, J.S., Yoon, D. and Song, W., 2016. Effect of aerobic training and resistance training on circulating irisin level and their association with change of body composition in overweight/obese adults: a pilot study. Physiological Research 65: 271-279. https://doi.org/10.33549/physiolres.932997

Kraemer, R.R., Shockett, P., Webb, N.D., Shah, U. and Castracane, V.D., 2014. A transient elevated irisin blood concentration in response to prolonged, moderate aerobic exercise in young men and women. Hormone and Metabolic Research 46: 150-154. https://doi.org/10.1055/s-0033-1355381

Kurdiova, T., Balaz, M., Vician, M., Maderova, D., Vlcek, M., Valkovic, L., Srbecky, M., Imrich, R., Kyselovicova, O., Belan, V., Jelok, I., Wolfrum, C., Klimes, I., Krssak, M., Zemkova, E., Gasperikova, D., Ukropec, J. and Ukropcova, B., 2014. Effects of obesity, diabetes and exercise on Fndc5 gene expression and irisin release in human skeletal muscle and adipose tissue: *in vivo* and *in vitro* studies. Journal of Physiology 592: 1091-1107. https://doi.org/10.1113/jphysiol.2013.264655

Löffler, D., Müller, U., Scheuermann, K., Friebe, D., Gesing, J., Bielitz, J., Erbs, S., Landgraf, K., Wagner, I.V., Kiess, W. and Körner, A., 2015. Serum irisin levels are regulated by acute strenuous exercise. Journal of Clinical Endocrinology and Metabolism 100: 1289-1299. https://doi.org/10.1210/jc.2014-2932

Maalouf, G.-E. and Khoury, D.E., 2019. Exercise-induced irisin, the fat browning myokine, as a potential anticancer agent. Journal of Obesity 2019: 6561726. https://doi.org/10.1155/2019/6561726

Malnick, S.D.H. and Knobler, H., 2006. The medical complications of obesity. QJM: An International Journal of Medicine 99: 565-579. https://doi.org/10.1093/qjmed/hcl085

Moienneia, N. and Hosseini, S.R.A., 2016. Acute and chronic responses of metabolic myokine to different intensities of exercise in sedentary young women. Obesity Medicine 1: 15-20. https://doi.org/10.1016/j.obmed.2015.12.002

Montes-Nieto, R., Martínez-García, M.Á., Luque-Ramírez, M. and Escobar-Morreale, H.F., 2016. Differences in analytical and biological results between older and newer lots of a widely used irisin immunoassay question the validity of previous studies. Clinical Chemistry and Laboratory Medicine 54: e199-201. https://doi.org/10.1515/cclm-2015-1071

Moreno-Navarrete, J.M. and Fernández-Real, J.M., 2019. The complement system is dysfunctional in metabolic disease: evidences in plasma and adipose tissue from obese and insulin resistant subjects. Seminars in Cell and Developmental Biology 85: 164-172. https://doi.org/10.1016/j.semcdb.2017.10.025

Moreno-Navarrete, J.M., Ortega, F., Serrano, M., Guerra, E., Pardo, G., Tinahones, F., Ricart, W. and Fernandez-Real, J.M., 2013. Irisin is expressed and produced by human muscle and adipose tissue in association with obesity and insulin resistance. Journal of Clinical Endocrinology and Metabolism 98: 769-778. https://doi.org/10.1210/jc.2012-2749

Murawska-Cialowicz, E., Wojna, J. and Zuwala-Jagiello, J., 2015. Crossfit training changes brain-derived neurotrophic factor and irisin levels at rest, after wingate and progressive tests and improves aerobic capacity and body composition of young physically active men and women. Journal of Physiology and Pharmacology 66: 811-821.

Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., Mullany, E.C., Biryukov, S., Abbafati, C., Abera, S.F., Abraham, J.P., Abu-Rmeileh, N.M.E., Achoki, T., AlBuhairan, F.S., Alemu, Z.A., Alfonso, R., Ali, M.K., Ali, R., Guzman, N.A., Ammar, W., Anwari, P., Banerjee, A., Barquera, S., Basu, S., Bennett, D.A., Bhutta, Z., Blore, J., Cabral, N., Nonato, I.C., Chang, J., Chowdhury, R., Courville, K.J., Criqui, M.H., Cundiff, D.K., Dabhadkar, K.C., Dandona, L., Davis, A., Dayama, A., Dharmaratne, S.D., Ding, E.L., Durrani, A.M., Esteghamati, A., Farzadfar, F., Fay, D.F.J., Feigin, V.L., Flaxman, A., Forouzanfar, M.H., Goto, A., Green, M.A., Gupta, R., Hafezi-Nejad, N., Hankey, G.J., Harewood, H.C., Havmoeller, R., Hay, S., Hernandez, L., Husseini, A., Idrisov, B.T., Ikeda, N., Islami, F., Jahangir, E., Jassal, S.K., Jee, S.H., Jeffreys, M., Jonas, J.B., Kabagambe, E.K., Khalifa, S.E.A.H., Kengne, A.P., Khader, Y.S., Khang, Y., Kim, D., Kimokoti, R.W., Kinge, J.M., Kokubo, Y., Kosen, S., Kwan, G., Lai, T., Leinsalu, M., Li, Y., Liang, X., Liu, S., Logroscino, G., Lotufo, P.A., Lu, Y., Ma, J., Mainoo, N.K., Mensah, G.A., Merriman, T.R., Mokdad, A.H., Moschandreas, J., Naghavi,

M., Naheed, A., Nand, D., Narayan, K.M.V., Nelson, E.L., Neuhouser, M.L., Nisar, M.I., Ohkubo, T., Oti, S.O., Pedroza, A., Prabhakaran, D., Roy, N., Sampson, U., Seo, H., Sepanlou, S.G., Shibuya, K., Shiri, R., Shiue, I., Singh, G.M., Singh, J.A., Skirbekk, V., Stapelberg, N.J.C., Sturua, L., Sykes, B.L., Tobias, M., Tran, B.X., Trasande, L., Toyoshima, H., Van de Vijver, S., Vasankari, T.J., Veerman, J.L., Velasquez-Melendez, G., Vlassov, V.V., Vollset, S.E., Vos, T., Wang, C., Wang, S.X., Weiderpass, E., Werdecker, A., Wright, J.L., Yang, Y.C.,Yatsuya, H., Yoon, J., Yoon, S., Zhao, Y., Zhou, M., Zhu, S., Lopez, A.D., Murray, C.J.L. and Gakidou, E., 2014. Global regional and national prevalence of overweight and obesity in children and adults 1980-2013: a systematic analysis. The Lancet 384: 766-781. https://doi.org/10.1016/S0140-6736(14)60460-8

Nimptsch, K., Konigorski, S. and Pischon, T., 2019. Diagnosis of obesity and use of obesity biomarkers in science and clinical medicine. Metabolism: Clinical and Experimental 92: 61-70. https://doi.org/10.1016/j.metabol.2018.12.006

Norheim, F., Langleite, T.M., Hjorth, M., Holen, T., Kielland, A., Stadheim, H.K., Gulseth, H.L., Birkeland, K.I., Jensen, J. and Drevon, C.A., 2014. The effects of acute and chronic exercise on PGC-1α, irisin and browning of subcutaneous adipose tissue in humans. FEBS Journal 281:739-749. https://doi.org/10.1111/febs.12619

Pardo, M., Crujeiras, A.B., Amil, M., Aguera, Z., Jiménez-Murcia, S., Baños, R., Botella, C., De la Torre, R., Estivill, X., Fagundo, A.B., Fernández-Real, J.M., Fernández-García, J.C., Fruhbeck, G., Gómez-Ambrosi, J., Rodríguez, R., Tinahones, F.J., Fernández-Aranda, F. and Casanueva, F.F., 2014. Association of irisin with fat mass, resting energy expenditure, and daily activity in conditions of extreme body mass index. International Journal of Endocrinology 2014: 857270. http://dx.doi.org/10.1155/2014/857270.

Perakakis, N., Triantafyllou, G.A., Fernández-Real, J.M., Huh, J.Y., Park, K.H., Seufert, J. and Mantzoros, C.S., 2017. Physiology and role of irisin in glucose homeostasis. Nature Reviews Endocrinology 13: 324-337. https://doi.org/10.1038/nrendo.2016.221

Peterson, J.M., Mart, R. and Bond, C.E., 2014. Effect of obesity and exercise on the expression of the novel myokines, myonectin and fibronectin type III domain containing 5. PeerJ 2: e605. https://doi.org/10.7717/peerj.605

Pratley, R.E., Hagberg, J.M., Dengel, D.R., Rogus, E.M., Muller, D.C. and Goldberg, A.P., 2000. Aerobic exercise training-induced reductions in abdominal fat and glucose-stimulated insulin responses in middle-aged and older men. Journal of the American Geriatrics Society 48: 1055-1061. https://doi.org/10.1111/j.1532-5415.2000.tb04780.x

Rosella, L.C., Kornas, K., Huang, A., Grant, L., Bornbaum, C. and Henry, D., 2019. Population risk and burden of health behavioral-related all-cause, premature and amenable deaths in Ontario, Canada: Canadian Community Health Survey – linked mortality files. Annals of Epidemiology 32: 49-57. https://doi.org/10.1016/j.annepidem.2019.01.009.

Spiegelman, B.M., 2013. Banting lecture 2012: regulation of adipogenesis: toward new therapeutics for metabolic disease. Diabetes 62: 1774-1782. https://doi.org/10.2337/db12-1665

Sudargo, T., Freitag, H., Rosiyani, F. and Kusmayanti, N.A., 2016. Dietary habit and obesity. Gadjah Mada University Press, Yogyakarta, Indonesia.

Sudikno Syarief, H., Dwiriani, C.M. and Riyadi, H., 2015. Risk factors of overweight and obese in Indonesian adults (analysis data of basic health research 2013). Journal of the Indonesian Nutrition Association 38: 91-104.

Tew, G.A., Leighton, D., Carpenter, R., Anderson, S., Langmead, L., Ramage, J., Faulkner, J., Coleman, E., Fairhurst, C., Seed, M. and Bottoms, L., 2019. High-intensity interval training and moderate-intensity continuous training in adults with Crohn's disease: a pilot randomised controlled trial. BMC Gastroenterology 19: 1-11. https://dx.doi.org/10.1186/s12876-019-0936-x

The Global Burden of Disease (GBD) 2015 Obesity Collaborators, 2017. Health effects of overweight and obesity in 195 countries over 25 years. New England Journal of Medicine 377: 13-27. https://doi.org/10.1056/NEJMoa1614362

Tsuchiya, Y., Ando, D., Goto, K., Kiuchi, M., Yamakita, M. and Koyama, K., 2014. High-intensity exercise causes greater irisin response compared with low-intensity exercise under similar energy consumption. Tohoku Journal of Experimental Medicine 233: 135-140. https://doi.org/10.1620/tjem.233.135

Tsuchiya, Y., Ando, D., Takamatsu, K. and Goto, K., 2015. Resistance exercise induces a greater irisin response than endurance exercise. Metabolism: Clinical and Experimental 64: 1042-1050. https://doi.org/10.1016/j.metabol.2015.05.010

Vatier, C., Poitou, C. and Clément, K. 2014. Evaluation of visceral fat in massive obesity. In: Watson, R.R (ed.) Nutrition in the prevention and treatment of abdominal obesity. Elsevier Inc., New York, NY, USA, pp. 67-77. https://doi.org/10.1016/B978-0-12-407869-7.00006-4

Visscher, T.L.S., Snijder, M.B. and Seidell, J.C., 2010. Epidemiology: definition and classification of obesity. In: Kopelman, P.G. and Caterson, I.D. (eds.) Clinical obesity in adults and children. Wiley-Blackwell, Hoboken, NJ, USA, pp. 3-14.

Wen, C.P., Cheng, T.Y.D., Tsai, S.P., Chan, H.T., Hsu, H.L., Hsu, C.C. and Eriksen, M.P., 2009. Are Asians at greater mortality risks for being overweight than Caucasians redefining obesity for Asians. Public Health Nutrition 12: 497-506. https://doi.org/10.1017/S1368980008002802

Wewege, M., Van den Berg, R., Ward, R.E. and Keech, A., 2017. The effects of high-intensity interval training vs. moderate-intensity continuous training on body composition in overweight and obese adults: a systematic review and meta-analysis. Obesity Reviews 18: 635-646. https://doi.org/10.1111/obr.12532

Winn, N.C., Grunewald, Z.I., Liu, Y., Heden, T.D., Nyhoff, L.M. and Kanaley, J.A., 2017. Plasma irisin modestly increases during moderate and high-intensity afternoon exercise in obese females. PLoS ONE 12: e0170690. https://doi.org/10.1371/journal.pone.0170690

Xu, B., 2013. BDNF (I) rising from exercise. Cell Metabolism 18: 612-614. https://doi.org/10.1016/j.cmet.2013.10.008

Zeng, Q., Dong, S.Y., Sun, X.N., Xie, J. and Cui, Y., 2012. Percent body fat is a better predictor of cardiovascular risk factors than body mass index. Brazilian Journal of Medical and Biological Research 45: 591-600. https://doi.org/10.1590/S0100-879X2012007500059

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$$0.9 = \frac{122 \text{ Citations } 2017 - 2020}{132 \text{ Documents } 2017 - 2020}$$

Calculated on 05 May, 2021

CiteScoreTracker 2021 ⓘ

$$1.3 = \frac{211 \text{ Citations to date}}{167 \text{ Documents to date}}$$

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CiteScore rank 2020 ⓘ

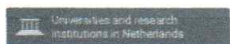| Category	Rank	Percentile
Veterinary └ Veterinary (miscellaneous)	#10/16	40th
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Medicine		

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Comparative Exercise Physiology

COUNTRY	SUBJECT AREA AND CATEGORY	PUBLISHER	H-INDEX
Netherlands	Biochemistry, Genetics and Molecular Biology	Wageningen Academic Publishers	**17**

COUNTRY

Netherlands

Universities and research institutions in Netherlands

SUBJECT AREA AND CATEGORY

Biochemistry, Genetics and Molecular Biology
- Biochemistry
- Biophysics
- Physiology

Medicine
- Endocrinology, Diabetes and Metabolism
- Orthopedics and Sports Medicine
- Physiology (medical)

Veterinary
- Veterinary (miscellaneous)

PUBLISHER

Wageningen Academic Publishers

Wageningen University and Research Centre in Scimago Institutions Rankings

H-INDEX

17

PUBLICATION TYPE	ISSN	COVERAGE	INFORMATION
Journals	17552540, 17552559	2008-2010, 2012-2021	Homepage

INFORMATION

Homepage

How to publish in this journal

CEP@WageningenAcademic.com

SCOPE

'Comparative Exercise Physiology' is the only international peer-reviewed scientific journal specifically dealing with the latest research in exercise physiology across all animal species, including humans. The major objective of the journal is to use this comparative approach to better understand the physiological, nutritional, and biochemical parameters that determine levels of performance and athletic achievement. Core subjects include exercise physiology, biomechanics, gait (including the effect of riders in equestrian sport), nutrition and biochemistry, injury and rehabilitation, psychology and behaviour, and breeding and genetics. This comparative and integrative approach to exercise science ultimately highlights the similarities as well as the differences between humans, horses, dogs, and other athletic or non-athletic species during exercise. The result is a unique forum for new information that serves as a resource for all who want to understand the physiological challenges with exercise.
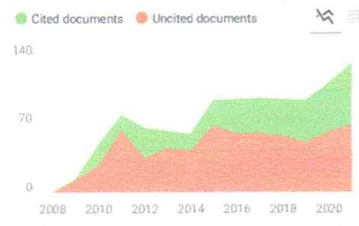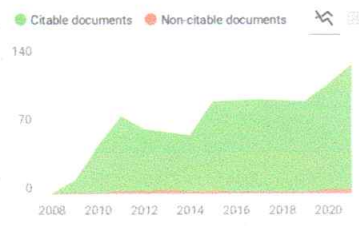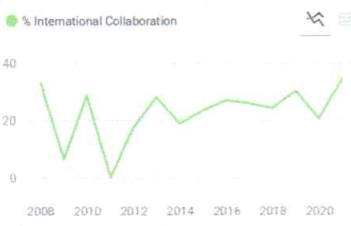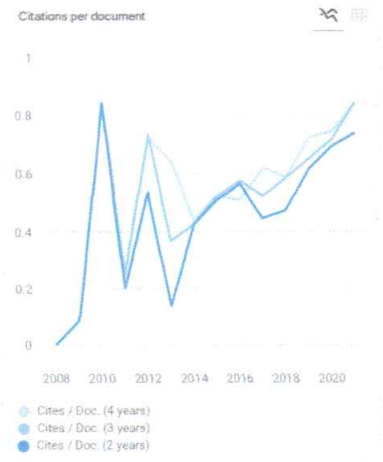
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Comparative Exercise Physiology

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