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Serum irisin concentration and its association with muscle and fat mass in aerobic and anaerobic endurance athlete men and women

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Abstract

Introduction. Irisin is released in response to exercise, but the regulatory effect of exercise on serum irisin is controversial. Evidence linking irisin with muscle mass or fat mass is limited. Little is known about the connection of irisin with the type and intensity of exercise in athletes. Aim of Study. This study sought to determine serum irisin concentration (SIC) in athletes and non-athletes and assess its association with anthropometric indices, including body weight (BW), body mass index (BMI), waist-to-height ratio (WHtR), mid-upper arm circumference (MUAC), lean body mass (LBM), and fat mass (FM). Material and Methods. We conducted a case-control study on 72 athletes and non-athletes comprising three age-and sex--matched groups with a 1 : 1 sex ratio: 24 footballers (aerobic endurance exercise), 24 bodybuilders (anaerobic strength exercise), and 24 non-exercised controls. Standard protocols for measuring anthropometric indices and quantifying SIC were followed. Results. Whole athletes had higher SIC than controls, with footballer men and women having higher values than bodybuilders and controls. Athletic men and women exhibited higher SIC than control men. SIC showed no sex differences within each experimental and control group. SIC negatively correlated with BW, BMI, LBM, MUAC, and WHtR in athlete women, BMI and MUAC in bodybuilders, FM in whole footballers, and BW in total control, but positively correlated with overall bodybuilders. Conclusions. The findings indicate that irisin is exercise-dependent, as it is enhanced in aerobic endurance more than in anaerobic strength exercise but is gender-independent. The results also support the relationship between irisin and body composition, as it generally correlates negatively with BW, BMI, FM, and WHtR.

KEYWORDS: irisin, soccer players, bodybuilders, muscle mass, fat mass.

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Introduction

Irisin is a novel hormone identified in 2012 [5]. It is released in response to exercise after stimulation of peroxisome proliferator activator γ coactivator-1 alpha (PGC1α), which in turn stimulates the expression of the fibronectin type III domain containing 5 (FNDC5) and the proteolysis of this gene produces irisin. Irisin is released from skeletal muscle in mice and humans into circulation targeted toward white adipose tissue as a chemical messenger [5]. Irisin is also considered an adipokine released from adipose tissue [23]. The hormone increases the expression of uncoupling protein 1, resulting in increased thermogenesis, enhanced systemic metabolism, and boosted energy expenditure [17]. Thus, irisin seems promising in controlling chronic disorders such as cardiometabolic disease, obesity, and diabetes [14]. In th on the net energy balance than the exercise's direct energy cost; thus, exercise may boost the resting metabolic rate [18, 24]. Browning the white adipose tissue by irisin is one of the suggested mechanisms [5]. Sports are classified according to the type and intensity of exercise, into dynamic and static, and based on

muscle metabolism, into aerobic and anaerobic [19]. Most high-intensity static exercises, such as muscle building, are performed anaerobically; while high--intensity, dynamic exercises lasting for more than several minutes, like football, are performed aerobically [19]. Although the connection between irisin and exercise has been suggested, the evidence is inconsistent. Several debatable studies that relate irisin to exercise in normal subjects are available [6, 7, 10, 13, 20, 22, 28]. Circulating irisin levels did not rise after aerobic endurance training, or with strength endurance training [10, 20, 22]. Cooke et al. [6] and Daskalopoulou et al. [7] reported that different protocols of exercise raised irisin levels, while Tsuchiya et al. [28] suggested that different exercise intensities affected irisin secretion. Kraemer et al. [13] indicated that prolonged aerobic exercise produces a transient increase in irisin concentrations during the first hour for both genders. The different experimental protocols, gender, age, body composition, and genetics are among the reasons for the present controversy.

Muscle mass is responsible for about 80% of energy expenditure, and irisin is proposed to increase energy expenditure, suggesting an interchangeable relationship between muscle mass and irisin [26]. Muscle mass is also affected by the type of exercise, and high-intensity anaerobic exercise is responsible for the anabolic process that leads to muscle hypertrophy, a critical adaptation in muscles for optimal performance [27]. Circulating irisin levels decrease as the body mass index (BMI) decreases in normal and obese individuals [25]. However, the connection between irisin and indices of body composition, including body weight (BW), BMI, waist circumference (WC), hip circumference (HC), waist-hip ratio (WHR), waist-to-height ratio (WHtR), mid-upper arm circumference (MUAC), lean body mass (LBM), and fat mass (FM) among athletes and non--athletes is generally lacking. Therefore, the objective of the present study was to determine serum irisin concentration in non-athletes and athletes who regularly engaged in aerobic and anaerobic sports and assess its association with anthropometric indices, including BW, BMI, WC, HC, WHR, WHtR, MUAC, LBM, and FM.

Materials and Methods

Participants and study design

A case-control study was undertaken and included three groups of healthy Jordanian men and women aged 20-35, performing aerobic endurance exercise, strength endurance exercise, and not performing any exercise. The study sample (72 participants, 36 men, and 36 women) included three age-and sex-matched groups with varying levels of physical activity. The first group was 24 participants (12 men and 12 women) who followed their habitual lifestyle and physical activity and were not performing any regular exercise regimens (unexercised status: 1 hour a week of regular activity for at least one year), as described elsewhere [10]. The participants were recruited from office workers who usually came to their job by car. The second and the third groups, each of which were also 24 participants (12 men and 12 women) and for at least one year were regularly performing either dynamic aerobic endurance exercise, i.e., aerobic high intensity and long-duration exercise, or strength endurance exercise, i.e., static anaerobic high--intensity exercise [1]. The second group comprised football players who were regularly training for 90 minutes every day, three times a week (Jordan Football Association, personal communication, 2022) and were recruited from among the professional players of the Jordan Football Association, Amman-Jordan. The third group included bodybuilders who were regularly training for 90 minutes every day, six days a week (Jordan Bodybuilding Federation, personal communication, 2022), and were recruited from among the professional players of the Jordan Bodybuilding Federation, Amman-Jordan.

Inclusion criteria included: age 20 to 35 years, non--smokers, non-pregnant and non-lactating women, taking no medications or medicinal herbs, and having no diseases or abnormalities that would interfere with exercise or require regular medication, including heart, kidney, thyroid, and respiratory problems, diabetes mellitus, and iron deficiency anemia [10]. Any participant who did not fit the inclusion criteria was excluded. The study was approved by the Institutional Ethics Committee. All participants provided written informed consent before their involvement in the study. The investigator interviewed each participant to obtain information regarding their personal, social, and health history to affirm the inclusion and exclusion criteria. The investigator was also authorized to refer to each player's medical records to check their health condition to see if it did fit the inclusion criteria.

Data collection

The investigator interviewed each participant for data collection, including personal information and anthropometric measurements. The BW, height, BMI, WC, HC, MUAC, LBM, and FM were evaluated following standard methods of anthropometry [15]. The weight was measured with light clothing and without shoes to the nearest 0.1 kg using a measuring scale, and height was recorded to the nearest 0.5 cm using

a stadiometer. The WC was measured standing to the nearest 5 mm at a level midway between the lower rib margin and the iliac crest during the normal end--expiratory phase. The HC was measured at the level of the greater trochanters. The MUAC was measured on a straight left arm, mid-way between the tip of the shoulder and the tip of the elbow. The BMI was calculated as BW (kg) divided by height (m^2), WHtR was obtained by dividing the WC by height, and WHR was computed as the WC divided by HC. A Harpenden skinfold caliper (British Indicators Ltd., England) was used to measure the skinfold thickness of two body sites, from which body fat and LBM were calculated according to the regression equations of Durnin and Womersley, 1974 [8]. Systolic (SBP) and diastolic (DBP) blood pressure were measured twice using a standardized mercury sphygmomanometer after seating the subject for at least 15 minutes, and then the average blood pressure was recorded [15].

Serum irisin determination

Blood samples (5 ml) were collected from each participant following an overnight fast (10-12 h) and 24 hours of not performing any exercise by a licensed phlebotomist in a sitting position according to a standard protocol. Serum was obtained using a serum separator tube. Samples were allowed to clot at room temperature for 30 minutes before centrifugation for 20 minutes and stored frozen at –20°C until analysis. Serum from each participant was processed in one batch for irisin concentrations using standard biochemical kits and the ELISA (catalog # K4761-100, 100assays; Biovision, S. Milpitas Blvd., Milpitas, CA 95035 USA) assay method.

Statistical analysis

Data analysis was performed using statistical analysis software (SPSS Inc., version 19.0.1, Chicago, USA) and processed using ANOVA followed by a Tukey *post hoc* test. Results were presented as means ± standard error of the mean (SEM). Significance was set at $p < 0.05$. Pearson correlations were used to test the relationship between anthropometric measures and serum irisin concentrations.

Results

Table 1 shows the anthropometric measures and blood pressure of athletic and control men and women. Men of both athletics and control groups had the highest height and were significantly different ($p \leq 0.05$) from women of both groups, but were non-significantly different

Table 1. Group-gender anthropometric measures and blood pressure in the study sample

Variable	Control		Footballers		Bodybuilders	
	Men n = 12	Women n = 12	Men n = 12	Women n = 12	Men n = 12	Women n = 12
Height (cm)	174.6 ± 1.9^{a}	160.9 ± 1.6^{b}	178.3 ± 1.9^{a}	162.3 ± 1.9^{b}	176.5 ± 1.8^{a}	160.90 ± 1.4^{b}
Weight (kg)	67.9 ± 2.5^{bc}	56.2 ± 1.6^{de}	74.2 ± 2.3^{b}	54.5 ± 1.9^{e}	91.1 ± 3.6^{a}	64.4 ± 1.0^{cd}
BMI (kg/m²)	22.2 ± 0.6^{cd}	21.7 ± 0.5^{cd}	23.3 ± 0.4^{bc}	20.7 ± 0.4^{d}	29.2 ± 1.0^{a}	24.9 ± 0.2^{b}
MUAC (cm)	28.4 ± 1.0b^{cd}	26.4 ± 0.8^{cd}	29.3 ± 0.6^{bc}	24.8 ± 0.8^{d}	41.3 ± 1.2^{a}	31.7 ± 0.7^{b}
FM (kg)	9.90 ± 0.6^{b}	13.5 ± 0.7^{a}	10.5 ± 0.8^{b}	11.0 ± 0.7^{ab}	11.8 ± 0.8^{ab}	9.3 ± 0.7^{b}
LBM (kg)	57.9 ± 2.0^{bc}	42.7 ± 1.1^{d}	63.7 ± 1.9^{b}	43.4 ± 1.2^{d}	79.4 ± 3.1^{a}	55.1 ± 1.3^{c}
WC (cm)	82.4 ± 2.2^{ab}	72.3 ± 2.6^{c}	82.2 ± 1.5^{b}	75.1 ± 1.9^{bc}	90.9 ± 2.4^{a}	79.3 ± 1.7^{bc}
HC (cm)	95.2 ± 1.6^{b}	95.3 ± 1.4^{b}	98.8 ± 1.4^{b}	93.7 ± 1.5^{b}	106.0 ± 2.3^{a}	96.4 ± 1.8^{b}
WHR	0.87 ± 0.02^{a}	0.76 ± 0.02^{b}	0.83 ± 0.01^{a}	0.80 ± 0.01^{ab}	0.86 ± 0.01^{a}	0.82 ± 0.02^{ab}
WHtR	0.47 ± 0.01^{abc}	0.45 ± 0.02^{c}	0.46 ± 0.01^{bc}	0.46 ± 0.01^{bc}	0.51 ± 0.01^{a}	0.49 ± 0.01^{ab}
SBP (mmHg)	124.3 ± 3.0^{a}	107.9 ± 2.7^{b}	127.1 ± 2.9^{a}	116.4 ± 2.2^{ab}	127.0 ± 5.9^{a}	113.3 ± 2.6^{ab}
DBP (mmHg)	83.8 ± 3.0^{ab}	74.3 ± 3.2^{b}	78.5 ± 2.2^{ab}	81.5 ± 3.0^{ab}	75.7 ± 3.6^{b}	91.3 ± 4.0^{a}

Note: BMI – body mass index, MUAC – mid-upper arm circumference, FM – fat mass, LBM – lean body mass, WC – waist circumference, HC – hip circumference, WHR – waist-to-hip ratio, WHtR – waist-to-height ratio, SBP – systolic blood pressure, DBP – diastolic blood pressure

Data are given as means ± SEM.

Means in rows with different superscripts are significantly different ($p \leq 0.05$).

($p > 0.05$) for the entire group. Athletic men had the highest BW, BMI, MUAC, LBM, and HC and were significantly different ($p \leq 0.05$) from the other study groups. These variables of total athletics were ($p \leq 0.05$) higher than those of the overall control. The highest FM was that of the control women and significantly different ($p \leq 0.05$) from the other study groups. On the other hand, FM was non-significantly different ($p > 0.05$) when comparing total control to total athletics. Control men had the highest WHR and were non-significantly different ($p > 0.05$) from athletic men and women, but significantly different ($p \leq 0.05$) from control women. No significant difference ($p > 0.05$) in WHR existed between total control and total athletics. Athlete men had the highest WHtR and were non-significantly different ($p > 0.05$) from other study groups except for control women. Whole athletics had significantly ($p \leq 0.05$) higher WHtR than total control. Athlete men had higher ($p \leq 0.05$) SBP than overall athletics and control women. The highest DBP was that of athlete women and it non-significantly differed ($p > 0.05$) from that of control men. The DBP and SBP were non-significantly different ($p > 0.05$) between total athletics and total control.

Table 2 shows group-gender serum irisin concentrations of the study sample. Footballer women had higher ($p \leq 0.05$) serum irisin (0.290 ± 0.010 mcg/ml) than bodybuilder women (0.210 ± 0.009 mcg/ml) and control men (0.200 ± 0.008 mcg/ml) and women (0.220 ± 0.009 mcg/ml), but non-significantly different ($p > 0.05$) from both footballer men (0.260 ± 0.014 mcg/ml) and bodybuilder men (0.250 ± 0.011 mcg/ml). Serum irisin concentrations did not show gender differences within each experimental and control group.

Table 3 presents serum irisin concentrations of athletic and non-athletic subjects of the study. Serum irisin did not differ ($p > 0.05$) between athlete men, athlete women, and control women or between control men and women. Serum irisin of athlete men and women was significantly higher ($p \leq 0.05$) than those of control men. The highest mean value of serum irisin was that of athlete men (0.260 ± 0.009 mcg/ml). The respective mean values of control men, control women, and athlete women were 0.200 ± 0.008, 0.220 ± 0.009, and 0.250 ± 0.010 mcg/ml. The overall athletics had significantly ($p = 0.000$) higher serum irisin (0.250 ± 0.007 mcg/ml) than the total control (0.210 ± 0.006 mcg/ml).

Serum irisin concentrations in the overall control, football players, and bodybuilders are shown in Table 4. Footballers had the highest serum irisin and were significantly different ($p \leq 0.05$) from both bodybuilders and the control. The respective serum irisin mean values for the footballer, bodybuilder, and control groups were 0.280 ± 0.009, 0.230 ± 0.008, and 0.210 ± 0.006 mcg/ml.

Table 5 shows the Pearson correlations between serum irisin anthropometric indices and blood pressure in the study sample. Serum irisin positively correlated with

Table 2. Group-gender serum irisin levels of the study sample

Variable	Control		Footballers		Bodybuilders	
	Men n = 12	Women n = 12	Men n = 12	Women n = 12	Men n = 12	Women n = 12
Serum irisin (mcg/ml)	0.200 ± 0.008^{c}	0.220 ± 0.009^{bc}	0.260 ± 0.014^{a}	0.290 ± 0.010^{a}	0.250 ± 0.011^{ab}	0.210 ± 0.009^{bc}

Data are given as means ± SEM.
Means in rows with different superscripts are significantly different.

Table 3. Serum irisin levels of athletic and non-athletic subjects of the study

Variable	Control		Athletics		Total control n = 24	Total athletics n = 48	*p-value
	Men n = 12	Women n = 12	Men n = 24	Women n = 24			
Serum irisin (mcg/ml)	0.200 ± 0.008^{b}	0.220 ± 0.009^{ab}	0.260 ± 0.009^{a}	0.250 ± 0.010^{a}	0.210 ± 0.006	0.250 ± 0.007*	0.000

Data are given as means ± SEM.
Means in rows with different superscripts are significantly different.
*p-value significant at 0.05 levels donates a significant difference between total athletics and total control.

Table 4. Serum irisin concentrations of the overall control, footballers, and bodybuilders

Variable	Total control n = 24	Total footballers n = 24	Total bodybuilders n = 24
Serum irisin (mcg/ml)	0.210 ± 0.006[b]	0.280 ± 0.009[a]	0.230 ± 0.008[b]

Data are given as means ± SEM.
Means in rows with different superscripts are significantly different.

height in the whole bodybuilder group (r = 0.498, $p \leq 0.05$) and negatively correlated in the entire control group (r = –0.44, $p \leq 0.05$). A significant negative correlation existed between serum irisin and BW in athlete women (r = –0.545, $p \leq 0.01$) and total control (r = –0.432, $p \leq 0.05$). The BMI of athlete women negatively correlated with serum irisin (r = –0.698, $p \leq 0.01$). The MUAC negatively correlated with serum irisin in bodybuilder women (r = –0.826, $p \leq 0.05$) and athlete women (r = –0.431, $p \leq 0.05$), whereas positively correlated with this variable in total bodybuilders (r = 0.494, $p \leq 0.05$). Serum irisin negatively correlated with body FM in overall footballers (r = 0.433, $p \leq 0.05$). Furthermore, serum irisin negatively correlated with LBM and WHtR in athlete women (r = –0.636, $p \leq 0.01$; r = –0.422, $p \leq 0.01$, respectively). The DBP negatively correlated with serum irisin in footballer women, athlete women, and overall athletes (r = –0.676, $p \leq 0.05$; r = –0.322, $p \leq 0.05$ and r = 0.432, $p \leq 0.05$, respectively). No correlations were found between serum irisin and other studied variables.

Discussion

Serum irisin concentrations between footballer men and women and bodybuilder men did not differ significantly, while footballer women had the highest value. Non-significant differences were also seen between bodybuilder men and women and control women and between bodybuilder women, control women, and control men. In this study, gender did not affect irisin concentrations, which is consistent with other studies that encountered no significant main or interaction effect of gender on the irisin [3, 11]. It was also found that the circulating irisin of men and women are almost similar [25, 30]. However, after adjusting for LBM, Anastasilakis et al. [2] found that males had lower

Table 5. Pearson correlations between serum irisin and study variables

Variables	Footballers		Body builders		Control		Athletics		Overall athletics n = 48	Overall footballers n = 24	Overall bodybuilders n = 24	Overall control n = 24
	Men n = 12	Women n = 12	Men n = 12	Women n = 12	Men n = 12	Women n = 12	Men n = 24	Women n = 24				
Height (cm)	0.109	0.571	0.418	–0.149	–0.473	–0.317	0.254	0.145	0.169	–0.133	0.498*	–0.440*
Weight (kg)	0.181	0.500	0.051	–0.406	–0.325	–0.444	–0.020	–0.545**	–0.090	–0.135	0.387	–0.432*
BMI (kg/m²)	0.206	0.148	–0.196	–0.441	–0.085	–0.309	–0.144	–0.698**	–0.284	–0.090	0.197	–0.208
MUAC (cm)	0.311	0.438	–0.07	–0.826*	–0.111	–0.366	–0.098	–0.431*	–0.155	0.017	0.494*	–0.284
FM (kg)	0.407	0.533	0.161	–0.267	–0.212	–0.431	0.256	0.290	0.278	–0.433*	0.202	–0.086
LBM (kg)	0.039	0.423	0.019	–0.184	–0.343	–0.389	–0.083	–0.636**	–0.146	–0.231	0.391	–0.396
WC (cm)	0.266	0.241	–0.019	–0.302	0.074	–0.489	–0.003	–0.324	–0.091	–0.019	0.231	–0.329
HC (cm)	0.2	0.487	0.137	–0.193	–0.216	–0.385	0.056	–0.188	–0.018	0.044	0.284	–0.282
WHR	0.159	–0.061	–0.196	–0.121	0.242	–0.410	–0.069	–0.234	–0.139	–0.075	0.017	–0.233
WHtR	0.239	–0.002	–0.209	–0.254	0.33	–0.457	–0.108	–0.422*	–0.250	0.105	–0.045	–0.199
SBP (mmHg)	0.565	–0.288	0.071	–0.324	–0.541	0.05	0.231	–0.036	0.138	0.063	0.173	–0.353
DBP (mmHg)	0.257	–0.676*	–0.493	0.042	–0.16	–0.161	–0.131	–0.457*	–0.322*	–0.119	–0.432*	–0.248

Note: BMI – body mass index, MUAC – mid-upper arm circumference, FM – fat mass, LBM – lean body mass, WC – waist circumference, HC – hip circumference, WHR – waist-to-hip ratio, WHtR – waist-to-height ratio, SBP – systolic blood pressure, DBP – diastolic blood pressure
* correlation is significant at the 0.05 level; ** correlation is significant at the 0.01 level

irisin levels than females. Huh et al. [12], on the other hand, found that male adolescents had a higher increase in irisin levels following acute swimming than female adolescents. The discrepancy in these results could be attributed to the individuals' varying ages, sample sizes, and experimental protocols. The participants in this study were between the ages of 20 and 35. Huh et al. [11] used middle-aged women, while Stengel et al. [25] omitted those under the age of 18, and Huh et al. [12] included adolescents as participants. Moreover, a small sample size of elite taekwondo competitors (7 males and 6 females) and college students (8 males and 6 females) between the ages of 16 and 20 were the participants in a recent study [3].

Irisin concentrations were substantially higher in the entire athletes than in total controls. This study is possibly the first case-control study to compare serum irisin in professional athletes and regular active people. Arıkan et al. [3], using a small sample size, reported that irisin levels are exercise independent. On the other hand, other studies examined the levels of irisin in the athlete population and revealed a connection between irisin levels and exercise and considered irisin to be one putative mediator of the positive effects of exercise on the metabolic profile [30]. The results of the numerous studies in the literature presented in the debate frequently lack a suitable control group sample size, necessitating an interpretation and partial downsizing of their findings.

Almost all previous study designs were intervention training programs, with the subjects' pre-exercise intervention serving as the control group. The current research, which included professional Jordanian athletes in two different sports, reveals that irisin may be an exercise-related hormone. Our findings are consistent with those of Bostrom et al. [5], who found that exercise can promote irisin expression in human muscle and blood. As a result, irisin has been proposed as a potential treatment drug for metabolic disorders [5]. Another study also suggested that children and adults both have an acute and brief rise in blood irisin levels after short bursts of intense exercise, but not after sustained increases in physical activity [16].

There are significant inconsistencies in the results of several studies looking at irisin and its association with exercise. Type, intensity, and duration of exercise, age, gender, and sample size, along with other lifestyle factors, such as energy intake, diet quantity and quality, nutritional status, and body composition, as well as different experimental protocols and the genetic factor, are among the many potential confounders that may contribute to this discrepancy. Some investigations have agreed with the findings of the current study. Daskalopoulou et al. [7] looked at the post-to-pre--exercise variations in irisin levels after a maximal relative and absolute workload exercises and found that serum irisin increased after three workloads. Cooke et al. [6] also discovered comparable results. Irisin levels increased at the end of interventional exercise [2]. Huh et al. [11] found that circulating irisin levels rise in response to exercise. Norheim et al. [20] found that in pre-diabetic participants compared to controls, plasma irisin levels increased initially 45 minutes after exercise and then dropped after 2 hours of rest in an intervention study. Huh et al. [12] investigated the influence of exercise intensity on serum irisin levels in high- and moderate--intensity swimming in teenage boys and girls. Circulating irisin levels were shown to peak immediately after high--intensity interval exercise and then fall 1 hour later [12]. Irisin levels were also higher in men and women during the first hour following exercise [13].

On the other hand, other research yielded mixed results. Compared to previously untrained women, no changes in serum irisin were seen following 12 weeks of intense strength training [9]. Serum irisin was measured after 1 hour of low-intensity aerobic exercise, heavy-intensity resistance exercise, 21 weeks of endurance exercise, and a combination of endurance and resistance exercise [22]. A majority of the participants were men of various ages and BMIs. There were no substantial changes in serum irisin after any procedure [22]. Irisin levels were also not enhanced following training [10]. In this study, Jordanian athlete participants competed in two sports: football and bodybuilding. Footballers and bodybuilders were compared to one another and to a control group. Footballers had the highest serum irisin levels and were considerably higher than bodybuilders and controls. This result indicated that aerobic endurance exercise, but not anaerobic resistance strength exercise, could change circulating irisin levels, which go in line with the findings reported by Bostrom et al. [5]. Serum irisin increased 2-fold following ten weeks of aerobic endurance training exercise compared to the non-exercised state [5]. These findings are consistent with Huh et al. [11], who stated that plasma irisin decreased after eight weeks of anaerobic intermittent sprint training. Endurance-trained athletes were found to have higher concentrations of circulating irisin than sedentary controls [4]. Furthermore, Ellefsen et al. [9] reported similar results.

The result of the present study is inconsistent with those of [22], who observed no changes in irisin levels

after 21 weeks of combined endurance aerobic exercise and resistance exercise. Norheim et al. [20] found that plasma irisin levels acutely increased 45 minutes after aerobic exercise of ergometer cycling and then decreased after 2 hours of rest in pre-diabetes subjects vs controls, but declined after 12 weeks of training. On the other hand, Huh et al. [12] reported that serum irisin increased after high-intensity interval exercise in an adolescent swimmer who depended on an anaerobic system, and it did not increase after moderate-intensity aerobic exercise. In the same study, eight weeks of sprint training significantly induced irisin biomarkers FNDC5 and PGC1_ mRNA levels. Tsuchiya et al. [28] suggested that irisin is affected by the intensity of exercise as it increased after high-intensity anaerobic exercise, but not after low-intensity aerobic exercise. Several reports indicated that circulating irisin was also influenced by the method of analysis used [5, 11, 20], a matter that could be responsible for the dissimilarity in the results of different studies. The muscle phenotype could also be another confounding factor. Ellefsen et al. [9] observed that FNDC5 expression is related closely to aerobic muscle fibers, the myosin heavy chain 2X isoform (MyHC2X), but not with 2A ioform (MyHC2A), which increased in response to strength training. Participants in the present study were all healthy with normal BMIs. Participants who were overweight BMIs were bodybuilders with high lean body mass and not high--fat mass. However, subjects enrolled in the Huh et al. [11] study; their MBIs were all above 37 kg/m^2, while those of Stengel et al. [25] had a wide range of BMIs. Nevertheless, irisin, a new myokine, has recently been linked to human exercise-induced changes in oxidative stress and antioxidant defense, and its concentrations were unaffected by increased training volume or intensity [29].

The present study also investigated the correlations between serum irisin levels and several anthropometric indices. Irisin positively correlated with height in the bodybuilders' group and negatively in the control group. Serum irisin levels showed a strong negative correlation with body weight and BMI in athlete women and a negative correlation with body weight in the control group. Conversely, much research showed that irisin positively correlated with body weight and BMI [9, 11, 21, 25]. This controversy could be due to the differences between subjects enrolled in different studies. While the participants in the present study were all healthy with normal BMI, participants in previous studies were obese [11, 25]. Obese subjects could have insulin resistance. Stengel et al. [25] reported a positive correlation of serum irisin with insulin. The increase in irisin levels in the obese subject could indicate a physiological function to improve glucose intolerance and insulin sensitivity, which is often impaired in obese subjects [25].

The MUAC is an indicator for muscle mass, and irisin correlated negatively with MUAC in bodybuilders and athlete women, while it was positively correlated in total bodybuilders. These results merit further investigations. The positive correlation for irisin with MUAC in total bodybuilders agrees with that reported by Huh et al. [11]. In this study, irisin negatively correlated with MUAC and LBM in athlete women. Similarly, Ellefsen et al. [9] reported a positive correlation between LBM and irisin in untrained women, while this correlation seemed to disappear in trained women after 12 weeks of strength training. Ellefsen et al. [9] explained this result that strength training could affect the regulation of irisin secretion in skeletal muscle and is likely to be linked to the complex biological induction imposed on muscle cells by training. In turn, Stengel et al. [25] and Ellefsen et al. [9] reported positive correlations between body fat mass and serum irisin, while the present study showed a negative correlation between irisin and body fat mass in footballers. These differences could be due to different exercise habits, as irisin may interact with fat cells resulting in its removal from the bloodstream [9]. In the present study, a negative correlation was observed between serum irisin and WHtR, which is consistent with that reported elsewhere [21]. No correlation was obtained between serum irisin and WHR, which accords with the finding of Stengel et al. [25].

One limitation of the present study is the small sample size, and the sample was a convenient one. The timing of sampling could affect the results. Anastasilakis et al. [2] reported that irisin levels followed a day-night rhythm with a peak at 9:00 pm. In this study, all samples were collected before training. The prime feature of this study is that it is possibly the first case-control investigation to compare serum irisin concentration in professional athletes and regular active people.

Conclusions

Taken together, the current findings point to regular exercise training as a means of inducing irisin in the general population. Irisin appears to be a hormone linked to physical activity, and gender did not affect it. The data confirm the theory that the type of exercise can impact circulating irisin, as footballers had the highest levels of irisin. Strength training or static sports may enhance serum irisin levels more than aerobic endurance exercise or dynamic sports. The control group and the

participants of the static sport were not statistically different. The complex pattern of inter-group variation in correlations between irisin and anthropometric indices suggests a complex relationship between body composition and regulation of serum irisin and the complexity of understanding irisin biology.

Conflict of Interest

The authors declare no conflict of interest.

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