Original article

Cardiorespiratory response to high intensity interval exercise in endurance-trained postmenopausal women

Beatriz Rael[1], Miguel A. Rojo-Tirado[1], Cristina Maestre-Cascales[1], Nuria Romero-Parra[1], Víctor M. Alfaro-Magallanes[1], Rocío Cupeiro[1], Ana B. Peinado[1] on behalf of the IronFEMME Study Group

[1]LFE Research Group. Department of Health and Human Performance. Faculty of Physical Activity and Sport Science (INEF). Universidad Politécnica de Madrid. Madrid.

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Summary

Objectives: To evaluate the cardiorespiratory response to high-intensity interval exercise in endurance-trained postmenopausal women and compare it with their counterparts eumenorrheic females.
Material and method: Twenty-one eumenorrheic (30.5±6.5 years, 58.4±8.7 kg, 25.2±6.7% fat mass, 48.4±4.4 ml/kg/min $\dot{V}O_{2peak}$) and thirteen postmenopausal (51.3±3.6 years, 54.1±4.1 kg, 24.2±5.2% fat mass, 46.01±9.8 ml/kg/min $\dot{V}O_{2peak}$) endurance-trained women performed a high-intensity interval running protocol consisted of 8 bouts of 3-min at 85% with 90-s recovery at 30% of their maximal aerobic speed. It was carried out in the early-follicular phase for the eumenorrheic group and at any time for the postmenopausal group. Cardiorespiratory variables were continuously monitored throughout the protocol.
Results: The Mann–Whitney U test reported lower values in postmenopausal women compared to eumenorrheic females for ventilation (66.9±10.1 vs 78.6±11.1 l/min; p<0.001), oxygen consumption (33.7±3.9 vs 38.6±4.1 ml/kg/min; p<0.001), % maximal oxygen consumption (79.6±5.3 vs 76.0±10.6 %; p=0.003), heart rate (154.6±9.5 vs 167.3±11.4 bpm; p<0.001) and carbon dioxide production (1914.8±248.9 vs 2127.5±296.8 ml/min; p<0.001). On the contrary, % maximal carbon dioxide production (60.6±15.0 vs 65.3±8.9 %; p=0.010), respiratory exchange ratio (1.03±0.08 vs 0.96±0.06; p<0.001) and % maximal respiratory exchange ratio (75.4±19.0 vs 83.3±8.2 %; p<0.001) were higher in the postmenopausal group. Finally, % maximal heart rate (91.9±1.7 vs 91.1±2.4 %, p=0.443) and % maximal ventilation (71.9±6.7 vs 71.1±8.4 %, p=0.138) lacked of difference between study groups.
Conclusions: Postmenopausal women appear to have a lower cardiorespiratory response to high-intensity interval exercise than eumenorrheic females, because of the age-related physiological changes, along with the chronic sex hormone decrease. Nonetheless, trained postmenopausal women present a similar cardiac strain when comparing to eumenorrheic females in relative values, which could be associated to the regular practice of physical activity.

Key words:
Eumenorrheic. Exercise. Heart rate. Menopause. Oxygen consumption. Sex hormones.

Respuesta cardiorrespiratoria en mujeres postmenopáusicas deportistas durante un ejercicio interválico de alta intensidad

Resumen

Objetivo: Analizar la respuesta cardiorrespiratoria en mujeres deportistas postmenopáusicas y compararla con la de las eumenorreicas.
Material y método: Veintiuna mujeres eumenorreicas (30,5±6,5 años, 58,4±8,7 kg, 25,2±6,7% masa grasa, 48,4±4,4 ml/kg/min $\dot{V}O_{2peak}$) y trece postmenopáusicas (51,3±3,6 años, 54,1±4,1 kg, 24,2±5,2% masa grasa, 46,01±9,8 ml/kg/min $\dot{V}O_{2peak}$) entrenadas realizaron un protocolo de interválico de alta intensidad. Éste consistió en 8 series de 3 minutos al 85% con descansos de 90 segundos al 30% de su velocidad aeróbica máxima. Las mujeres eumenorreicas realizaron el protocolo en su fase folicular temprana. Las variables cardiorrespiratorias fueron constantemente monitorizadas a lo largo del protocolo.
Resultados: El test de U Mann-Whitney mostró que la respuesta cardiorrespiratoria en el protocolo interválico fue menor en las mujeres postmenopáusicas comparado con las eumenorreicas para la ventilación (66,9±10,1 *vs* 78,6±11,1 l/min; p<0,001), consumo de oxígeno (33,7±3,9 *vs* 38,6±4,1 ml/kg/min; p<0,001), porcentaje del consumo máximo de oxígeno (79,6±5,3 *vs* 76,0±10,6 %; p=0,003), frecuencia cardiaca (154,6±9,5 *vs* 167,3±11,4 lpm; p<0,001) y producción de dióxido de carbono (1914.8±248,9 vs 2127,5±296,8 ml/min; p<0,001). Por el contrario, el porcentaje de la máxima producción de dióxido de carbono (60.6±15.0 vs 65,3±8,9 %; p=0,010), cociente respiratorio (1,03±0,08 *vs* 0,96±0,06; p<0,001) y el porcentaje del máximo cociente respiratorio (75,4±19,0 *vs* 83,3±8,2 %; p<0,001) fue mayor en el grupo de postmenopáusicas. Por último, el porcentaje de la frecuencia cardiaca máxima (91,9±1,7 *vs* 91,1±2,4 %, p=0,443) y el porcentaje de la ventilación máxima (71,9±6,7 *vs* 71,1±8,4 %, p=0,138) no mostraron diferencias entre grupos.
Conclusión: Las mujeres postmenopáusicas presentan una respuesta cardiorrespiratoria menor en ejercicio interválico de alta intensidad que la de las mujeres eumenorreicas, debido a los cambios fisiológicos asociados con la edad y el descenso de las hormonas sexuales. Sin embargo, ambas presentan un trabajo cardíaco similar en valores relativos, lo que podría estar asociado a la práctica regular de ejercicio.

Palabras clave:
Eumenorrea. Ejercicio. Frecuencia cardiaca. Menopausia. Consumo de oxígeno. Hormonas sexuales.

Correspondence: Cristina Maestre-Cascales
E-mail: cristina.maestre@upm.es

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Introduction

Physical fitness performance is reduced with aging. However, its pattern differs by sex showing women a more rapid decline than men during middle age[1]. This sex difference might be related to the hormonal changes that women experience during their menopausal years. Menopause is characterised by the loss of the ovarian function along with dramatic changes in endogenous sex hormones secretion[2]. Based on previous research, follicle-stimulating hormone (FSH) concentrations rises approximately 68% the following 7 to 10 months after the last menstruation, with a concomitant drop of 60% in 17β-estradiol (E2) level[3].

Endogenous sex hormones change after menopause, specially E2 decrease, may have an impact on women´s physiology. Previous research reported body composition adaptations such as an increase in fat mass[4] as well as a decrease in muscle mass[1,5] and bone mineral density[6] in postmenopausal women. Besides, some cardiorespiratory shifts have also been observed in this population such as a rise in arterial stiffness and blood pressure as well as a drop in heart rate (HR) and oxygen consumption ($\dot{V}O_2$)[1,7,8]. Indeed, literature showed a HRmax reduction of 6 beats/min per decade[9] and a maximal oxygen consumption ($\dot{V}O_{2max}$) decrease of 1% per year after the third decade of life in women[10]. Apart from sex hormones influence, it has been suggested that postmenopausal women have a more sedentary lifestyle than premenopausal females[11]. Hence, the reduction in cardiorespiratory fitness observed in this population may partially occur because of the decrease in E2[3,12,13] as well as the decline in physical activity level[11]. All these factors that postmenopausal women experience at this stage enhance the risk of suffering cardiovascular diseases and several types of cancer[14,15]. However, impairments on cardiorespiratory system caused by both, age and sex hormones change after menopause, may be partially offset in trained females because of the positive effect that physical activity has on these systems, especially high intensity exercise[16-21].

In this regard, few authors have analysed the cardiorespiratory response to high intensity interval exercise in postmenopausal sedentary women[7,22] and, as far as we are concerned, none has evaluated it in endurance-trained postmenopausal women. Therefore, the aim of the present study was to assess the cardiorespiratory response to high intensity interval exercise in endurance-trained postmenopausal women and compare it with their counterparts premenopausal females.

Material and method

Participants

A total of twenty-one eumenorrheic females and thirteen postmenopausal women (at least one year without menstruation[23]) participated in this study. All of them were healthy and well-trained in endurance activities such as running, obstacle races, triathlon, and cycling. Eumenorrheic females had regular menstrual cycles (MC), occurring from 23 to 38 days in length, during the six months prior the study[24]. Characteristics of the study population are described in Table 1.

Participants were required to meet the following criteria: (a) healthy adult females between 18 and 40 years old for the eumenorrheic group and under 60 years old for the postmenopausal group; (b) presenting healthy iron parameters (serum ferritin >20μg/l, haemoglobin >115 μg/l and transferrin saturation >16%); (c) performing endurance training at least 3 h per week. Exclusion criteria included (a) oral contraceptive users; (b) smoking; (c) metabolic or hormonal disorder; (d) medication or dietary supplements that alter vascular function (e.g., tricyclic antidepressants, α-blockers, β-blockers, etc.); (e) any surgery interventions (e.g. ovariectomy); (f) pregnancies in the year preceding; (g) any musculoskeletal injury in the last six months. At the start of the data collection, all participants conducted a questionnaire gathering information about training experience, health status and dietary supplements. All participants were informed about the procedures and risks involved and informed consent was provided by each participant. The experimental protocol was approved by the institutional Ethics Committee board of the Universidad Politécnica de Madrid and is in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki)[25].

Study design

The present work is part of the IronFEMME study, an observational cross-sectional study performed by physically active and healthy women which methodology has been recently published (Contract DEP2016-75387-P)[26].

Participants came to our laboratory on two occasions. To avoid diurnal variability[27], participants came to the laboratory between 8 and 10 a.m., abstaining from alcohol, caffeine and any intense physical activity or exercise practice the 24 hours prior the testing day. Nutritional recommendations were provided to the participants by a nutritionist to standardize the diet, and volunteers followed them 24h prior every protocol. Volunteers underwent a screening (first visit) and interval running protocol (second visit), which were conducted any time for postmenopausal women and during the early follicular phase for the eumenorrheic group (i.e., between 2nd and 5th day of the menstrual cycle with day 1 being the onset of menstrual bleeding), to measure them under similar hormonal environments (low estrogen and progesterone levels). Regarding postmenopausal women, at least one rest day was between the first and the second visit.

On the first visit, volunteers came to our laboratory between 8 and 10 a.m. in a rested and overnight fasted state. Volunteers did not perform moderate or vigorous physical activity, intake caffeine or any supplementation 24 h prior to the test. Firstly, they signed all the informed consents and participant´s weight and height were recorded. Then, baseline blood samples were collected, for a complete blood count, genetic testing, biochemistry, and hormonal analyses. Subsequently, a dual-energy X-ray absorptiometry was done with a GE Lunar Prodigy apparatus using GE Encore 2002 software (version 6.10.029; GE Healthcare, Madison, WI). Finally, after eating and resting for a minimum of 2 hours, participants completed a maximal aerobic ramp test on a computerized treadmill (H/P/COSMOS 3PW 4.0, H/P/Cosmos Sports & Medical, Nussdorf-Traunstein, Germany) to determine their $\dot{V}O_{2peak}$. Expired gases were measured breath-by-breath with the gas analyser Jaeger Oxycon Pro (Erich Jaeger, Viasys Healthcare, Germany), which validity and reliability has been previously demonstrated[28,29], whilst heart response was continuously monitored with a 12-lead ECG. Participants began with a warm-up of 3 min at 6 km/h. Once the warm-up finished, the speed was set at 8 km/h and then increased by 0.2 km/h every 12 s until exhaustion. A slope of 1% was set throughout the test to simulate air resistance[30]. To verify that $\dot{V}O_{2peak}$ was reached, a confirmatory test was carried out as suggested in previous studies[31,32] after a 5 min recovery of the maximal aerobic test[32]. The confirmatory test consisted of a 3 min warm-up (2 min at 50% and 1 min at 70% of the maximal speed reached in the maximal aerobic test). Then, speed was set at 110% of the maximal speed reached in the maximal aerobic test until volunteers´ exhaustion. The $\dot{V}O_{2peak}$ was determined as the mean of the three highest $\dot{V}O_2$ measurements in the maximal aerobic test if it was not less than 3% compared to the one obtained in the confirmatory trial. If the value was less than 3%, $\dot{V}O_{2peak}$ was calculated as the mean of the three highest $\dot{V}O_2$ values recorded during the last 30-s of the confirmatory trial. The maximal aerobic speed (v$\dot{V}O_{2peak}$) was recorded as the minimum speed required to elicit $\dot{V}O_{2peak}$[33]. Then, the speed equivalent to 85% of the v$\dot{V}O_{2peak}$ was calculated to use in the interval running protocol.

Interval running protocol

After this screening day, eumenorrheic participants attended to the laboratory to perform the interval running protocol. The protocol of the testing procedure day has been previously described[34,35]. Firstly, a blood sample was collected to analyze sex hormones, followed by a resting blood pressure (BP) measurement, using the auscultatory method with a calibrated sphygmomanometer. Subsequently, participants started the interval running protocol, which consisted of a 5 min warm-up at 60% of the v$\dot{V}O_{2peak}$ followed by 8 bouts of 3 min at 85% of the v$\dot{V}O_{2peak}$, with 90-second recovery at 30% of the v$\dot{V}O_{2peak}$ between bouts. Finally, 5 min cool down was performed at 30% of the v$\dot{V}O_{2peak}$. During exercise, ventilation ($\dot{V}e$), $\dot{V}O_2$, carbon dioxide production ($\dot{V}CO_2$), respiratory exchange ratio (RER), and HR among others ventilatory variables were continuously measured using the same apparatus as mentioned for the maximal aerobic test. Besides, maximal cardiorespiratory values percentage (%$\dot{V}e_{max}$, %$\dot{V}O_{2max}$, %$\dot{V}CO_{2max}$, %RER max and %HR max) throughout the interval running protocol was calculated considering maximal values, previously obtained in the maximal aerobic test, as 100%. Cardiorespiratory values were obtained as the mean of the 5 min warm-up, as well as the mean of the 5 min cool down. Likewise, values over the interval running protocol were elicited as the mean of the 3 min high intensity bouts and the mean of the 90-second recovery intervals.

Additionally, Rate of Perceived Exertion (RPE) and Perceived Readiness (PR) were measured by RPE Borg 6-20 scale[36] and PR Nurmekivi 1-5 scale[37]. Participants were asked for RPE in the last 5 s of warm-up, of every running bout, and at the end of the cool-down. PR scale was applied in the last 5 s of warm-up, of every active recovery interval, and at the end of the cool down.

Blood samples analyses

Blood samples were obtained with venepuncture into a vacutainer containing clot activator. Following inversion and clotting, the whole blood was centrifuged (Biosan LMC-3000 version V.5AD) for ten minutes at 1610 g to obtain the serum (supernatant). After that, serum was transferred into eppendorf tubes and stored at -80ºC until further analysis. Within 1 to 15 days after testing, the serum samples were delivered to the clinical laboratory of the Spanish National Centre of Sport Medicine (Madrid, Spain) to determine sex hormones and verify hormonal profiles. Total E2, progesterone, FSH and luteinizing hormone (LH) were measured via ADVIA Centaur® solid-phase competitive chemiluminescent enzymatic immunoassay (Siemens city, Germany). Inter- and intra-assay coefficients of variation (CV) reported by the laboratory for each variable were previously described[35].

Statistical analysis

Data are presented as mean and standard deviation (±SD). A Saphiro-Wilk test to assess the normality of the variables was conducted. The Mann–Whitney U test was applied to analyze differences in sex hormones (FSH, LH, E2 and progesterone) and cardiorespiratory variables (BP, $\dot{V}e$, $\dot{V}O_2$/kg, $\dot{V}CO_2$, RER, HR, RPE, PR) throughout the interval running protocol between both groups tested. Then, Cohen´s d[38] and their 95% confidence intervals (CI) were calculated to assess the magnitude of effect on the changes found. Threshold values were set as small (≥0.2 and <0.5), moderate (≥0.5 and <0.8) and large (≥0.8)[38]. Statistical significance was set at p<0.05 and all procedures were conducted with SPSS software 21 version (IBM Corp., Armonk, NY, USA).

Results

Firstly, it is worth mentioning that a homogeneous group of females have been studied since no differences in descriptive variables (height, weight, FM percentage, LM percentage, training status and $\dot{V}O_{2peak}$), other than age, were observed between eumenorrheic and postmenopausal women (Table 1). Regarding sex hormone concentrations in the testing day, significant differences between groups were observed, presenting postmenopausal women higher values of LH and FSH, whereas eumenorrheic females reported higher E2 and progesterone levels (Table 1). Eumenorrheic volunteers´ menstrual cycles ranged from 28±2 to 31±2 days in length, and their early follicular phase was at day 3.43±0.93.

Speed throughout the interval running protocol was lower for the postmenopausal group compared to eumenorrheic females in the warm-up (8.2±0.7 and 9.0±0.7 km/h, respectively; Z=-2.463; p=0.014; d=1.14; CI=0.40 to 1.89), high intensity intervals (11.7±1.1 and 12.8±0.9 km/h, respectively; Z=-2.428; p=0.015; d=1.12; CI=0.38 to 1.86), active recovery intervals (4.2±0.5 and 4.6±0.5 km/h, respectively; Z=-2.218; p=0.027; d=0.80; CI=0.08 to 1.52) and cool down (4.2±0.4 and 4.5±0.4 km/h, respectively; Z=-2.304; p=0.021; d=0.75; CI=0.04 to 1.46).

Secondly, neither resting systolic blood pressure (eumenorrheic group: 106.15±8.44 and postmenopausal group: 107.85±8.09 mmHg; Z=-1.004; p=0.316; d=0.21; CI=-0.49 to 0.90) nor diastolic blood pressure (eumenorrheic group: 65.75±7.66 and postmenopausal group: 68.57±7.48 mmHg; Z=-1.815; p=0.070; d=0.37; CI=-0.33 to 1.07) showed differences between both groups tested.

Table 1. Characteristics of the study population (mean±SD).

	Eumenorrheic in the EFP	Postmenopausal	Z	*p*	d	CI
Age (years)	30.5±6.5	51.3±3.6	-5.059	<0.001	3.37	2.31 to 4.43
Height (cm)	163.1±6.4	160.8±5.6	-0.755	0.450	-0.49	-1.19 to 0.21
Weight (kg)	58.4±8.7	54.1±4.1	-0.562	0.574	-0.55	-1.25 to 0.16
Fat mass (%)	25.2±6.7	24.2±5.2	-0.471	0.637	-0.16	-0.86 to 0.53
Lean mass (%)	70.4±6.5	72.9±5.6	-1.145	0.252	0.41	-0.29 to 1.10
Experience (years)	7.4±5.3	7.9±3.3	-1.297	0.195	0.11	-0.59 to 0.80
Training volume (mins/week)	295.9±183.6	258.5±90.45	-0.273	0.785	-0.24	-0.94 to 0.45
$\dot{V}O_{2peak}$ (ml/kg/min)	48.4±4.4	46.01±9.8	-1.577	0.115	-0.35	-1.04 to 0.35
LH (mIU/ml)	6.70±2.71	41.22±12.26	-4.790	<0.001	4.42	3.16 to 5.68
FSH (mIU/ml)	7.15±2.36	81.99±38.20	-4.739	<0.001	3.19	2.16 to 4.22
E2 (pg/ml)	48.60 ±32.23	33.03±57.34	-2.433	0.015	-0.36	-1.06 to 0.34
Progesterone (ng/ml)	0.32±0.19	0.17±0.13	-2.250	0.024	-0.88	-1.61 to -0.16

EFP: early-follicular phase; $\dot{V}O_{2peak}$: peak oxygen consumption; FSH: follicle-stimulating hormone; LH: luteinizing hormone; E2: 17 β-estradiol.

Regarding the warm-up, $\dot{V}e$, $\dot{V}O_2$/Kg, $\dot{V}CO_2$ and HR exhibited lower values in postmenopausal women than in eumenorrheic females; while RER, RPE and PR did not show differences between study groups. However, when comparing relative values, only %HR max was lower in postmenopausal women throughout the warm-up, since %$\dot{V}e$ max, %$\dot{V}O_2$/Kg max, %$\dot{V}CO_{2\ max}$ and %RER max reported no differences between study groups (Table 2). Lastly, cool down outcomes showed lower values for $\dot{V}e$ and $\dot{V}O_2$/Kg in the postmenopausal group compared to the eumenorrheic one, whereas RER was higher. Besides, no differences between study groups were observed for $\dot{V}CO_2$, HR, RPE, PR, %$\dot{V}e$ max, %$\dot{V}O_2$/Kg max, %$\dot{V}CO_2$ max and %RER max and %HRmax (Table 2).

According to the interval running protocol (Table 3) postmenopausal women exhibited lower values of $\dot{V}e$, $\dot{V}O_2$/Kg, %$\dot{V}O_2$/Kg max, $\dot{V}CO_2$, HR and RPE, whereas %$\dot{V}CO_2$ max, RER and %RER max were higher for this group throughout the high intensity bouts compared to the premenopausal one. Nonetheless, no differences in %$\dot{V}e$ max and %HRmax were reported between study groups across the high intensity bouts. Moreover, postmenopausal women reported lower values of $\dot{V}e$, $\dot{V}O_2$Kg, %$\dot{V}O_2$/Kg max, $\dot{V}CO_2$, and HR while %$\dot{V}CO_2$ max, RER, %RER max and PR were higher for this group during the active recovery. Finally, no differences in %$\dot{V}e$ max, %$\dot{V}CO_2$max and %HRmax were observed between study groups during the active recovery intervals.

Discussion

The purpose of this study was to examine cardiorespiratory response to high intensity interval exercise in postmenopausal endurance-trained women and compare it with their counterparts eumenorrheic females. The findings of the present work suggest a lower aerobic fitness in postmenopausal women than in premenopausal females. However, it is wort mentioning the similar cardiorespiratory response between groups when comparing relative values.

The lack of difference in %HRmax means a similar cardiac strain between eumenorrheic and postmenopausal endurance-trained women. This finding might be explained by the positive effect exercise has on cardiac function. It is well known that cardiac myocytes are increased and strengthened due to the regular practice of exercise, leading to a better cardiac function and lower myocardial stiffness in this population[17]. Although very few studies have evaluated this variable, a recent study carried out with active (3 times per week during the last 3 months) postmenopausal (62 years old) women reported a 65% HRmax throughout a cycle ergometer test at 75% of their $\dot{V}O_{2max}$, while postmenopausal volunteers from the present study reported a 91% HRmax throughout a high intensity interval running protocol[39]. Discrepancies in %HRmax between studies could be explained by differences in exercise protocols as well as volunteers´ training status and age.

The lower cardiovascular response with aging previously documented[7,9,40,41], is in line with the findings from the present study since postmenopausal women reported lower HR response throughout the interval running protocol compared to premenopausal females. An age-related decline in heart function has been long time accepted[42,43]. On the one hand, a pivotal aspect of the aging heart is the increase in myocardial stiffness, leading to a drop in myocardial distensibility and, thereby, cardiac filling is impaired[44]. Meanwhile, the decrease in cardiac compliance limits the recruitment of the Franck-Starling mechanism and reduces the possibility of increasing the systolic volume and, therefore, cardiac output[44]. On the other hand, E2 enhances cardiac contractility[45] as well as vasodilation of the coronary and peripheral arteries[46]; thereby, its drastic decrease after menopause may compromise cardiac function.

Turning on to the respiratory system in elderly women, the lower values observed in relative and absolute values observed in the postmenopausal group from the present study agrees with previous research[7,9,40,41]. This system also undergoes a measurable decline in the physiological function. With advancing age, the thoracic cage stiff and airways resistance increase, and this in turn elevates the work of

Table 2. Performance variables (Mean±SD) throughout the warm-up and cool down between eumenorrheic females and postmenopausal women.

		Eumenorrheic in the EFP	Postmenopausal	Z	*p*	d	CI
Warm-up	$\dot{V}e$ (l/min)	48.24±8.65	39.38±6.58	-2.746	0.006	-1.12	-1.86 to -0.38
	$\dot{V}e$ max (%)	44.71±5.49	42.65±5.63	-1.085	0.291	-0.37	-1.09 to 0.34
	$\dot{V}O_2$/Kg (ml/kg/min)	29.07±2.56	23.41±2.19	-3.739	<0.001	-2.33	-3.22 to -1.45
	%$\dot{V}O_2$/Kg max (%)	60.18±3.87	55.86±7.20	-1.683	0.096	-0.82	-1.55 to -0.08
	$\dot{V}CO_2$ (ml/min)	1481.21±215.57	1235.88±131.10	-2.395	0.017	-1.30	-2.06 to -0.54
	%$\dot{V}CO_2$ max (%)	42.23±10.86	44.65±6.85	-0.112	0.927	0.25	-0.46 to 0.96
	RER	0.88±0.05	0.94±0.11	-1.953	0.051	0.65	-0.06 to 1.36
	%RER max (%)	69.20±18.26	76.69±9.75	-1.235	0.228	0.48	-0.24 to 1.19
	HR (bpm)	135.95±12.83	117.50±16.03	-2.208	0.027	-1.31	-2.07 to -0.55
	%HR max (%)	75.62±8.57	70.10±7.77	-2.533	0.011	-0.73	-1.44 to -0.02
	RPE	9.33±1.77	10.86±1.68	-1.822	0.068	0.85	0.13 to 1.57
	PR	4.86±0.28	4.70±0.49	-0.573	0.566	-0.43	-1.13 to 0.27
Cool down	$\dot{V}e$ (l/min)	43.19±6.35	42.58±6.06	-2.463	0.014	-0.10	-0.79 to 0.59
	%$\dot{V}e$ max (%)	39.61±5.11	39.76±6.66	-0.299	0.782	0.03	-0.68 to 0.74
	$\dot{V}O_2$/Kg (ml/kg/min)	19.49±2.67	19.01±2.47	-2.948	0.003	-0.19	-0.88 to 0.51
	%$\dot{V}O_2$/Kg max (%)	38.44±9.91	37.66±6.13	-1.045	0.309	-0.09	-0.80 to 0.62
	$\dot{V}CO_2$ (ml/min)	1069.41±180.80	1058.41±164.94	-1.658	0.097	-0.06	-0.76 to 0.63
	%$\dot{V}CO_2$ max (%)	30.44±8.05	31.94±5.24	0.000	1.000	0.21	-0.50 to 0.92
	RER	0.94±0.06	0.97±0.08	-2.505	0.012	0.33	-0.37 to 1.02
	%RER max (%)	73.64±18.75	81.01±7.49	-1.385	0.175	0.47	-0.25 to 1.19
	HR (bpm)	137.91±15.16	138.54±13.55	-1.239	0.215	0.04	-0.65 to 0.74
	%HR max (%)	75.99±7.51	74.65±6.91	-0.713	0.476	-0.28	-0.97 to 0.42
	RPE	9.81±2.91	9.44±1.97	-0.921	0.357	-0.14	-0.84 to 0.55
	PR	4.09±1.13	4.28±0.71	-0.343	0.732	0.19	-0.50 to 0.88

EFP: early-follicular phase; $\dot{V}e$: ventilation; %$\dot{V}e$ max: maximal ventilation percentage; $\dot{V}O_2$: oxygen consumption; %$\dot{V}O_2$ max: maximal oxygen consumption percentage; $\dot{V}CO_2$: carbon dioxide production; %$\dot{V}CO_2$ max: maximal carbon dioxide production percentage; RER: respiratory exchange ratio; %RER max: maximal respiratory exchange ratio percentage; HR: heart rate; %HR max: maximal heart rate percentage; RPE: rate of perceived exertion; PR: perceived readiness.

breathing[47]. In addition, sex hormones shift occurring in women at this stage have also been linked to impairment of respiratory function[48]. For instance, a cross-sectional study found a significantly lower spirometric measures and more respiratory symptoms in postmenopausal women compared to women of the same age but with regular menstruations[49]. Besides, it appears that E2 concentrations can increase pulmonary blood volume and pulmonary diffusion capacity[50,51]; thus, its fall after menopause could compromise pulmonary function.

Nonetheless, it should be pointed out that, in the present study the interval running protocol speed was lower for the postmenopausal group. Consequently, the lower respiratory response observed in this group might be related to this factor. Besides, a recent publication carried out with these eumenorrheic and postmenopausal endurance-trained women reported no differences in most cardiorespiratory values either at resting or at peak values[52]. Thus, outcomes from the present study should be taken with cautious since resting and peak values lack of differences between eumenorrheic and postmenopausal women[52] and the cardiorespiratory response to a high intensity interval exercise might be altered by differences in speed.

Finally, according to RER and %RER max, the present study showed higher values in the postmenopausal group throughout the high intensity interval protocol, indicating a higher glycogen consumption and a lower fat oxidation in this population. Women´s metabolism could also be affected by the fall in E2 levels after menopause, since this sex hormone enhances glycogen sparing and fat oxidation by promoting lipolysis in the muscles[51,53-55].

The current study attempts to address a gap in the research through the investigation of important cardiorespiratory variables in endurance-trained postmenopausal women. The strengths of our study included the recruitment of a homogeneous group, regardless the age, of premenopausal and postmenopausal endurance-trained women, since most of previous research have evaluated healthy sedentary women. Thus, longitudinal studies with an intra-subject design should be carried out to explore the influence of the hormonal changes over the life span.

Table 3. Performance variables (Mean±SD) throughout the interval running protocol.

		Eumenorrheic in the EFP	Postmenopausal	Z	*p*	d	CI
Bouts	$\dot{V}e$ (l/min)	78.61±11.09	66.95±10.08	-7.906	<0.001	-1.09	-1.83 to -0.35
	%$\dot{V}e$ max (%)	71.91±6.65	71.11±8.36	-1.485	0.138	-0.11	-0.82 to 0.60
	$\dot{V}O_2$/Kg (ml/kg/min)	38.62±4.04	33.74±3.95	-8.270	<0.001	-1.22	-1.97 to -0.47
	%$\dot{V}O_2$/Kg max (%)	79.64±5.26	75.98±10.64	-2.980	0.003	-0.48	-1.20 to 0.24
	$\dot{V}CO_2$ (ml/min)	2127.48±296.78	1914.77±248.91	-5.634	<0.001	-0.76	-1.48 to -0.05
	%$\dot{V}CO_2$ max (%)	60.62±15.04	65.33±8.91	-2.564	0.010	0.36	-0.36 to 1.07
	RER	0.962±0.060	1.031±0.083	-6.623	<0.001	1.03	0.29 to 1.76
	%RER max (%)	75.35±19.02	83.33±8.21	-4.499	<0.001	0.50	-0.22 to 1.22
	HR (bpm)	167.29±11.44	154.59±9.48	-7.578	<0.001	-1.18	-1.93 to -0.44
	%HR max (%)	91.86±1.73	91.07±2.44	-0.767	0.443	-0.39	-1.09 to 0.31
	RPE	15.15±3.18	13.97±1.81	-4.753	<0.001	-0.43	-1.13 to 0.27
Active recovery intervals	$\dot{V}e$ (l/min)	64.34±8.77	55.06±9.47	-6.669	<0.001	-1.03	-1.76 to -0.29
	%$\dot{V}e$ max (%)	58.96±6.33	58.54±8.53	-0.033	0.974	-0.06	-0.77 to 0.65
	$\dot{V}O_2$/Kg (ml/kg/min)	30.23±3.60	26.05±3.12	-8.395	<0.001	-1.22	-1.97 to -0.47
	%$\dot{V}O_2$/Kg max (%)	62.36±5.59	58.39±9.36	-3.296	0.001	-0.56	-1.28 to 0.17
	$\dot{V}CO_2$ (ml/min)	1801.27±257.15	1615.70±220.42	-5.878	<0.001	-0.76	-1.48 to -0.05
	%$\dot{V}CO_2$ max (%)	51.30±12.72	54.20±8.22	-0.555	0.579	0.26	-0.46 to 0.97
	RER	1.050±0.075	1.121±0.104	-5.579	<0.001	0.80	0.08 to 1.51
	%RER max (%)	82.11±20.36	90.51±9.83	-3.680	<0.001	0.48	-0.23 to 1.20
	HR (bpm)	156.17±13.12	142.96±13.93	-6.607	<0.001	-0.98	-1.71 to -0.25
	%HR max (%)	84.86±2.24	82.63±5.17	-0.889	0.374	-0.62	-1.32 to 0.09
	PR	4.00±0.99	4.15±0.82	-2.979	0.003	0.16	-0.53 to 0.85

$\dot{V}e$: ventilation; %$\dot{V}e$ max: maximal ventilation percentage; $\dot{V}O_2$: oxygen consumption; %$\dot{V}O_2$ max: maximal oxygen consumption percentage; $\dot{V}$CO2: carbon dioxide production; %$\dot{V}CO_2$ max: maximal carbon dioxide production percentage; RER: respiratory exchange ratio; %RER max: maximal respiratory exchange ratio percentage; HR: heart rate; %HR max: maximal heart rate percentage; RPE: rate of perceived exertion; PR: perceived readiness.

Conclusions

This investigation suggests that postmenopausal cardiorespiratory response to exercise cannot be as high as premenopausal one when performing a high intensity interval training. This fact appears to be associated with age-related physiological changes, along with the chronic sex hormone decrease after menopause. Nonetheless, postmenopausal women present a similar cardiac strain when comparing to eumenorrheic females in relative values, which could be associated to the regular practice of physical activity. Further research is recommended to provide a better understanding of the potential effects of different hormonal profiles in cardiorespiratory system when studying physically active women.

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Conflict of interest

The authors do not declare a conflict of interest.

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