



Official Research Journal of
the American Society of
Exercise Physiologists

ISSN 1097-9751

JEPonline

Effectiveness of an Upper and Lower Limb Resistance Training Program on Body Composition, Nerve Conduction Velocity, and Cardiac Autonomic Nervous Activity in University Athletes

Tadsawiya Padkao^{1,2}, Piyapong Prasertsri^{1,2}

¹Faculty of Allied Health Sciences, Burapha University, Chonburi, Thailand, ²Exercise and Nutrition Sciences and Innovation Research Unit, Burapha University, Chonburi, Thailand

ABSTRACT

Padkao T, Prasertsri P. Effectiveness of an Upper and Lower Limb Resistance Training Program on Body Composition, Nerve Conduction Velocity, and Cardiac Autonomic Nervous Activity in University Athletes. **JEPonline** 2019;22(2):78-98. The purpose of this study was to evaluate the effects of an 8-wk resistance training program of the upper and lower limb muscles on body composition, nerve conduction velocity, and cardiac autonomic nervous activity in Burapha University athletes. A randomized pretest-posttest study was conducted in 60 athletes at Burapha University aged 18 to 22 yrs. Subjects were randomized into a control group (CT, n = 20), a high-intensity interval training group (HII, n = 20), and an upper and lower limb resistance training group (ULLR, n = 20). Subjects in the HII and ULLR training groups engaged in exercise training for 30 min·d⁻¹, 3 d·wk⁻¹ for 8 wks. Before and after the intervention, the following variables were measured in all groups: body composition, nerve conduction velocity, and cardiac autonomic nervous activity. There were significant increases in fat-free mass, protein mass, and water mass in the ULLR training group (P<0.05). In addition, motor conduction amplitude of the median nerve in the ULLR training group was significantly higher than in the CT group (P<0.05). Values of total power and very low frequency power of heart rate variability were significantly higher in the HII training group when compared with the CT group (P<0.05). This study showed that a resistance training program incorporating upper and lower limb muscles improved body composition and motor nerve conduction amplitude. Moreover, HII training improved cardiac autonomic nervous activity.

Key Words: Muscle Mass, Nerve Conduction, Resistance Exercise

INTRODUCTION

Exercise training has been proven to improve body composition (42). Aerobic training is optimal for reducing fat mass and body mass, while resistance training is desirable for increasing lean mass (22,47,74). The targets for improvements in body composition are not only aimed at the enhancement of physical fitness (36), but also for the reduction of cardiovascular disease risk (65).

Body composition is associated with nerve conduction velocity (5). Motor and sensory conduction velocity is slower with an increase in body mass index (BMI) (50). In fact, Pawar et al. (50) suggested that the amount of body fat is related to the epineurium (i.e., the outermost layer of dense irregular connective tissue that surrounds a peripheral nerve) and affects nerve conduction. Body composition is also correlated with cardiac autonomic function (53). Moreover, body fat percentage seems to present the strongest independent association with cardiovascular autonomic nervous activity (25).

Several studies have reported that high-intensity interval (HII) exercise training improved body composition by increasing muscle mass and decreasing body mass, fat mass, waist circumference, visceral adiposity tissue, fasting blood glucose, plasma total cholesterol, low-density lipoprotein-cholesterol, triglyceride concentrations, and inflammatory cytokines (23,35,46,48,49,62,73). An increase in muscle mass or a decrease in fat mass (or body fat percentage) is linked to improved nerve conduction velocity (12,50) as well as cardiac autonomic nervous activity (25,60).

Resistance exercise training has also been shown to improve body composition by increasing lean muscle mass and decreasing fat mass and visceral adipose tissue (18,64). Yet, there is insufficient and inconsistent data regarding improved nerve conduction velocity (21) or cardiac autonomic nervous activity (16,31,37,71) following resistance training. Furthermore, to our knowledge, there is very little research reporting the influence of upper and lower limb resistance training on body composition, nerve conduction velocity, and cardiac autonomic nervous activity and, in particular, in regards to HII training. Therefore, we conducted a randomized controlled trial to evaluate the effect of an 8-wk resistance training program for the upper and lower limb muscles (ULLR training) versus HII training on body composition, nerve conduction velocity, and cardiac autonomic nervous activity in Burapha University athletes.

Accordingly, we hypothesized that the ULLR training would improve body composition, nerve conduction velocity, and cardiac autonomic nervous activity, and that these benefits would be similar to those achieved with HII training. Findings from the present study may provide advantageous data in terms of a multimodal resistance training program that could be applied for improving concurrent body composition, nerve conduction velocity, and cardiac autonomic nervous activity in sports participants.

METHODS

Subjects

This study was experimental in design with a pretest-posttest analysis. Sixty-six athletes at Burapha University aged 18 to 22 yrs participated. Eligibility criteria were: (a) male or female athlete at Burapha University, Bangsaen Campus; (b) aged between 18 to 30 yrs; and (c) healthy of body and mind. The exclusion criteria were: (a) obese or underweight; and (b) a regular smoker or drinker. All subjects were screened prior to participation via physical examination that included an assessment of systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR) accompanied

by a health questionnaire form to examine the subjects' history of illness, sports and exercise participation, injuries, and supplementation intake.

Ethics Statement

All subjects received information regarding the risks and potential benefits of participation in the study. Subsequently, each subject signed a written informed consent before screening. The consent form and the study protocols were in accordance with the ethical standards of the Human Ethics Committee of Burapha University (approval no. 18/2561), as well as with the 1964 Helsinki declaration and its later amendments.

Experimental Design

Sixty-six subjects were randomized into 3 groups: Control Group (CT, $n = 22$), High-Intensity Interval Training Group (HII, $n = 22$), and Upper and Lower Limb Resistance Training Group (ULLR, $n = 22$). A random number table was generated using IBM SPSS Statistics (IBM, Armonk, NY, USA). The subjects were numbered according to participation sequence.

Exercise Sessions

The subjects in the CT Group were asked to continue with their daily routine with unaltered physical activity and dietary intake behaviors for 8 wks. The subjects in the HII Training Group engaged in cycling exercise training program on a bicycle ergometer (Monark 828E ergomedic, Sweden) for 30 $\text{min}\cdot\text{d}^{-1}$, 3 $\text{d}\cdot\text{wk}^{-1}$ for 8 wks. Prior to the initial exercise session, the subjects started with a 3-min warm-up period with a free workload. The intensity was adjusted to 30% of maximal oxygen consumption ($\text{VO}_2 \text{ max}$) for 1 min and, then, it was increased to an intensity of 70% of $\text{VO}_2 \text{ max}$. Exercise intensity was interchanged between 30% and 70% $\text{VO}_2 \text{ max}$ every min for 24 min. During exercise, the subjects were required to maintain a cadence of 50 to 60 $\text{rev}\cdot\text{min}^{-1}$. Subsequently, they terminated the exercise session with a 3-min cool down period with a free workload.

The subjects in the ULLR Training Group engaged in a resistance exercise training program of the upper and lower limb muscles for 30 $\text{min}\cdot\text{d}^{-1}$, 3 $\text{d}\cdot\text{wk}^{-1}$ for 8 wks. The subjects began with a 3-min warm-up period of brisk marching. Then, the program was initiated with exercise of the upper limb muscles at a low resistance. This program consisted of the following exercises: lateral pulldown, biceps curls, triceps extension, seated dumbbell press, and lateral dumbbell raise, respectively. The exercise intensity was 30% of 1 repetition maximum (1 RM) with the subjects required to complete 15 reps with each lasting for 1-min. They were then instructed to continue with the exercise of the upper limb muscles at a higher resistance using the same exercise. In this step, lateral pulldown, biceps curls, triceps extension, seated dumbbell press, and lateral dumbbell raise were performed at 70% intensity of 1 RM for 8 reps lasting for 1-min each.

Subsequently, the subjects were switched to exercising the lower limb muscles at low resistance. This program consisted of leg press, lying leg curls, leg extension, hip abduction, and hip adduction, respectively. Similarly, the intensity of the exercise was initiated at 30% of 1 RM with the subjects required to repeat 15 reps lasting for 1-min each, except for hip abduction and adduction that lasted for 2 min each. The upper limb muscle exercise at high resistance was continued. Likewise, leg press, lying leg curls, leg extension, hip abduction, and hip adduction were performed for 8 reps at 70% intensity of 1 RM. The subjects concluded the exercise program with a 3-min cool down period with brisk marching. The exercise period between the two exercise sessions (HII and ULLR trainings) was comparable (i.e., 30 min including a warm-up and cool down period).

The subjects in the HII and ULLR Training Groups were also requested to maintain a normal dietary intake behavior throughout the study. Pre- and post-enrollment, the subjects were evaluated for

dependent variables including body composition, nerve conduction velocity, and cardiac autonomic nervous activity.

Evaluation of Maximal Oxygen Consumption

VO₂ max was evaluated on a bicycle ergometer (Monark Ergomedic 828E, Sweden) according to the YMCA cycle test. Seat height was adjusted appropriately for each subject and remained constant throughout the test. The subjects were instructed to warm-up at a free workload (0 Kp) for 3 min. The initial workload was set at 1.0 kp or 50 watts for the males and 0.5 kp or 25 watts for the females, which was then increased every 3 min depending on subject's HR. The test was considered to take account of three stages. However, a fourth stage was supplementary if the subject's HR did not exceed 75% of predicted HR (220-age). During the test, subjects were required to cycle at a cadence of 50 to 60 rev·min⁻¹. The test was terminated once the subject could not maintain cadence or HR increased to 75% of predicted HR. Data including gender, weight, workload, and HR at the last two submaximal stages were used to calculate VO₂ max in accordance with the program provided by ExRx.net (10).

Evaluation of 1 Repetition Maximum

The 1 RM test is considered the gold standard for evaluating muscle strength in non-laboratory situations. It is defined as the maximal weight that can be lifted once with correct lifting technique (58). In this study, the subjects were evaluated in accordance with 1 RM for lateral pulldown, biceps curls, triceps extension, seated dumbbell press, lateral dumbbell raise, leg press, lying leg curls, leg extension, hip abduction, and hip adduction using weight machines (Body-Solid G9S Multi-Station Home Gym, Taiwan). Prior to the test, each subject was instructed to perform a 3-min warm-up by stretching the entire body as well as being instructed on proper technique for all attempts. A minimum of a 3-min rest period was allowed between each strength evaluation. In case of the maximum number of repetitions being more than 1 repetition (i.e., 2 to 15 reps), the Baechle and Earle's prediction equation was applied to estimate the 1 RM (4). The weight (W) and number of repetitions (R) were used to calculate with the equation expressed as $1 \text{ RM} = W \times [1 + (0.033 \times R)]$.

Evaluation of Body Composition and Anthropometry

Body composition was evaluated by applying a body composition analyzer (InBody 270, Korea) based on the principle of bioelectrical impedance analysis. The subjects were in the standing position while wearing minimal clothes that enabled body mass, BMI, body fat percentage, fat mass, fat-free mass, muscle mass, protein mass, mineral mass, water mass, and basal metabolic rate (BMR) to be analyzed. Height measurement was taken during inspiration using a stadiometer (Health-O-Meter ProSeries, USA). Waist (W) and hip (H) circumferences were determined using a standard measuring tape, with their ratio (W/H ratio) yielded to evaluate fat distribution. Waist circumference was determined at the mid-point between the bottom rib and the superior iliac spine at the end of a normal expiration. Hip circumference was evaluated on a horizontal plane at the line between femur heads (52).

Evaluation of Nerve Conduction Velocity

Nerve conduction velocity was evaluated at subjects' dominant in both the upper and lower limbs as well as in both motor and sensory nerves. The Neuro-MEP digital EMG and EP system (Neurosoft, Russia) was used to evaluate the median and deep peroneal nerves of the upper and lower limbs respectively. Subjects rested in the supine and supination position in a quiet room at $24.64 \pm 0.64^\circ\text{C}$ and humidity $51.71 \pm 3.02\%$. In the evaluation of motor nerve conduction velocity of the median nerve, the recording electrode was placed on the most exposed part of the thumb. Stimulation was applied at three distinct points: the wrist, elbow, and arm, with the stimulating electrode positioned 2-cm above the wrist-crease, under the bicipital aponeurosis and bicipital groove. Stimulus intensity

was set at 10 mA with a stimulus duration of 0.2 ms. For sensory nerve conduction velocity of the median nerve, the recording electrode was placed on a proximal phalanx of a middle finger. Stimulation was then applied at the wrist, with the stimulating electrode positioned at the midline of the wrist, 14-cm above the proximal phalanx of the middle finger (above the pisiform bone). Stimulus intensity was set at 2 mA at a duration of 0.1 ms.

For motor nerve conduction velocity of the deep peroneal nerve, the recording electrode was placed on the projection of the short extensor of the toes. Stimulation was applied at three distinct points: the ankle, fibula head, and popliteal fossa, with the stimulating electrode positioned on the midline between malleoli tops, under the head of the fibula, and popliteal space. Stimulus intensity was set at 25 mA and stimulus duration was 0.2 ms. For sensory nerve conduction velocity of the deep peroneal nerve, the recording electrode was placed on the middle of the line connecting the most prominent parts of the malleoli. Stimulation was applied at the ankle, with the stimulating electrode positioned on the dorsal foot, 8-cm below the midline between the most prominent parts of the malleoli. Stimulus intensity was set at 2 mA at a duration of 0.1 ms. The above stimulations were applied at each point until provoking maximum subject response. As well as nerve conduction velocity, nerve conduction amplitude and nerve conduction latency were also evaluated.

Evaluation of Cardiac Autonomic Nervous Activity

Heart rate variability (HRV) is a non-invasive tool applied to evaluate the autonomic nervous system control on the HR (11). In this study, short-term HRV was recorded and analyzed for evaluating cardiac autonomic nervous activity. The HRV recording was gained for 10 min using Lead II electrocardiography (PowerLab 4/30, ADInstruments, Australia). Analysis of HRV parameters involved time domain and frequency domain. The time domain comprised of the standard deviation of normal beat-to-beat (R-R) intervals (SDNN) in addition to the root-mean-square of successive R-R (RMSSD). Frequency domain consisted of the values of total power (TP), very low, low, and high frequency powers (VLF: DC to 0.04 Hz, LF: 0.04 to 0.15 Hz, and HF: 0.15 to 0.4 Hz), and LF/HF ratio. LF and HF powers in normalized units (nu.) were calculated by LF power (nu.) = LF power (ms²)/total power (ms²) × 100 and HF power (nu.) = HF power (ms²)/total power (ms²) × 100. Data obtained from HRV parameters reflect sympathetic and parasympathetic nervous control of the heart as well as their balance (61).

Statistical Analyses

The sample size in this study was calculated using a statistical formula by Bonferroni *t* test for means comparison. A study by Ucan (67) reported a mean difference in fat mass between a circuit resistance training group and a control group of 2.8% with SD of 1.72. Alpha error was set at 0.05, beta error was at 0.20, and power of test was at 0.80. Thus, the sample size was 20 subjects per group totaling 60 subjects, including 20% drop out. Data analyses were performed using IBM SPSS Statistics 21 (IBM, Armonk, NY, USA). All data were expressed as mean ± SD. The Shapiro-Wilk test was applied to examine normal distribution of data. One-way analysis of variance (ANOVA) and Bonferroni *post-hoc* tests were applied to assess the differences between groups (CT, HII Training, and ULLR Training Groups) at baseline and after intervention. Paired *t*-test was used to evaluate the differences within each group with statistical significance set at P<0.05.

RESULTS

A total of 66 subjects were eligible and included in this study, which consisted of 46 men (69.70%) and 20 women (30.30%), aged 20.52 ± 0.86 yrs, BMI 22.78 ± 8.79 kg·m⁻². During the study period, 6

subjects withdrew from the study. Hence, 60 subjects completed the study (90.90%), accounting for 20 subjects in each group.

Physical and Physiological Characteristics

There were no significant differences in gender, age, height, BMI, BMR, VO_2 max, SBP, DBP, and HR between the CT, HII Training Group, and ULLR Training Group prior to intervention. Nevertheless, the HII Training Group demonstrated greater body mass ($P < 0.05$) than the ULLR Training Group (Table 1).

Table 1. Physical and Physiological Characteristics of Subjects Before Intervention.

Variables	CT Group	HII Training Group	ULLR Training Group
Gender (male/female), n (%)	12/8 (60/40)	16/4 (80/20)	13/7 (65/35)
Age (yrs)	20.75 ± 1.02	20.30 ± 0.57	20.40 ± 0.82
Height (m)	1.68 ± 0.08	1.73 ± 0.10	1.69 ± 0.08
Body Mass (kg)	61.41 ± 12.00	69.46 ± 10.54	59.44 ± 9.79 ^a
BMI (kg·m ⁻²)	21.57 ± 3.36	26.20 ± 15.10	20.67 ± 2.28
BMR (kcal·day ⁻¹)	1426.75 ± 216.42	1580.70 ± 211.92	1426.90 ± 184.31
VO₂ max (mL·kg ⁻¹ ·min ⁻¹)	42.25 ± 9.53	43.84 ± 9.39	46.39 ± 16.43
SBP (mmHg)	116.70 ± 17.43	122.60 ± 10.92	119.50 ± 11.97
DBP (mmHg)	73.25 ± 7.64	74.65 ± 8.85	71.15 ± 5.78
HR (beats·min ⁻¹)	65.65 ± 8.62	60.80 ± 9.53	65.80 ± 15.02

Data expressed as mean ± SD; n = 20 per group; **BMI** = Body Mass Index; **BMR** = Basal Metabolic Rate; **VO₂ max** = Maximal Oxygen Consumption; **SBP** = Systolic Blood Pressure; **DBP** = Diastolic Blood Pressure; **HR** = Heart Rate; **CT** = Control; **HII** = High-Intensity Interval; **ULLR** = Upper and Lower Limbs Resistance. ^aSignificantly different from HII Training Group ($P < 0.05$)

Body Composition

Within Group Comparison

There were significant increases in fat-free mass, water mass, and protein mass in the ULLR Training Group subsequent to intervention ($P < 0.05$). On the contrary, fat-free mass, water mass, and protein mass were significantly decreased in the HIIT Training Group ($P < 0.05$) (see Figure 1). Notwithstanding, body mass tended to decrease in the HII Training Group ($P = 0.08$), and mineral mass tended to increase in the ULLR Training Group ($P = 0.07$) post intervention (Table 2).

Between Group Comparison

The results showed a significantly higher body mass as well as mineral mass in the HII Training Group compared with the ULLR Training Group prior to intervention ($P < 0.05$). A lower mineral mass in the ULLR Training Group when compared with the HII Training Group was not observed after intervention (Table 2).

Table 2. Body Composition of Subjects Before and After Intervention.

Variables	CT Group		HIIT Training Group		ULLR Training Group	
	Before	After	Before	After	Before	After
Body Mass (kg)	61.41 ± 12.00	61.62 ± 12.16	69.46 ± 10.54	68.75 ± 9.95	59.44 ± 9.79 ^a	60.00 ± 9.38 ^a
BMI (kg·m ⁻²)	21.57 ± 3.36	21.72 ± 3.45	26.20 ± 15.10	22.98 ± 2.30	20.67 ± 2.28	20.92 ± 2.38
Fat Mass (%)	19.80 ± 10.46	20.69 ± 10.66	19.38 ± 6.60	19.71 ± 6.61	17.68 ± 5.14	17.23 ± 5.75
Fat Mass (kg)	12.48 ± 8.06	13.07 ± 8.46	13.42 ± 4.84	13.53 ± 4.86	10.50 ± 3.40	10.30 ± 3.69
Fat-Free Mass (%)	80.18 ± 10.44	79.29 ± 10.68	80.64 ± 6.60	80.28 ± 6.60	82.33 ± 5.17	82.77 ± 5.74
Fat-Free Mass (kg)	48.92 ± 10.01	48.54 ± 10.34	56.06 ± 9.81	55.21 ± 9.26*	48.94 ± 8.53	49.70 ± 8.63*
Water Mass (%)	58.81 ± 7.71	58.15 ± 7.91	59.05 ± 4.86	58.75 ± 4.87	60.35 ± 3.83	60.68 ± 4.26
Water Mass (kg)	35.88 ± 7.36	35.60 ± 7.61	41.05 ± 7.18	40.40 ± 6.79*	35.87 ± 6.24	36.44 ± 6.34*
Protein Mass (kg)	9.69 ± 2.05	9.63 ± 2.12	11.14 ± 1.99	10.96 ± 1.83*	9.72 ± 1.75	9.87 ± 1.77*
Mineral Mass (kg)	3.35 ± 0.60	3.32 ± 0.63	3.88 ± 0.65 [#]	3.85 ± 0.63 [#]	3.35 ± 0.56 ^a	3.39 ± 0.53
W/H ratio	0.85 ± 0.06	0.85 ± 0.07	0.84 ± 0.06	0.84 ± 0.06	0.83 ± 0.04	0.83 ± 0.05
Visceral Fat Level	4.45 ± 3.36	4.65 ± 3.39	4.75 ± 2.15	4.75 ± 2.10	3.65 ± 1.53	3.45 ± 1.73

Data expressed as mean ± SD; n = 20 per group; **BMI** = Body Mass Index; **W/H** = Waist to Hip Circumference; **CT** = Control; **HIIT** = High-Intensity Interval; **ULLR** = Upper and Lower Limbs Resistance. *Significantly different from Before Intervention (P<0.05), [#]Significantly different from the Control Group (P<0.05), ^aSignificantly different from HIIT Training Group (P<0.05)

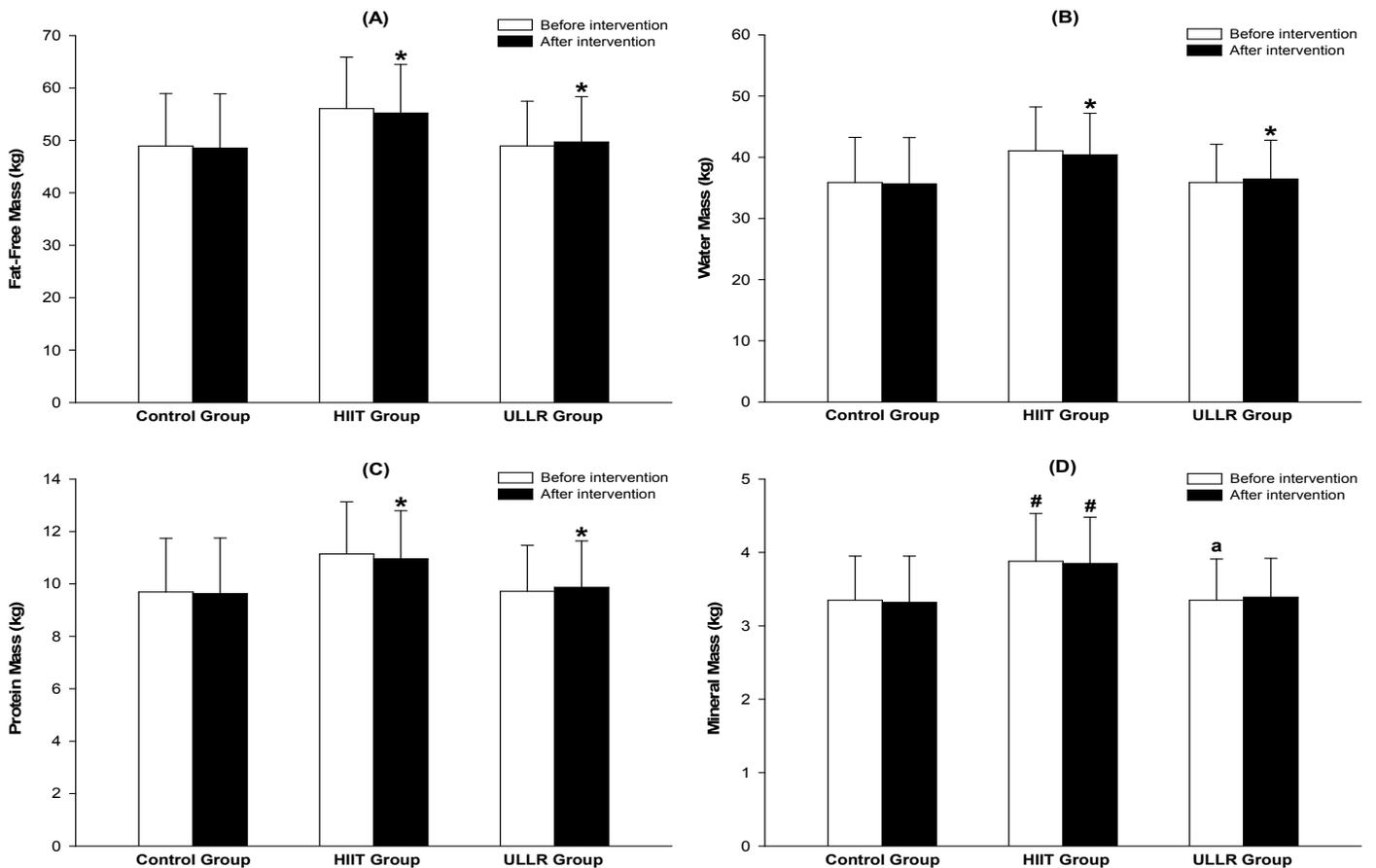


Figure 1. Fat-Free Mass (A), Water Mass (B), Protein Mass (C), and Mineral Mass (D) of Control, High-Intensity Interval Training (HIIT), and Upper and Lower Limbs Resistance Training (ULLR) Groups. Data expressed as mean ± SD; n = 20 per group. *Significantly different from Before Intervention (P<0.05), [#]Significantly different from the Control Group (P<0.05), ^aSignificantly different from HIIT Group (P<0.05)

Nerve Conduction Velocity, Amplitude, and Latency

Within Group Comparison

Sensory nerve conduction velocity of the lower limbs significantly increased with nerve conduction latency significantly decreased in the CT Group post intervention ($P < 0.05$). There were also unexpected results in terms of motor nerve conduction velocity in the lower limbs in the HII Training Group, which was significantly decreased subsequent to intervention ($P < 0.05$). However, the nerve conduction velocity of the upper limbs was markedly increased ($P < 0.05$), and the nerve conduction amplitude of the lower limbs tended to increase after intervention ($P = 0.09$). Nerve conduction velocity and latency in the ULLR Training Group were unaltered. Yet, motor nerve conduction amplitude of the upper limbs significantly increased ($P < 0.05$) post intervention (Figure 2 and Tables 3-5).

Between Group Comparison

The HII Training Group presented significantly higher sensory nerve conduction velocity in the lower limbs than the CT Group before intervention ($P < 0.05$). Nerve conduction latency was significantly lower in the HII and ULLR Training Groups when compared with the CT Group ($P < 0.05$). Differences in nerve conduction velocity and latency between Groups were not observed post intervention. Nonetheless, motor nerve conduction upper limb amplitude was significantly higher in the ULLR Training Group as compared with the CT Group ($P < 0.05$). In addition, lower limb motor nerve conduction amplitude in the HII Training Group had a tendency to be greater ($P = 0.08$) than in the ULLR Training Group subsequent to intervention (Figure 2 and Tables 3-5).

Table 3. Motor and Sensory Nerve Conduction Velocity of Subjects.

Variables	CT Group		HII Training Group		ULLR Training Group	
	Before	After	Before	After	Before	After
Motor Nerve Velocity						
Median Nerve						
Elbow ($m \cdot s^{-1}$)	49.58 ± 16.30	53.93 ± 14.16	57.94 ± 6.17	57.49 ± 3.94	56.46 ± 11.55	57.43 ± 4.59
Arm ($m \cdot s^{-1}$)	260.27 ± 766.39	67.40 ± 20.24	107.85 ± 135.72	87.91 ± 50.15	84.71 ± 56.64	109.27 ± 113.68
Peroneus Nerve						
Head of Fibula ($m \cdot s^{-1}$)	45.79 ± 15.77	50.79 ± 6.64	50.99 ± 4.95	40.79 ± 16.73*	52.83 ± 9.39	196.93 ± 640.35
Popliteal Fossa ($m \cdot s^{-1}$)	71.01 ± 50.96	61.07 ± 19.94	62.13 ± 18.49	213.99 ± 714.77	107.07 ± 181.75	61.59 ± 24.59
Sensory Nerve Velocity						
Median Nerve						
Wrist ($m \cdot s^{-1}$)	75.36 ± 64.99	107.40 ± 87.55	80.91 ± 61.80	81.81 ± 64.88	96.61 ± 68.50	112.51 ± 93.55
Peroneus Nerve						
Ankle ($m \cdot s^{-1}$)	26.38 ± 24.31	59.66 ± 34.30*	50.53 ± 32.55 [#]	42.93 ± 27.67	43.82 ± 32.64	43.44 ± 31.14

Data expressed as mean ± SD; n = 20 per group; **CT** = Control; **HII** = High-Intensity Interval; **ULLR** = Upper and Lower Limbs Resistance. * Significantly different from Before Intervention ($P < 0.05$), [#] Significantly different from the Control Group ($P < 0.05$)

Table 4. Motor and Sensory Nerve Conduction Latency of Subjects.

Variables	CT Group		HII Training Group		ULLR Training Group	
	Before	After	Before	After	Before	After
Motor Nerve Latency						
<i>Median Nerve</i>						
Wrist (ms)	3.22 ± 0.48	3.30 ± 0.45	3.19 ± 0.27	3.17 ± 0.42	3.14 ± 0.45	3.25 ± 0.42
Elbow (ms)	7.50 ± 1.01	7.55 ± 0.92	7.48 ± 0.55	7.42 ± 0.60	7.87 ± 2.32	7.45 ± 0.70
Arm (ms)	7.67 ± 1.95	8.10 ± 1.84	8.69 ± 0.71	8.57 ± 0.57	8.71 ± 2.79	8.45 ± 0.79
<i>Peroneus Nerve</i>						
Sole of Foot (ms)	3.47 ± 1.05	3.49 ± 0.46	3.99 ± 1.07	3.59 ± 1.03	3.71 ± 1.18	4.23 ± 1.98
Head of Fibula (ms)	10.38 ± 1.49	10.12 ± 0.96	10.90 ± 1.45	10.95 ± 1.42	10.24 ± 0.76	10.49 ± 1.34
Popliteal Fossa (ms)	11.01 ± 3.09	11.18 ± 2.02	12.44 ± 1.80	10.78 ± 3.84	11.63 ± 0.92	11.50 ± 2.23
Sensory Nerve Latency						
<i>Median Nerve</i>						
Wrist (ms)	3.00 ± 2.11	2.80 ± 2.69	2.78 ± 2.12	2.99 ± 2.27	2.75 ± 2.85	2.83 ± 2.82
<i>Peroneus Nerve</i>						
Ankle (ms)	6.00 ± 3.66	2.87 ± 3.10*	3.28 ± 2.53 [#]	3.92 ± 3.26	3.45 ± 2.39 [#]	4.47 ± 4.46

Data expressed as mean ± SD; n = 20 per group; **CT** = Control; **HII** = High-Intensity Interval; **ULLR** = Upper and Lower Limbs Resistance. * Significantly different from Before Intervention (P<0.05), [#]Significantly different from the Control Group (P<0.05)

Table 5. Motor and Sensory Nerve Conduction Amplitude of Subjects.

Variables	CT Group		HII Training Group		ULLR Training Group	
	Before	After	Before	After	Before	After
Motor Nerve Amplitude						
<i>Median Nerve</i>						
Wrist (mV)	7.55 ± 2.49	8.63 ± 3.17	9.32 ± 3.39	10.81 ± 3.32*	8.95 ± 4.13	11.07 ± 2.78 [#]
Elbow (mV)	6.92 ± 2.53	7.31 ± 3.59	8.62 ± 3.52	9.95 ± 4.02	8.90 ± 3.43	9.48 ± 2.65
Arm (mV)	6.71 ± 3.07	7.34 ± 3.34	7.10 ± 3.18	8.48 ± 2.88	7.79 ± 3.93	9.31 ± 3.43
<i>Peroneus Nerve</i>						
Sole of Foot (mV)	4.57 ± 2.07	4.83 ± 2.81	4.17 ± 2.68	4.83 ± 1.20	3.55 ± 2.73	3.99 ± 2.00
Head of Fibula (mV)	4.94 ± 2.17	4.78 ± 2.61	4.72 ± 2.21	5.75 ± 1.36	4.14 ± 2.22	4.32 ± 1.80
Popliteal Fossa (mV)	5.17 ± 2.42	4.98 ± 2.37	5.13 ± 2.43	5.69 ± 1.48	4.43 ± 2.23	4.50 ± 1.77
Sensory Nerve Amplitude						
<i>Median Nerve</i>						
Wrist (mV)	8.59 ± 7.53	11.10 ± 11.11	7.95 ± 5.61	11.86 ± 13.10	6.52 ± 4.15	6.80 ± 7.29
<i>Peroneus Nerve</i>						
Ankle (mV)	4.81 ± 2.59	4.74 ± 2.61	3.87 ± 1.82	5.05 ± 2.21	4.93 ± 5.16	6.45 ± 3.29

Data expressed as mean ± SD; n = 20 per group; **CT** = Control; **HII** = High-Intensity Interval; **ULLR** = Upper and Lower Limbs Resistance. * Significantly different from Before Intervention (P<0.05), [#]Significantly different from the Control Group (P<0.05)

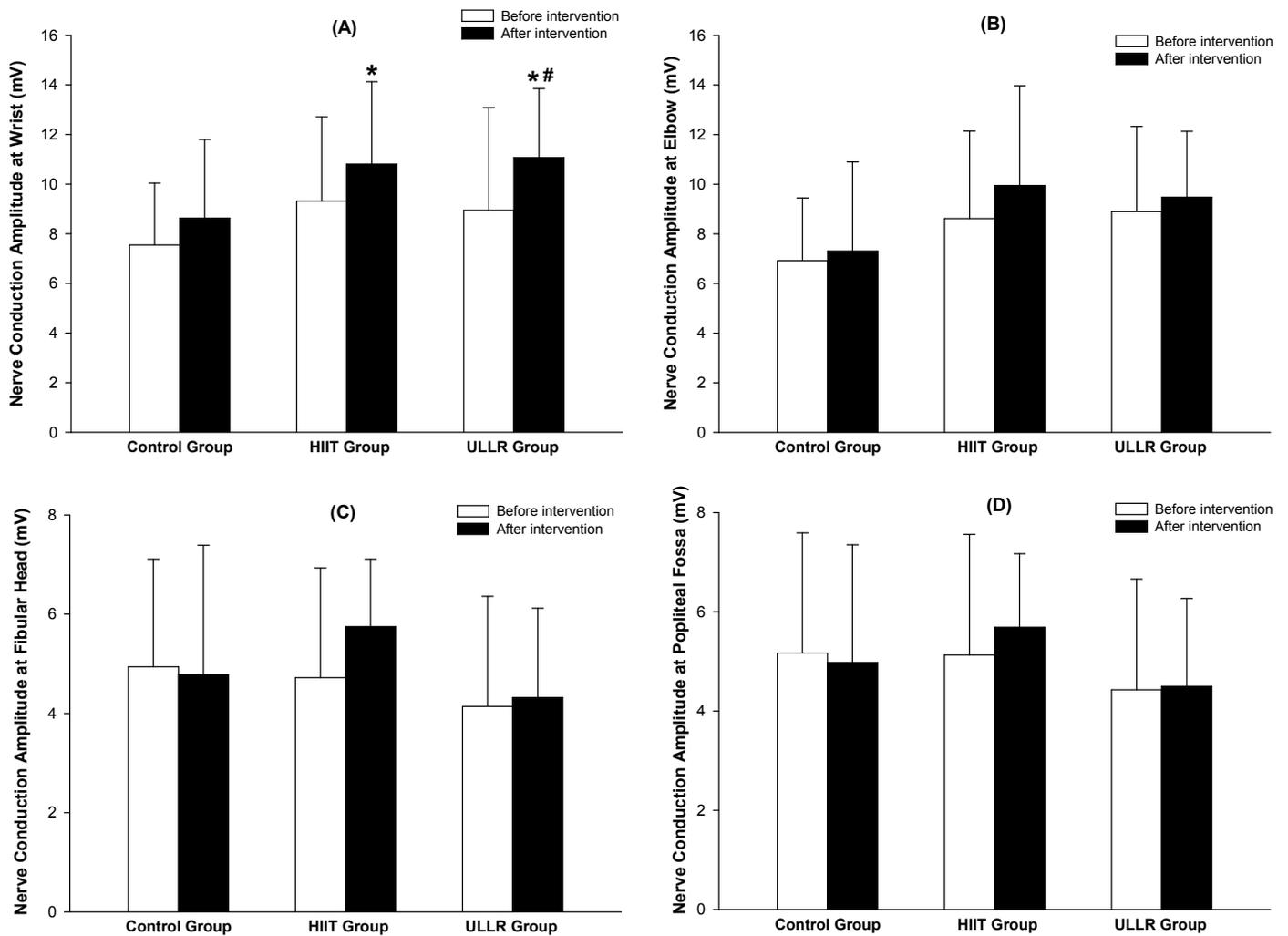


Figure 2. Motor Nerve Conduction Amplitude at Wrist (A), Elbow (B), Head of Fibula (C), and Popliteal Fossa (D) of Control, High-Intensity Interval Training (HIIT), and Upper and Lower Limbs Resistance Training (ULLR) Groups. Data expressed as mean \pm SD; $n = 20$ per group. *Significantly different from Before Intervention ($P < 0.05$), #Significantly different from the Control Group ($P < 0.05$)

Cardiac Autonomic Nervous Activity

Within Group Comparison

Table 6 shows cardiac autonomic nervous activity among subjects. There were no significant alterations in variables of cardiac autonomic nervous activity in both CT and ULLR Training Groups after intervention. Notwithstanding, there was a significant increase in VLF power value amid the HIIT Training Group ($P < 0.05$) (Figure 3). Furthermore, HR in the HIIT Training Group tended to reduce post intervention ($P = 0.07$).

Between Group Comparison

There were no significant differences in variables of cardiac autonomic nervous activity among CT, HIIT Training, and ULLR Training Groups preceding intervention. However, TP and VLF power values amid the HIIT Training Group were markedly higher than in the CT Group succeeding intervention ($P < 0.05$). VLF power value in the HIIT Training Group was also significantly higher than in the ULLR Training Group ($P < 0.05$) (Figure 3 and Table 6). Moreover, SDNN value in the HIIT Training Group tended to be greater than in the CT Group ($P = 0.08$).

Table 6. Cardiac Autonomic Nervous Activity of Subjects.

Variables	CT Group		HIIT Training Group		ULLR Training Group	
	Before	After	Before	After	Before	After
HR (beats·min ⁻¹)	62.91 ± 7.89	64.55 ± 16.20	66.29 ± 16.55	59.52 ± 9.99	63.71 ± 11.69	64.64 ± 14.64
SDNN (ms)	69.41 ± 24.12	73.55 ± 28.27	84.52 ± 47.44	97.46 ± 39.77	79.40 ± 34.96	75.20 ± 30.54
RMSSD (ms)	61.88 ± 37.97	70.60 ± 37.07	89.96 ± 73.42	93.69 ± 57.89	83.17 ± 52.17	74.27 ± 34.45
Total Power (ms ²)	5239.92 ± 4049.96	6025.46 ± 4568.17	8772.56 ± 11292.91	11506.09 ± 10056.10 [#]	6829.46 ± 5579.94	6228.15 ± 4243.97
VLF Power (ms ²)	2190.31 ± 1994.88	2214.30 ± 1517.39	2452.15 ± 2149.11	4533.17 ± 3751.70 ^{*#}	1932.69 ± 1512.29	1956.44 ± 1624.81 ^a
LF Power (ms ²)	1120.29 ± 800.93	1404.97 ± 1344.45	2093.81 ± 2063.55	2402.55 ± 1871.21	1780.73 ± 1760.81	1862.60 ± 1666.73
LF Power (nu.)	44.09 ± 20.78	39.27 ± 20.24	39.85 ± 21.13	43.38 ± 18.99	40.49 ± 15.96	42.73 ± 17.68
HF Power (ms ²)	1754.01 ± 2270.10	2095.44 ± 2136.43	3467.34 ± 5763.98	4198.91 ± 5583.40	2728.63 ± 2691.75	2172.83 ± 1916.74
HF Power (nu.)	50.92 ± 19.64	49.45 ± 17.93	49.69 ± 18.54	51.75 ± 19.92	52.37 ± 17.68	49.08 ± 17.89
LF/HF Ratio	1.28 ± 1.21	1.03 ± 0.95	1.18 ± 1.46	1.31 ± 1.48	0.98 ± 0.75	1.06 ± 0.68

Data expressed as mean ± SD; n = 20 per group; HR = Heart Rate; SDNN = Standard Deviation of Normal Beat-to-Beat (R-R) Intervals; RMSSD = Root-Mean-Square of Successive R-R; VLF = Very Low Frequency; LF = Low Frequency; HF = High Frequency; LF/HF = Low to High Frequency; CT = Control; HIIT = High-Intensity Interval; ULLR = Upper and Lower Limbs Resistance. *Significantly different from Before Intervention (P<0.05), #Significantly different from the Control Group (P<0.05), ^aSignificantly different from HIIT Training Group (P<0.05)

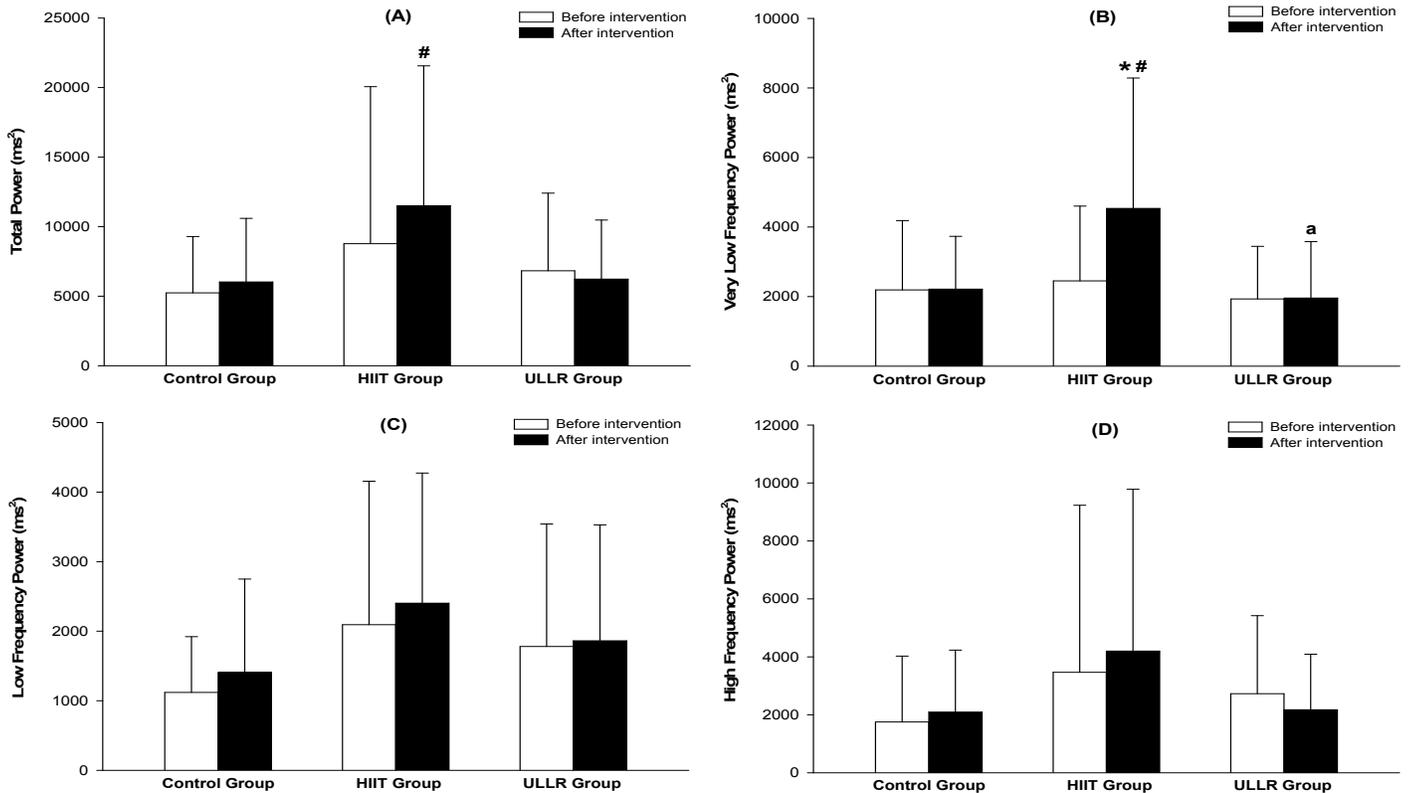


Figure 3. Total Power (A), Very Low Frequency Power (B), Low Frequency Power (C), and High Frequency Power (D) of Heart Rate Variability of Control, High-Intensity Interval Training (HIIT), and Upper and Lower Limbs Resistance Training (ULLR) Groups. Data expressed as mean ± SD; n = 20 per group. *Significantly different from Before Intervention (P<0.05), #Significantly different from the Control Group (P<0.05), ^aSignificantly different from HIIT Group (P<0.05)

DISCUSSION

Physical fitness is the body's ability to function at optimal competence. Cardiorespiratory fitness, muscular endurance, muscular strength, flexibility, and body composition reflect physical fitness. Each one is vital to overall health and performance amid functional activities (63). Body composition is not only directly related to physical fitness, but also linked to cardiovascular disease (17,68). Higher body fat percentage, BMI, and W/H ratio are associated with an increased risk of mortality and cardiovascular disease, with W/H ratio appearing to demonstrate the paramount predictive index (45,56).

A multidisciplinary approach of combining dietary intake and regular exercise is a potentially effective strategy to improving body composition (3). Varieties in exercise training programs including HII training and resistance training on the improvement of body composition are also important. HII training is characterized by brief bouts of intense exercise (i.e., >80% of maximum HR) followed by periods of low-intensity trials or rests. This model has shown to be similar or superior to moderate-intensity continuous training on the reduction of body fat and visceral fat and increased cardiorespiratory fitness (14,66). Resistance training is the primary mode of exercise for enhancing muscular adaptations that include muscle strength and hypertrophy. Current guidelines recommend that applying loads of $\geq 65\%$ 1 RM are needed to elicit favorable increases in hypertrophy, with higher loads necessary to maximize strength (57).

The American College of Sports Medicine (ACSM) and World Health Organization (WHO), recommend that adults perform resistance training at least twice a week for health benefits (75). This mode has shown to augment muscle mass and lower body fat (40,59). Our study demonstrated negative results in regards HII training on body composition, namely, significantly decreased fat-free mass, protein mass, or water mass succeeding intervention. On the contrary, these outcomes had significantly increased in the ULLR Training Group post intervention. Obviously, regular resistance training exercise of the upper and lower limb muscles for 8 wks modifies body composition that includes fat-free mass, protein mass, water mass, as well as mineral mass of which was significantly lower than in the HII Training Group at baseline, yet no significant difference was observed post-training. In the HII Training Group, although body mass tended to decrease, fat mass also tended to increase along with a significant decrease in fat-free mass, protein mass, and water mass following intervention. These decreases may partly be clarified by certain explanations. Exercise-induced muscle damage is known to be a causal mechanism for decreased strength and hypertrophy (55). A previous study reported that HII training incorporating cycling revealed a trend for lower body strength development indicating that HII training incorporating cycling may attenuate muscular strength development in the lower limbs (55).

Furthermore, our HII training protocol which consisted of cycling at 70/30% VO_2 max with work/rest duration of 1-min/1-min may produce muscle damage to the lower limbs (19,72). Although it is an indirect inference, it is plausible that HII training would induce muscle damage amid the lower limbs resulting in a decreased fat-free mass as well as protein mass. A measurement of physical performance such as muscle strength of the lower limbs or muscle damage should be taken into consideration in a further study. Moreover, there was a significant decrease in motor nerve conduction velocity at the peroneus nerve in the HII Training Group post intervention. These consort data may support the link between changes in body composition (i.e., fat mass or fat-free mass) in addition to changes in nerve conduction velocity. It is well known that varying exercise training methodology appears to obtain diverse results (13,42). Hence, our results were rather dissimilar to previous studies that reported increased muscle mass as well as decreased fat mass following HII training (1,2,13,54,76).

Exercise training with high loads may lead to adaptation responses in the muscles, bones, tendons, and nerves. Also, training frequency and volume may affect motor nerve conduction velocity (12). There are many factors influencing the higher motor nerve conduction velocity among individuals engaging in exercise training. First, lower body fat percentage appears to promote motor nerve conduction velocity and enhance efficiency of neuromuscular function integration, thus facilitating neural transmission. Second, functional overload may contribute to increased nerve fiber diameter and myelin sheath (12). Third, there are alterations in structure and function of neuromuscular junctions (NMJ). Exercise increases both the size and degree of motor nerve terminal branching at the NMJ, total area of both pre- and postsynaptic terminals, and acetylcholine release (30).

The results of this research did not present any significant difference in motor nerve conduction velocity, despite previous studies having similarly reported an increase in motor nerve conduction velocity following exercise training (21). However, motor nerve conduction amplitude of the median nerve at the wrist was observed to increase after ULLR training. This reveals adaptation of the median nerve function in that it is beneficial as a result of our training program. Meanwhile, there was a lack of any alteration in nerve conduction velocity; and adjacent outcomes such as nerve conduction latency are arduous to explain. Some distinct points that could be mentioned are that fat-free mass and protein mass among subjects in the ULLR Training Group significantly increased. Also, it has been evidenced that hypertrophy of muscles adjacent to the nervous tract of the limbs among trained individuals may lead to compression of the nerve and consequent delay in nervous impulse (12). Therefore, neither sensory nor motor nerve conduction velocity exhibited any significant change in the ULLR Training Group.

In addition, the nature of our exercise training program emphasized weight training, categorized as a high static, low dynamic sport (41). A previous work by Huang et al. (32) suggested that reaction, coordination, and speed ability are related to nerve conduction velocity. In their study, faster nerve conduction velocity was found in soccer players than in sanshou players. Another suggestion is that adaptation of nerve conduction velocity may depend on movement requirement (i.e., changing movement direction quickly and skillfully). Collectively, lower static or higher dynamic training may elicit alterations in nerve conduction velocity superior to high static or low dynamic training (51). Our observation is similar to Kludding et al. (38) who reported that a 10-wk aerobic and resistance exercise program improved intradermal nerve fiber branching at proximal sites with neuropathic pain score, but no significant alteration in nerve conduction velocity nor nerve conduction amplitude.

One possible factor that could lead to a decrease in motor conduction velocity amid the peroneus nerve in the HII Training Group is a tendency to increase body fat percentage or body fat mass, although a statistical significance was not reached. According to previous reports (39,50), an increased amount of body fat is related to an increased adipose tissue level in the epineurium that slows nerve conduction. We also observed an increase in sensory nerve conduction velocity in the lower limbs amid the Control Group. In this group, we did not govern their physical activities including daily exercise, and subjects were in a free-living condition during the study period. Because it has been suggested that sensory nerves are more sensitive to stimuli such as hyperglycemia or exercise-related adaptations (29), it is possible that, without adding an exercise training program, those athletes who regularly exercised tended to display improved sensory nerve conduction velocity.

Exercise training has been accepted to reduce cardiovascular disease risks, for instance, hypertension and heart failure resultant of reducing sympathetic nervous system overactivity and enhancing parasympathetic nervous activity (8,15). Recent evidence suggests that central nervous

system plasticity and cardiorespiratory center remodeling occurs under exercise training (26,44). Additionally, exercise training can provide cardiac remodeling, increase cardiac size and mass, and improve cardiac function (26). In healthy subjects, autonomic nervous system responses differ by exercise modality (i.e., duration, frequency, intensity, recovery, and volume) (6). Studies in patients with heart diseases revealed positive effects as an outcome of HII training amid improvements in HRV indices (9,28,70). Results of the present study revealed significant increases in TP and VLF power values in the HII Training Group. VLF power may be produced by physical activity, thermoregulatory, renin-angiotensin, and endothelial influences on the heart. In addition, parasympathetic nerve activity may contribute to VLF power (61), and it has been shown that low VLF power correlates with arrhythmic death, post-traumatic stress disorder, high inflammation, and a low testosterone level (61). Total power is calculated by the sum of VLF, LF, and HF power (33). Due to no significant alterations in either LF power or HF power, an increase in total power in the present study was a consequence of increased VLF power.

Based on the aforementioned data, it is likely that HII training may provide a beneficial effect on improved cardiac parasympathetic nervous function among athletes. It has also been suggested that HII training induces increased baroreflex sensitivity that may also be considered to enhance parasympathetic function (7). On the other hand, results gathered from the ULLR Training Group did not show any significant change in HRV parameters. Resistance exercise training has been reported to have no influence on HRV in healthy young adults (20,34) while it may augment parasympathetic activity in middle-aged adults (37), and older adults (27) with autonomic dysfunction. However, inconsistent data have also been reported. de Sousa Fortes et al. (24) found an increased HRV in trained young adult males after 8 wks of resistance training. The authors suggested that resistance training at high intensity (>70% of 1 RM) and medium term (8 wks) may increase HRV through the mechanism of reduction of the concentrations of metabolites and pro-inflammatory cytokines leading to optimization of parasympathetic activation as well as reduction of the sympathetic tone.

In the current study, our resistance training program differed from previous studies. We designed it in such a way to render efforts in moving high resistance loading (70% 1 RM) interspersed with low resistance loading (30% 1 RM). Hence, it is possible that interchanges in applied loads may be insufficient in terms of inducing adaptation amid cardiac autonomic function. In addition, sequence of exercise in the present study, for instance 30% 1 RM lateral pulldown followed by 30% 1 RM biceps curls - which means applying low resistance followed by low resistance - might not facilitate cardiac autonomic modulation. Because low intensity exercise results in low stress to the cardiovascular system (43), an adjustment of exercise sequence to low resistance, alternated with high resistance, for example 30% 1 RM lateral pulldown followed by 70% 1 RM lateral pulldown, may elicit positive HRV metric results.

Limitations in this Study

Data from the present study supports the need for future investigations on biochemical assays such as blood glucose, lipid profile, inflammatory and oxidative stress markers in order to provide a comprehensive discussion. Measurements concerning physical performance such as muscle strength of the upper and lower limbs should be taken into consideration as well. Furthermore, a reformed resistance exercise sequence, that is, a high resistance alternative to low resistance may produce greater overload of the nervous and cardiovascular systems which may result in additional nervous and cardiovascular modifications.

CONCLUSIONS

The findings of the present study suggest that a resistance training program targeting the upper and lower limb muscles may be beneficial to improving body composition and motor nerve conduction amplitude in young adult athletes. Notwithstanding, the program is in need of further adjustments and exploration, especially with regards to cardiac autonomic nervous activity prior to applying it to a sports training program.

ACKNOWLEDGMENTS

This work was supported by the Faculty of Allied Health Sciences, Burapha University, Thailand under Grant AHS 03/2561.

Address for correspondence: Piyapong Prasertsri, PhD, Faculty of Allied Health Sciences, Burapha University, 169 Longhaad Bangsaen Road, Saensook, Mueang, ChonBuri 20131, Thailand, Phone: 66 3810 3166, Email: piyapong@go.buu.ac.th

REFERENCES

1. Andonian BJ, Bartlett DB, Huebner JL, Willis L, Hoselton A, Kraus VB, et al. Effect of high-intensity interval training on muscle remodeling in rheumatoid arthritis compared to prediabetes. *Arthritis Res Ther.* 2018;20(1):283.
2. Astorino TA, Heath B, Bandong J, Ordille GM, Contreras R, Montell M, et al. Effect of periodized high intensity interval training (HIIT) on body composition and attitudes towards hunger in active men and women. *J Sports Med Phys Fitness.* 2018;58(7-8):1052-1062.
3. Aziz NSA, Shahar S, Ambak R, Nor NSM, Jamil AT, Aris T. Influence of co-morbidity on body composition changes after weight loss intervention among overweight housewives: A follow-up study of the MyBFF@home. *BMC Womens Health.* 2018;18(Suppl 1):115.
4. Baechle TR, Earle RW. Essentials of strength training and conditioning. 2008. Champaign, IL: Human Kinetics.
5. Bernal AS, Pattar MY, Taklikar RH. Effect of height and BMI on nerve conduction velocity. *Indian J Clin Anat Physiol.* 2015;2(4):231-234.
6. Besnier F, Labrunée M, Pathak A, Pavy-Le Traon A, Galès C, Sénard JM, et al. Exercise training-induced modification in autonomic nervous system: An update for cardiac patients. *Ann Phys Rehabil Med.* 2017;60(1):27-35.
7. Bhati P, Moiz JA. High-intensity interval training and cardiac autonomic modulation. *Saudi J Sports Med.* 2017;17:129-134.
8. Billman GE. Counterpoint: Exercise training-induced bradycardia: The case for enhanced parasympathetic regulation. *J Appl Physiol (1985).* 2017;123(3):686-688.

9. Boidin M, Gayda M, Amoussou R, Hayami D, Juneau M, Henri C, et al. Effects of high intensity interval training on heart rate recovery, heart rate variability and arrhythmias in patients post-acute coronary syndrome. *Can J Cardiol*. 2015;31(10)(Suppl): S208-S209.
10. Boonla O, Prasertsri P. Lipid peroxidation, nerve conduction velocity and physical performance among male university athletes. *JEPonline*. 2018;21(5):184-197.
11. Borchini R, Veronesi G, Bonzini M, Gianfagna F, Dashi O, Ferrario MM. Heart rate variability frequency domain alterations among healthy nurses exposed to prolonged work stress. *Int J Environ Res Public Health*. 2018;15(1).pii:E113.
12. Borges LPNC, Leitão WCV, Ferreira JO, Carvalho LC. Measurement of motor nerve conduction velocity in three different sports. *Rev Bras Med Esporte*. 2013;19(5):328-331.
13. Brown EC, Hew-Butler T, Marks CRC, Butcher SJ, Choi MD. The impact of different high-intensity interval training protocols on body composition and physical fitness in healthy young adult females. *Biores Open Access*. 2018;7(1):177-185.
14. Carneiroa MAS, de Oliveiraa AA, Martins FM, Souza AP, Nunes PRP, Orsatti FL. High-intensity interval body weight training promotes different adaptations to combined training in body composition and muscle strength in young women. *Sci Sports*. 2018;33:e105-113.
15. Carter JR, Ray CA. Sympathetic neural adaptations to exercise training in humans. *Auton Neurosci*. 2015;188:36-43.
16. Caruso FR, Arena R, Phillips SA, Bonjorno JC Jr, Mendes RG, Arakelian VM, et al. Resistance exercise training improves heart rate variability and muscle performance: A randomized controlled trial in coronary artery disease patients. *Eur J Phys Rehabil Med*. 2015;51(3):281-289.
17. Chen A, Horwich T, Nardoni N. The effect of body composition on cardiovascular outcomes in cardiac rehabilitation patients with coronary heart disease. *J Am Coll Cardiol*. 2017;69(11)(Suppl).
18. Chiu SC, Yang RS, Yang RJ, Chang SF. Effects of resistance training on body composition and functional capacity among sarcopenic obese residents in long-term care facilities: A preliminary study. *BMC Geriatr*. 2018;18(1):21.
19. Cipryan L. IL-6, antioxidant capacity and muscle damage markers following high-intensity interval training protocols. *J Hum Kinet*. 2017;56:139-148.
20. Cooke WH, Carter JR. Strength training does not affect vagal-cardiac control or cardiovagal baroreflex sensitivity in young healthy subjects. *Eur J Appl Physiol*. 2005;93(5-6):719-725.
21. Dabagh nikookheslat S, Sarisarraf V, Salekzamani Y, Abdollahpour alni M, Fathollahi S. Effect of 12 weeks resistance training on neural conduction in type 2 diabetes men with peripheral neuropathy. *J Urmia Univ Med Sci*. 2017;28 (5):353-362.
22. Dawson JK, Dorff TB, Todd Schroeder E, Lane CJ, Gross ME, Dieli-Conwright CM. Impact of resistance training on body composition and metabolic syndrome variables during androgen

- deprivation therapy for prostate cancer: A pilot randomized controlled trial. *BMC Cancer*. 2018;18(1):368.
23. Delgado-Floody P, Latorre-Román P, Jerez-Mayorga D, Caamaño-Navarrete F, García-Pinillos F. Feasibility of incorporating high-intensity interval training into physical education programs to improve body composition and cardiorespiratory capacity of overweight and obese children: A systematic review. *J Exerc Sci Fit*. 2019;17(2):35-40.
24. de Sousa Fortes L, Pinheiro Paes P, Tavares Paes S, Oliveira Carvalho F, Serpeloni Cyrino E. Clustering vs multi-sets method in resistance training: Effect on heart rate variability. *Asian J Sports Med*. 2018;9(1):1-6.
25. Esco MR, Herron RL, Carter SJ, Flatt AA. Association of body composition and aerobic fitness on heart rate variability and recovery in young-adult black men. *Int J Clin Med*. 2013;4:532-538.
26. Fu Q, Levine BD. Exercise and the autonomic nervous system. *Handb Clin Neurol*. 2013;117:147-160.
27. Gambassi BB, Rodrigues B, Feriani DJ, Almeida FJF, Sauaia BA, Schwingel PA, et al. Effects of resistance training of moderate intensity on heart rate variability, body composition, and muscle strength in healthy elderly women. *Sport Sci Health*. 2016;12(3):389-395.
28. Ghardashi-Afousi A, Holisaz MT, Shirvani H, Pishgoo B. The effects of low-volume high-intensity interval versus moderate intensity continuous training on heart rate variability, and hemodynamic and echocardiography indices in men after coronary artery bypass grafting: A randomized clinical trial study. *ARYA Atheroscler*. 2018;14(6): 260-271.
29. Gholami F, Nikookheslat S, Salekzamani Y, Boule N, Jafari A. Effect of aerobic training on nerve conduction in men with type 2 diabetes and peripheral neuropathy: A randomized controlled trial. *Neurophysiol Clin*. 2018;48(4):195-202.
30. Hajimoradi M, Fazilati M, Gharib-Naseri MK, Sarkaki A. Gallic acid and exercise training improve motor function, nerve conduction velocity but not pain sense reflex after experimental sciatic nerve crush in male rats. *Avicenna J Phytomed*. 2015;5(4):288-297.
31. Holmes CJ, Wind SA, Esco MR. Heart rate variability responses to an undulating resistance training program in free-living conditions: A case study in a collegiate athlete. *Sports (Basel)*. 2018;6(4).pii:E121.
32. Huang YM, Chang YJ, Hsieh CH. Nerve conduction velocity investigation in athletes with trained lower extremity for well controlling movement. *Proceedings of 23 International Symposium on Biomechanics in Sports*. 2005.
33. Hulsege G, Gupta N, Proper KI, van Lobenstein N, IJzelenberg W, Hallman DM, et al. Shift work is associated with reduced heart rate variability among men but not women. *Int J Cardiol*. 2018;258:109-114.

34. Kanegusuku H, Queiroz AC, Silva VJ, de Mello MT, Ugrinowitsch C, Forjaz CL. High-intensity progressive resistance training increases strength with no change in cardiovascular function and autonomic neural regulation in older adults. **J Aging Phys Act.** 2015;23(3):339-345.
35. Khammassi M, Ouerghi N, Hadj-Taieb S, Feki M, Thivel D, Bouassida A. Impact of a 12-week high-intensity interval training without caloric restriction on body composition and lipid profile in sedentary healthy overweight/obese youth. **J Exerc Rehabil.** 2018;14(1):118-125.
36. Kim JW, Ko YC, Seo TB, Kim YP. Effect of circuit training on body composition, physical fitness, and metabolic syndrome risk factors in obese female college students. **J Exerc Rehabil.** 2018;14(3):460-465.
37. Kingsley JD, Figueroa A. Acute and training effects of resistance exercise on heart rate variability. **Clin Physiol Funct Imaging.** 2016;36(3):179-187.
38. Kluding PM, Pasnoor M, Singh R, Jernigan S, Farmer K, Rucker J, et al. The effect of exercise on neuropathic symptoms, nerve function, and cutaneous innervation in people with diabetic peripheral neuropathy. **J Diabetes Complications.** 2012;26(5):424-429.
39. Majumdar S, Chaudhuri A, Ghar M, Rahaman WB, Hai A. Effect of obesity on nerve conduction study in an urban population of a developing country. **Saudi J Sports Med.** 2017;17(3):162-167.
40. Miller T, Mull S, Aragon AA, Krieger J, Schoenfeld BJ. Resistance training combined with diet decreases body fat while preserving lean mass independent of resting metabolic rate: A randomized trial. **Int J Sport Nutr Exerc Metab.** 2018;28(1):46-54.
41. Mitchell JH, Haskell W, Snell P, Van Camp SP. Task Force 8: Classification of sports. **J Am Coll Cardiol.** 2005;45(8):1364-1367.
42. Mohammadi HR, Khoshnam MS, Khoshnam E. Effects of different modes of exercise training on body composition and risk factors for cardiovascular disease in middle-aged men. **Int J Prev Med.** 2018;9:9.
43. Moreira OC, Oliveira CEP, Matos DG, Silva SF, Hickner RC, Aidar FJ. Cardiovascular response to strength training is more affected by intensity than volume in healthy subjects. **Rev Andal Med Deporte.** 2017.
44. Mueller PJ. Exercise training and sympathetic nervous system activity: Evidence for physical activity dependent neural plasticity. **Clin Exp Pharmacol Physiol.** 2007;34(4):377-384.
45. Myint PK, Kwok CS, Luben RN, Wareham NJ, Khaw KT. Body fat percentage, body mass index and waist-to-hip ratio as predictors of mortality and cardiovascular disease. **Heart.** 2014;100(20):1613-1619.
46. Nunes PRP, Martins FM, Souza AP, Carneiro MAS, Orsatti CL, Michelin MA, et al. Effect of high-intensity interval training on body composition and inflammatory markers in obese postmenopausal women: A randomized controlled trial. **Menopause.** 2018.

47. Ostman C, Smart NA, Morcos D, Duller A, Ridley W, Jewiss D. The effect of exercise training on clinical outcomes in patients with the metabolic syndrome: A systematic review and meta-analysis. **Cardiovasc Diabetol**. 2017;16:110.
48. Ouerghi N, Fradj MKB, Bezrati I, Khammassi M, Feki M, Kaabachi N, et al. Effects of high-intensity interval training on body composition, aerobic and anaerobic performance and plasma lipids in overweight/obese and normal-weight young men. **Biol Sport**. 2017;34(4):385-392.
49. Parpa KM, Michaelides MA, Brown BS. Effect of high intensity interval training on heart rate variability in individuals with type 2 diabetes. **JEPonline**. 2009;12(4):23-29.
50. Pawar SM, Taksande AB, Singh R. Effect of body mass index on parameters of nerve conduction study in Indian population. **Indian J Physiol Pharmacol**. 2012;56(1):88-93.
51. Pawlak M, Kaczmarek D. Field hockey players have different values of ulnar and tibial motor nerve conduction velocity than soccer and tennis players. **Arch Ital Biol**. 2010;148(4):365-376.
52. Prasertsri P, Kaewaram J, Naravoratham K, Trongtosak P. Influence of arm swing exercise training on blood pressure regulation of cardiac autonomic function and cardiovascular risks in hypertensive elderly subjects. **JEPonline**. 2018;21(4):162-176.
53. Rastović M, Srdić-Galić B, Barak O, Stokić E. Association between anthropometric measures of regional fat mass and heart rate variability in obese women. **Nutr Diet**. 2017;74(1):51-60.
54. Rivera-Torres I, Delgado-Floody P. Effects of high-intensity interval training on the anthropometric profile of overweight and obese adult women. **Rev Fac Med**. 2016;64(3):465-469.
55. Sabag A, Najafi A, Michael S, Esgin T, Halaki M, Hackett D. The compatibility of concurrent high intensity interval training and resistance training for muscular strength and hypertrophy: A systematic review and meta-analysis. **J Sports Sci**. 2018;36(21):2472-2483.
56. Saito Y, Takahashi O, Arioka H, Kobayashi D. Associations between body fat variability and later onset of cardiovascular disease risk factors. **PLoS One**. 2017;12(4):e0175057.
57. Schoenfeld BJ, Peterson MD, Ogborn D, Contreras B, Sonmez GT. Effects of low- vs. high-load resistance training on muscle strength and hypertrophy in well-trained men. **J Strength Cond Res**. 2015;29(10):2954-2963.
58. Seo DI, Kim E, Fahs CA, Rossow L, Young K, Ferguson SL, et al. Reliability of the one-repetition maximum test based on muscle group and gender. **J Sports Sci Med**. 2012;11(2):221-225.
59. Serra R, Saavedra F, Jotta B, Novaes J, Cardozo D, Alves H, et al. The influence weekly resistance training frequency on strength and body composition. **Int J Sports Sci**. 2018;8(1):19-24.

60. Severino G, Sanchez-Gonzalez M, Walters-Edwards M, Nordvall M, Chernykh O, Adames J, et al. Whole-body vibration training improves heart rate variability and body fat percentage in obese Hispanic postmenopausal women. *J Aging Phys Act.* 2017;25(3):395-401.
61. Shaffer F, Ginsberg JP. An overview of heart rate variability metrics and norms. *Front Public Health.* 2017;5:258.
62. Shehata A, Mahmoud I. Effect of high intensity interval training (HIIT) on weight, body mass index and body fat percentage for adults. *Sci Mov Health.* 2018;18 (2):125-130.
63. Simon JE, Docherty CL. The impact of previous athletic experience on current physical fitness in former collegiate athletes and noncollegiate athletes. *Sports Health.* 2017;9(5): 462-468.
64. Stotzer US, Pisani GFD, Canevazzi GHR, Shiguemoto GE, Duarte ACGO, Perez SEA, et al. Benefits of resistance training on body composition and glucose clearance are inhibited by long-term low carbohydrate diet in rats. *PLoS One.* 2018;13(12):e0207951.
65. Su TT, Amiri M, Hairi FM, Thangiah N, Dahlui M, Majid HA. Body composition indices and predicted cardiovascular disease risk profile among urban dwellers in Malaysia. *Biomed Res Int.* 2015;2015:174821.
66. Tong TK, Zhang H, Shi H, Liu Y, Ai J, Nie J, et al. Comparing time efficiency of sprint vs. high-intensity interval training in reducing abdominal visceral fat in obese young women: A randomized, controlled trial. *Front Physiol.* 2018;9:1048.
67. Ucan Y. Effects of circuit resistance training on body composition and bone status in young males. *Sport J.* 2014;20.
68. Valentino G, Bustamante MJ, Orellana L, Krämer V, Durán S, Adasme M, et al. Body fat and its relationship with clustering of cardiovascular risk factors. *Nutr Hosp.* 2015;31(5):2253-2260.
69. van Meeteren NL, Brakkee JH, Hamers FP, Helders PJ, Gispen WH. Exercise training improves functional recovery and motor nerve conduction velocity after sciatic nerve crush lesion in the rat. *Arch Phys Med Rehabil.* 1997;78(1):70-77.
70. Villelabeitia-Jaureguizar K, Vicente-Campos D, Senen AB, Jiménez VH, Garrido-Lestache MEB, Chicharro JL. Effects of high-intensity interval versus continuous exercise training on post-exercise heart rate recovery in coronary heart-disease patients. *Int J Cardiol.* 2017; 244:17-23.
71. Vrachimis A, Hadjicharalambous M, Tyler C. The effect of circuit training on resting heart rate variability, cardiovascular disease risk factors and physical fitness in healthy untrained adults. *Health.* 2016;8:144-155.
72. Wiewelhove T1, Fernandez-Fernandez J, Raeder C, Kappenstein J, Meyer T, Kellmann M, et al. Acute responses and muscle damage in different high-intensity interval running protocols. *J Sports Med Phys Fitness.* 2016;56(5):606-615.

73. Wewege M, van den Berg R, Ward RE, Keech A. 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. **Obes Rev.** 2017;18(6):635-646.
74. Willis LH, Slentz CA, Bateman LA, Shields AT, Piner LW, Bales CW, et al. Effects of aerobic and/or resistance training on body mass and fat mass in overweight or obese adults. **J Appl Physiol (1985).** 2012;113(12):1831-1837.
75. Yang Y, Bay PB, Wang YR, Huang J, Teo HWJ, Goh J. Effects of consecutive versus non-consecutive days of resistance training on strength, body composition, and red blood cells. **Front Physiol.** 2018;9:725.
76. Zhang H, Tong TK, Qiu W, Zhang X, Zhou S, Liu Y, et al. Comparable effects of high-intensity interval training and prolonged continuous exercise training on abdominal visceral fat reduction in obese young women. **J Diabetes Res.** 2017;2017:5071740.

Disclaimer

The opinions expressed in **JEPonline** are those of the authors and are not attributable to **JEPonline**, the editorial staff or the ASEP organization.