

Acute effects of high intensity interval training on blood pressure in overweight/obese adolescents

<https://doi.org/10.11606/issn.1981-4690.v35i1p25-34>

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Abstract

The aim of this study was to analyze the acute responses of blood pressure (BP) to a high intensity interval training (HIIT) session on a treadmill in adolescents with excess body weight. This is a study with cross-over randomized design the sample consisted of 11 male adolescents aged 15 to 18 years. The volunteers performed two experimental protocols: HIIT and control. The HIIT protocol consisted of five series at 85 to 95% of VO_{2peak} for one minute, interspersed by three minutes of recovery at 40 to 50% of VO_{2peak} . Before and after the exercise protocols, hemodynamic parameters were obtained using an automatic ambulatory monitoring equipment (SpaceLabs model 90207), programmed to perform measurements every 20 minutes from 12:00 to 22:00 hours. A significant difference in systolic blood pressure (SBP) was only observed between the control and HIIT protocols (131.90 ± 7.93 vs 124.18 ± 7.56 mmHg, respectively) for the first hour after exercising. Comparisons of pre- and post-session (10 hours) hemodynamic measures between conditions (HIIT vs. control) demonstrated that HIIT promoted a significant reduction in mean blood pressure compared to pre-session values. In conclusion the HIIT protocol resulted in a low magnitude hypotensive effect on post-exercise hemodynamic measures with respect to SBP.

KEYWORDS: Interval training; Physical exercise; Blood pressure; Young.

Introduction

The high prevalence of obesity in the pediatric population is considered a worldwide public health concern, as this morbidity has been associated with diverse health risks^{1,2}. A condition that is typically associated with excess body weight is hypertension^{3,4} epidemiologic studies in obese children and adolescents reported a prevalence of hypertension ranging from 47% to 62%.

Studies have also observed associations between lower levels of physical activity and elevated blood pressure (BP) in epidemiological investigations^{5,6}. In this context, regular engagement in physical exercise, with special emphasis on aerobic continuous exercise, has been recommended for individuals with arterial hypertension⁷. In children and adolescents, evidence indicates that aerobic exercise promotes long-term⁸ as well as acute hypotensive

effects⁹, the latter being termed “post-exercise hypotension”. Research suggest that hypotensive effects after aerobic exercise sessions are able to predict the chronic hypotensive effect¹⁰.

Post-exercise hypotension and its possible mechanisms have been described in the literature⁷, however, few studies have investigated the effects of manipulating exercise prescription components, including training methods, on the magnitude and duration of the hypotensive response. The most commonly prescribed training method is continuous exercise, which is based on dynamic or cyclic exercises (e.g., walking, running, cycling) of low to moderate intensity lasting for prolonged periods. The research by CARPIO-RIVERA et al.¹¹ observed that incremental exercise protocols produce the largest reductions in BP. Conversely, the high intensity interval training

(HIIT) method is characterized by repeated series of short or medium duration exercises (10s to 5 min) performed at an intensity higher than the threshold speed of lactate¹².

Studies examining the effects of exercise intensity, duration, and methods of aerobic training on the magnitude and duration of post-exercise hypotensive responses have reported contradictory results^{13,14}. Thus, it is still necessary to elucidate the effects of high-intensity interval exercise on post-

exercise hemodynamic responses in adolescents with excess weight. A better understanding of this subject is of major clinical relevance, since the magnitude and duration of post-exercise hypotension induces better modulation of BP in the long term¹⁰.

Therefore, the objective of the present study was to examine the acute responses of BP to a high intensity interval exercise session in adolescents with excess body weight.

Methods

Participants

This was a randomized crossover design study. Participants consisted of male adolescents who met the following inclusion criteria: age between 15 and 18 years; no diagnosis of cardiovascular disease; classified as overweight or obesity (percentile > 85th); no diagnosis of diabetes *mellitus* and/or systemic arterial hypertension; insufficiently active for at least three months; not using medication; and not presenting conditions that could limit engagement in physical exercises (e.g., labyrinthitis and osteoarticular dysfunctions, among others). The exclusion criteria adopted were: not presenting intermediate chronotype; presenting any type of sleep disorder; having a reported stage of sexual maturation < G4; and not meeting the pre-participation recommendations in physical tests and experimental sessions.

Participants were duly informed about all procedures, potential risks, and benefits of the investigation. Written assent was obtained from adolescents interested in participating in the study. Their responsible guardians provided written informed consent for participation. All participants were instructed to maintain their normal routine during the period of participation in the study.

Sample size analysis was performed using Gpower 3.1 software. The parameters adopted for sample size calculation were: a power of 0.80; $\alpha = 0.05$; correlation coefficient of 0.5; correction of sphericity of 1; and an effect size of 0.50, according to the procedures suggested by BECK¹⁵ and results of CARPIO-RIVERA et al.¹¹. The calculation resulted in a required sample of 12 individuals, providing a power of 0.87.

Study Design

Data collection was carried out in the Laboratory of Biodynamics of Human Movement, at the Center of Health Sciences, at the University. Initially, all volunteers interested in participating in the study underwent screening to ensure their eligibility according to the inclusion criteria. In their second visit, participants were submitted to a treadmill cardiopulmonary exercise test. After a minimum interval of two days and a maximum of seven days, the volunteers performed two experimental sessions in a simple random order: control and HIIT.

Screening

The adolescents were screened before participating in the study, which consisted of obtaining the following information: socio-demographic data, clinical data (history of cardiovascular, metabolic, or osteoarticular diseases, symptoms suggestive of heart disease, and use of medications), chronotype, presence of sleep disorders, habitual physical activity level, biological maturation, anthropometric measures (body mass, height, waist circumference, and skinfolds), and BP measurement at rest.

Twenty-four volunteers agreed to participate in the study. At the initial screening, 10 did not accept or could not be included because they did not meet the established criteria. Thus, 14 adolescents and their parents signed the consent form and initiated the preliminary procedures. Of these, three adolescents left the study for personal reasons. Thus, 11 volunteers completed the experimental protocols, resulting in a power of 0.82.

Identification of chronotype and sleep quality index

To assess participants' chronotype, the Morningness-Eveningness Questionnaire (MEQ) was used to determine if the volunteer was a morning, evening, or intermediate person¹⁶. For the analysis of sleep quality, the Pittsburgh Sleep Quality Index (PSQI)¹⁷ was used. Volunteers who presented indices greater than 10 points, indicating the presence of a sleep disorder, were not included because poor sleep quality could interfere with cardiovascular functions, including blood pressure.

Habitual physical activity level

Habitual physical activity level was analyzed using the International Physical Activity Questionnaire (IPAQ-8, short version). Those who did not reach the World Health Organization recommendations for physical activity for children and adolescents¹⁸ and had not engaged in exercise programs in the previous three months were included in the study.

Biological Maturation

Biological maturation was assessed by self-evaluation of secondary sexual characteristics (genitals)¹⁹. Volunteers who reported a sexual maturation stage of G4 or G5 were included in the study.

Anthropometric Measurements

Body mass was evaluated using a Welmy digital scale, with a precision of 100 grams. Height was measured using a portable stadiometer (Welmy®), with a precision of 0.1 centimeter. Body mass index (BMI) was calculated by dividing body mass in kilograms by height in meters squared. The waist and hip circumferences were measured using an inextensible anthropometric tape (Sanny®). Volunteers presenting BMI above the 85th percentile according to the criteria for age and gender of the World Health Organization²⁰ were included in the study. Triceps, subscapular, and medial leg skinfolds were measured to the nearest 1.0 mm using a Lange skinfold caliper. To estimate the relative fat, the equation proposed by SLAUGHTER et al.²¹ for male children and adolescents aged seven to 18 years was used.

Resting blood pressure

To evaluate the values of systolic (SBP), diastolic blood pressure (DBP), and mean blood pressure (MBP) at rest, a SpaceLabs automatic oscillometric monitor model 90207 was used in the non-dominant arm with dimensions appropriate for the circumference of the arm²². Next, three measurements were taken in the sitting position with a two minute interval between them.

Cardiopulmonary exercise test on a treadmill

The cardiopulmonary test was conducted in a laboratory environment under controlled temperature (20 to 22°C). Participants performed an incremental test on a motorized treadmill (INBRAMED Super ATL) to measure the peak oxygen consumption (VO_{2peak}) and determine the ventilatory threshold. A modified Balke treadmill protocol was used according to the recommendations of the American Heart Association²³. During the protocol, respiratory and metabolic variables were measured every 10 seconds by a computerized metabolic system (VO2000 metabolic gas analyzer). A silicone facial mask set with mouth and nose seals was worn by the participants. The Polar FT1 was used to monitor heart rate during the test. Subjective perception of effort (CR-20) was obtained at the final 15 seconds of each stage. The test was discontinued when one or more of the following criteria were observed: voluntary fatigue or inability to maintain the pre-determined speed of the stage, $R > 1.1$, subjective perceived exertion (CR-20) above 18, and achievement of maximal heart rate (HR_{max}) estimated by the equation $HR_{max} = 208 - 0.7 \times \text{age}$.

Experimental Protocols

Upon arriving at the laboratory, participants rested for 10 minutes before resting hemodynamic measures were taken (SBP, DBP, MBP, and HR). After that, the adolescents performed the control or interval protocol randomly. After the end of the session, participants hemodynamic measures were taken again after a resting period of 10 minutes in order to minimize the influence of exercise-induced cardiovascular stress. Considering that dehydration

may be an intervening variable, each adolescent received a 500 ml bottle of mineral water. Bladder emptying occurred at the criteria of the volunteers during the protocols.

The HIIT protocol used in this study was adopted considering the tolerance of adolescents to high-intensity exercise and evidence from investigations that reported significant effects of HIIT on health parameters in obese populations^{14,24}. Thus, the interval exercise protocol consisted of three minutes of warm-up, with a velocity of 4.0 km/h. Subsequently, the volunteers were submitted to five sets of 1:3, that was, one minute in the active phase (above the ventilatory threshold, 85 to 95% of VO_{2peak}) followed by three minutes in the active recovery phase (40 to 50% of VO_{2peak}). At the end of the five sets, the adolescents performed a cool-down period for three minutes, gradually reducing the speed before stopping the treadmill belt. The total duration of the session was approximately 30 minutes.

For the control protocol, participants received the same instructions as the HIIT protocol, but participants rested in the seated position for 30 minutes and were instructed not to perform physical activities of moderate to vigorous intensity on the day of monitoring.

Ambulatory BP measurement

The analysis of ambulatory blood pressure monitoring (ABPM) was based on the position stand from the American Heart Association²². Thus, after the end of the experimental protocol (10 minutes), the ambulatory BP measurement was performed on the non-dominant arm using an oscillometric automatic monitor (SpaceLabs, model

90207). The monitor was programmed to perform measurements every 20 minutes from 12:00 to 22:00 hours. This period was sufficient to obtain daily representative measurements of blood pressure, as there is indication that six hours of measurement are associated with the results obtained from 24 hours in the pediatric population²⁵. The volunteers were instructed not to talk, sleep, or perform physical activities when the device was triggered and recording the measurements. In addition, for each protocol, participants received a diary to record stressful situations, meal times, transit times, and means of locomotion.

Statistical treatment

The Shapiro-Wilk test was used to verify the normality of the data. Participant characteristics are presented as mean and standard deviations, and median and interquartile range for the numerical variables, and frequency distribution for the categorical variables. The effects of the experimental protocols on hemodynamic responses (SBP, DBP, MBP, and HR) were tested using repeated measures analysis of variance, considering experimental protocol (control and HIIT) and time (pre-session and post-session). When the assumption of sphericity (Mauchly's test) was violated, the Greenhouse-Geisser correction was applied. If an effect and/or interaction was identified by the F test, the Bonferroni post hoc test was applied to locate the differences between the means. Effect sizes (η^2) are presented for significant differences. Data analyses were conducted in the statistical package SPSS version 20.0 (SPSS, USA, 2012), adopting a level of significance of $p < 0.05$.

Results

The general characteristics of the volunteers are described in TABLE 1. According to the World Health Organization criteria²⁰, 81.81% of adolescents were classified as obese (\geq 97th percentile), 27.27% presented altered BP values²², and 45.45% were of non-white ethnicity. Regarding habitual physical activity of moderate to vigorous intensity, participants accumulated, on average, 100 minutes per week. A total of 54.54% of the participants reported

being in stage V of sexual maturation.

FIGURE 1A demonstrates the SBP responses over the 10-hour period following the control and HIIT protocols. A significant interaction of time x experimental protocol was observed ($F=2.488$; $p=0.008$; $\eta^2=0.110$). The post hoc test indicated a significant difference in SBP means between the control and HIIT protocols only in the period from 12:00 to 13:00 hours, indicating post-exercise hypotension induced by HIIT in relation to the control protocol.

TABLE 1 - General characteristics of the volunteers (n = 11).

Variables	Mean \pm SD	Median (p ²⁵ – p ⁷⁵)	
Age (years)	16.10 \pm 0.92	15.78 (15.39 – 16.88)	
Height (m)	1.75 \pm 0.61	1.75 (1.70 – 1.80)	
Body mass (Kg)	92.80 \pm 8.95	93.00 (85.00 – 102.00)	BMI, body mass index; HR _{peak} , heart rate; VO _{2peak} , peak oxygen consumption.
BMI (Kg/m ²)	30.40 \pm 3.58	30.47 (27.44 – 33.96)	
BMI percentile	97.72 \pm 1.61	99 (97 – 99)	
Waist circumference (cm)	95.00 \pm 6.81	95.00 (90.00 – 99.00)	
Hip circumference (cm)	109.27 \pm 4.58	109.00 (106.00 – 114.00)	
Hip waist ratio	0.86 \pm 0.04	0.87 (0.84 – 0.90)	
Tricipital (mm)	25.64 \pm 2.83	25.00 (23.00 – 28.00)	
Subscapular (mm)	27.91 \pm 5.94	27.00 (23.00 – 32.00)	
Medial leg (mm)	24.64 \pm 3.50	22.00 (22.00 – 28.00)	
Relative fat (%)	37.95 \pm 4.14	37.75 (34.08 – 42.90)	
HR _{peak} (bpm)	185.81 \pm 14.06	186 (174 – 196)	
VO _{2peak} (ml/Kg/min)	39.19 \pm 6.91	43.07 (34.12 – 44.55)	
Chronotype	45.82 \pm 10.70	46.00 (37.00 – 56.00)	
Sleep quality index	6.55 \pm 1.91	6.00 (5.00 – 8.00)	
Moderate to vigorous physical activity (min / wk)	103.64 \pm 57.49	80 (70 – 100)	

DBP and MBP responses over the 10-hour period following the control and HIIT protocols are presented in FIGURES 1B and 1C, respectively. No effects of the protocols on these hemodynamic measures were found.

Regarding HR responses over the 10-hour period after the control and HIIT protocols (FIGURE 1D), a significant effect of time ($F = 2.784$; $p = 0.003$; $\eta^2 = 0.122$) and a significant interaction of time \times session ($F = 12.195$; $p < 0.001$; $\eta^2 = 0.379$) were observed. Thus, HR between 12:00 and 13:00 hours after the HIIT protocol was significantly superior to pre-session

and to the control protocol in the same period.

The comparison of pre-session and mean post-session hemodynamic measures (10 hours) between the experimental protocols is shown in TABLE 2. A significant effect of time on DBP was observed ($F = 4.914$; $p = 0.038$; $\eta^2 = 0.197$). The analysis of variance also showed an effect of time ($F = 4.442$; $p = 0.048$; $\eta^2 = 0.182$) on MBP, indicating that MBP values over the 10-hour period after the HIIT protocol were lower than pre-session. In relation to the other variables, no effects and/or interactions between protocols were observed.

FIGURE 1 - Behavior of systolic blood pressure (SBP) (A), diastolic blood pressure (DBP) (B), mean blood pressure (MBP) (C), and heart rate (HR) (D) over the 10 hours in the control (dashed line with circle) and HIT protocols (full line with triangle).

Data are expressed as mean and standard deviations. *p < 0.05 compared to the control protocol. #p < 0.05 compared to pre-session.

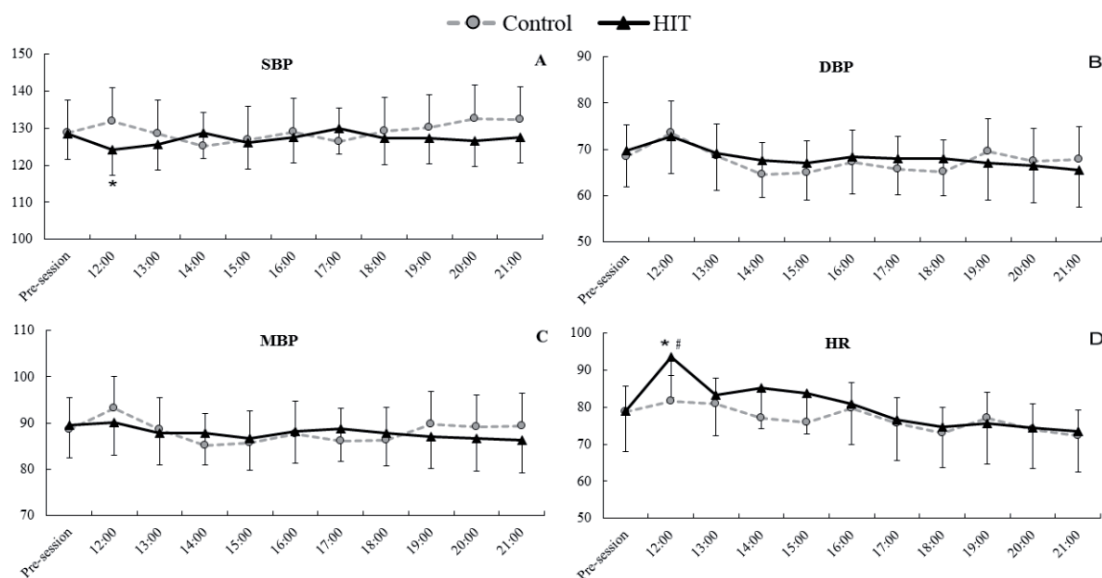


TABLE 2 - Effect of experimental protocols on hemodynamic responses pre-session and mean post-session (10 hours) in adolescents with excess weight.

	Control	HIIT	ANOVA			
			Effect	F	p	(η ²)
SBP			Time	0.320	0.578	0.016
Pre-session	128.63 ± 8.02	128.54 ± 6.60	Session	0.137	0.715	0.007
Mean post-session	129.20 ± 7.56	127.10 ± 6.49	Time x Session	1.712	0.206	0.079
DBP			Time	4.914	0.038	0.197
Pre-session	68.36 ± 6.71	69.81 ± 7.05	Session	0.146	0.706	0.007
Mean post-session	67.35 ± 5.35	68.00 ± 7.18	Time x Session	0.402	0.533	0.020
MBP			Time	4.442	0.048	0.182
Pre-session	88.54 ± 5.52	89.54 ± 5.71	Session	0.025	0.876	0.001
Mean post-session	88.00 ± 4.79	87.72 ± 6.10	Time x Session	1.288	0.270	0.060
HR			Time	0.089	0.768	0.004
Pre-session	78.63 ± 5.27	79.00 ± 9.48	Session	0.338	0.567	0.017
Mean post-session	76.68 ± 5.73	80.13 ± 11.29	Time x Session	1.275	0.272	0.060

SBP, systolic blood pressure; DBP, diastolic blood pressure; MBP, mean arterial pressure; HR, heart rate; HIIT, high intensity interval training. Data are expressed as mean and standard deviations.

Discussion

Exercise is an efficient non-pharmacological approach for prevention, treatment, and control of various morbidities¹⁸. However, the type and dose of exercise required to induce health benefits are still controversial. The high-intensity post-exercise hemodynamic responses assessed by means of ABPM in adolescents with excess body weight have not been investigated thoroughly in the literature. Our results indicate that a single session of HIIT promoted a significant reduction in SBP in the first 60 minutes post-exercise when compared to the control condition, characterizing a hypotensive effect after the session.

According to the study by BRITO et al.¹³, the characteristics of the population, such as age, BMI, and blood pressure status influence post-exercise hemodynamic responses. Therefore, in order to minimize bias in the study results, we only recruited overweight or obese male adolescents not diagnosed with hypertension. The HIIT protocol used in this study was based on the adolescents' tolerance of high-intensity exercise and on the evidence of investigations that reported significant effects of HIIT on health parameters in morbid populations, such as: obese, hypertensive, diabetic, and metabolic syndrome^{14,24}.

Regarding post-exercise hemodynamic responses in adolescents with excess body weight, the results from the present study demonstrated that SBP was significantly reduced in the first hour (12:00 to 13:00 hours) following the HIIT protocol (approximately - 4 mmHg) when compared to the control protocol. These results are close to the magnitude of effect observed after HIIT in normotensive individuals, in which a post-exercise BP reduction between 3 and 8 mmHg was observed²⁶⁻²⁸. The literature suggests that post-exercise hypotension is greater in hypertensive individuals compared to normotensive individuals⁷, yet this could not be verified in this study as we did not include a control group. An important finding from the present study was that post-exercise hypotension was of low magnitude and short duration, suggesting that frequent engagement in exercise is necessary for systematic reductions of BP.

Some methodological aspects in exercise prescription may have contributed to the similarity of the findings of the present study with the results observed in the literature regarding the magnitude and duration of the hypotensive effect induced by HIIT in normotensive young adults. For example,

the final exercise volume (27 min. at ~ 70% VO_{2peak}) from this study amounted to similar volumes used in the studies by JONES et al.²⁶, ANGADI et al.²⁸, and MIYASHITA et al.²⁷. JONES et al.²⁶ and ANGADI et al.²⁸ employed a protocol of three 10-minutes series of 70% VO_{2peak} intensity exercise, whereas MIYASHITA et al.²⁷ prescribed 10 series of 70% VO_{2peak} intensity exercise lasting for three minutes each.

The DBP and MBP over the 10-hour follow-up did not demonstrate significant alterations either for the control or HIIT protocols. However, Figure 1C indicates that the HIIT protocol attenuated the increase in MBP between 12:00 and 1:00 PM, and promoted reductions in MBP values of approximately 2 mmHg in subsequent hours. After the HIIT protocol, HR remained elevated from 12:00 to 3:00 p.m in relation to the pre-session and control conditions. An increase in ambulatory HR has been reported after performing aerobic exercises and may be attributed to increased sympathetic modulation and decreased vagal activity of the heart¹³.

In the present study, the comparison of pre- and post-session (10 hours) hemodynamic measurements between the experimental protocols indicated that HIIT promoted a reduction of 2 mmHg in MBP compared to pre-session ($p < 0.05$). Cohort studies indicate that outcomes of this magnitude can potentially reduce cerebral vascular accident mortality by up to 6%, coronary heart disease mortality by up to 4%, and all-cause mortality by as much as 3%²⁹.

Reductions in ambulatory BP have a greater clinical significance in relation to causal and self-assessed BP because such reductions are more valid in the prognosis for cardiovascular disease²². ABPM includes multiple measurements that more accurately reflect an individual's BP values throughout daily activities. In addition, this technology eliminates many problems associated with clinical assessments such as observer bias and the white coat syndrome²².

A high intensity physical exercise session induces considerable cardiovascular stress during its performance and, consequently, promotes homeostatic imbalance in the body of children and adolescents⁹. Considering the post-exercise hypotension of low magnitude and short duration and the concomitant increase in HR, it is postulated that in the present study the physiological mechanisms of BP control acted in order to minimize pressure stress generated during the HIIT protocol and reach homeostatic balance. Among the principal

mechanisms involved in this adjustment is the reduction in peripheral vascular resistance mediated by vasodilator agents produced during the session, such as nitric oxide, histamines, and prostaglandins⁷.

The hypotensive mechanisms of exercise are multifactorial and may be different between individuals¹³. This diversity may explain the contradictory results in this area of study in recent decades. The literature points out that the chronic effects of exercise on BP result from the accumulation of the acute physiological responses of each session¹⁰. LIU et al.¹⁰ demonstrated a strong and significant positive association ($r = 0.89$) between the reduction in BP after a single aerobic exercise session and the reduction in BP at rest after a certain period of aerobic training.

This research presents limitations such as lack of control of participants' eating habits, stress, and physical activity, which could alter BP values. However, to minimize bias, volunteers received

guidelines to maintain similar routines of physical activity, eating, and sleep time in the 24 hours prior to the intervention and during the monitoring period²². In addition, the experimental design of this study included a control session (without exercise) to allow for within-subject comparison of the exercise effect on BP.

Additional studies should be conducted using the HIIT physical training method in different populations and larger samples to assess BP responses to different exercise components, as well as to further evaluate the potential applications of the HIIT method in the prevention and treatment of hypertension in young individuals.

In conclusion the results of the present investigation indicate that, in adolescents with excess body weight, a HIIT protocol induced significant SBP reductions in the first 60 minutes post-exercise in relation to the control protocol. The results further indicate that the post-exercise hypotensive effect of the HIIT was of low magnitude and short duration.

Conflict of interest

They have no conflicts of interest.

Resumo

Efeitos agudos do treinamento intervalado de alta intensidade sobre a pressão arterial de adolescentes com sobrepeso/obesidade

O objetivo deste estudo foi analisar o comportamento da pressão arterial (PA) em adolescentes com excesso de peso após uma sessão de high intensity interval training (HIIT) na esteira ergométrica. Trata-se de uma pesquisa com delineamento cross-over aleatorizado, a amostra foi formada por 11 adolescentes do sexo masculino, 81,81% com obesidade e idade entre 15 e 18 anos. Os voluntários realizaram dois protocolos experimentais: controle e HIT. O protocolo HIIT foi constituído de cinco séries de 85 a 95% do $VO_{2\text{pico}}$ por um minuto, intercalados por três minutos de recuperação de 40 a 50% do $VO_{2\text{pico}}$. Antes e após os protocolos, os parâmetros hemodinâmicos foram obtidas por meio de um monitor automático (SpaceLabs 90207), programado para realizar medidas a cada 20 minutos no período das 12:00 às 22:00 horas. Foi observado diferença significativa entre as médias da pressão sistólica nos protocolos controle e HIIT somente na primeira hora após o final do exercício ($131,90 \pm 7,93$ vs $124,18 \pm 7,56$ mmHg). A comparação entre os protocolos e as medidas hemodinâmicas pré-sessão e média pós-sessão (10 horas) demonstrou que o HIIT promoveu uma redução significativa na pressão arterial média em comparação a pré-sessão. Em conclusão, o protocolo HIIT empregado promoveu efeito hipotensor de baixa magnitude sobre as medidas hemodinâmicas pós-exercício no que diz respeito a PAS.

PALAVRAS-CHAVE: Treinamento intervalado; Exercício físico; Pressão arterial; Jovens.

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Submitted: 03/03/2018

Revised: 07/20/2018

Accepted: 08/22/2018