THE EFFECT OF HIGH-INTENSITY INTERVAL TRAINING ON BLOOD LACTATE LEVELS AND RATE OF PERCEIVED EXERTION IN SEDENTARY HEALTHY ADULTS

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ABSTRACT

The high-intensity interval training has been seen to be beneficial for various populations in increasing physical capabilities and health quality. This study aimed to determine the effect of high-intensity interval training (HIIT) on blood lactate levels and rate of perceived exertion (RPE) in sedentary healthy adults to discuss the objective outcome of HIIT. A pre-post study was conducted on adults that were stated healthy and sedentary on physical activity. All participants were given HIIT with a total duration of 20 minutes for 12 sessions using a treadmill. Blood lactate level and RPE was recorded on the 1st and 12th session. A significant decrease in blood lactate level and RPE after giving HIIT was found with a reduction of 1,1 mmol/ L and 2 on the Borg Scale respectively ($p<0.0001$). Further research is needed using field-based exercise testing to determine exercise prescription and to obtain the benefit of HIIT in populations with cardiovascular risk factors before utilizing it in patients.

Keywords: High intensity interval training; HIIT; Lactate; Rate of perceived exertion

INTRODUCTION

High intensity interval training (HIIT) is a short repeatable period exercise which uses full effort or with intensity almost reaching max VO2 (≥90% of max VO2). The exercise could last from few seconds to minutes. The repeatable exercise is divided into few sessions with short rest period in-between.[1,2] This type of exercise will stimulate similar physiological changes to continuous mid-intensity exercise with shorter duration and exercise volume.[3] The metabolic adaptive process will be induced faster in HIIT compared to continuing endurance training. HIIT is also proven to be more beneficial in sedentary individuals as compared to continuous training, with the increasing max VO2, of which will increase aerobic fitness.[4] The reduction in lactate level and perceived exertion rate in sedentary individuals is seen as adaptation to HIIT. Other changes in cellular levels are also observed, such as increase of capillary density and mitochondria density in each muscle fibres, which will increase the capacity of free fatty acid transport from plasma to cells' cytoplasm, to the mitochondria. Other adaptive response due to HIIT on mitochondria also includes higher oxidative metabolism due to increasing oxygen uptake, increasing lipid metabolism, reduction of hydrogen ion synthesis, and increase of lactate deposition on liver.

The high intensity interval training has been seen to be beneficial for various populations. The benefit of HIIT is observed in obese individuals with the increase of lipid oxidation with the increasing oxidation capacity of mitochondria with the protein kinase pathway.[1,5,6] Patients with chronic obstructive pulmonary disease (COPD) and coronary artery disease (CAD) also gained substantial benefits with beneficial effects on peripheral muscle without a high increase of burden to the cardiorespiratory system. Patients with CAD are also observed to have higher stroke volume, myocardial contraction,

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and an increase of ejection fraction on the end of exercise.[7,8] Patients with COPD will also experience increasing muscle oxidative capacity and lactate clearance during the resting period which can decrease ventilation burden and reduce dyspnoea in patients.[9]

Various variables and parameters are used to evaluate the intensity of training. One of which is plasma lactate level. The plasma lactate level is usually used as exercise intensity marker, to evaluate the endurance training and/or predict lactate-based energy expenditure from a certain activity. Lactate is commonly produced by red blood cells, neural tissues, intestinal tissues, and dermal tissues. However, the muscle tissue becomes the main producer of lactate during exercise or training.[10] Other parameters used are perceived exertion, which can represent other factors, including psychological status and fitness status.[11]

The effect of HIIT on sedentary individuals are known to have beneficial effect, as to improve heart rate variability and postural stability in elderly population.[12,13] However. This study is intended to objectively observe the effect of high intensity interval training (HIIT) on plasma lactate level and perceived exertion on sedentary healthy adults. Plasma lactate and perceived exertion also might become a new indicator in evaluating the impact of HIIT on each individual.

MATERIAL AND METHODS

This research used interventional study with a pre-post design with targeted population of healthy adults in Indonesia. The research is conducted in the General Hospital of Cipto Mangunkusumo, Jakarta, Indonesia. The trial has been approved for ethical review by the committee of health research ethics in Faculty of Medicine Universitas Indonesia with registration number of 706/UN2.F1/ETIK/PPM.00.02/2019.

Sampling procedure & participants criteria

The enrolment process of participants used consecutive sampling out of all health adult individuals in the hospital. The inclusion criteria of participants include adults aged 18-40 years old, volunteered to follow the research protocol and exercise regimen by signing the informed consent form, no cardiorespiratory issues, and low activity level based on the International Physical Activity Questionnaire. Low activity level on IPQA is considered as insufficiently active (Category 1 of IPQA) if there is less than 3 days of vigorous activities or less than 5 days of moderate activities, or less than 600-MET (Metabolic Equivalents)-min/week as mentioned in the guideline.[14] The participants will be excluded if they were not able to understand the exercise instruction or research protocol, having history of cardiorespiratory ailments, having balance system disorder, and injury or abnormalities on lower extremities. Participants will be declared as dropouts, should they refuse or not able to execute HIIT for three times in a row or did not reach 80% of heart rate on three consecutive exercises.

Trial procedure

At the beginning of the study, all subjects were briefed on the study protocol, then signed informed consent should they consented for the study. Each subject who had signed informed consent performed anamnesis, filled out a PARQ+ questionnaire for pre-exercise screening, IPAQ to determine activity levels, electrocardiography (ECG) examination, and lung function test examination using peak flow meter and spirometry to determine the cardiorespiratory status of all participants. This data collection is done by researchers and research assistants who have been briefed to fill out questionnaires and conduct examinations.

Each subject who met the inclusion and exclusion criteria were then made to prepare for the training test, which included changing clothes and sports shoes, vital sign checks, oxygen mask installation, Polar® heart rate monitors, and gas analyzers. The training test on this study uses the CPET Cosmed K5® tool, which is calibrated prior to the use of the tool. The patient then undergoes familiarization first to get used to walking on the treadmill for one minute. The researcher describes the training test process and how the participants should signal if they are about to stop. During the training test the patient is monitored for heart rate, saturation, and blood pressure until there is an indication of discontinuation of the training test and if the subject's efforts reach the maximum. In the training test, the maximum heart rate will be recorded, of which then becomes a reference for a high intensity interval training program. The subjects then sat in a chair for the recovery phase for 15 minutes and underwent remeasurement of the vital signs.

After underwent a training test and getting the maximum heart rate, then the dose of exercise intensity is calculated by using Hrreserve (Hrmax / peak – Hrrest) for intensity of 80% and 40% which then becomes the reference for the exercise program. 80% intensity will be set for the high intensity exercise, while the intensity of 40% will be set as low intensity exercise, which becomes the interval on a high intensity interval training program. Exercise is given for 20 minutes with a duration of 60 seconds for high intensity and 120 seconds for low intensity. Before, during, and after the exercise, the participants is monitored for their vital signs and perceived exertion rate. In the first exercise, the participants will be measured for their lactate levels, right after the finished regiment, using Accutrend® Plus and asked the level of effort felt after underwent the exercise. On the second to eleventh exercise, the participants underwent an exercise program of the same intensity. In the twelfth exercise, another examination is carried out as done in the first exercise (lactate measurement and perceived exertion rate examination).

Statistical analysis

All retrieved data out of the trial will be inputted and displayed into tables and diagram as needed. The statistical analysis is carried out in sequence, starting with univariate analysis (descriptive analysis) on the participants' characteristic and a paired T-test on both pre-exercise and post-exercise group to observe the significance of its comparison. The confidence interval is set on 95%, thus p-value of <0.05 will be considered as significant. All the statistical analysis were conducted using IBM SPSS ver 23.0. All retrieved data out of the trial will be inputted and displayed into tables and diagram as needed. The statistical analysis is carried out in sequence, starting with univariate analysis (descriptive analysis) on the participants' characteristics and a paired T-test on both pre-exercise and post-exercise groups to observe the significance of its comparison. The confidence interval is set on 95%, thus p-value of <0.05 will be considered significant. All the statistical analysis were conducted using IBM SPSS ver 23.0.

RESULT

A total of 44 participants were included in this study. Due to the consecutive nature of the study, hence no selection or blinding is conducted on the study. Out of the 44 participants, there were 28 female participants with 16 males on the study. The characteristics of the participant could be seen in **Table 1**. The mean age of the participants was 30.1 years old with mean BMI of 23.5 kg/m2. All the participants are of bachelor's degree implying similar understanding on the instruction. Based on the International Physical Activity Questionnaire, the median of MET value was 330 (120-594) METs. Other physiological indicators of the participants are also recorded with FEV1 (Forced expiratory volume in 1 seconds), FVC (Forced vital capacity), PFR (Peak flow rate), and PCF (Peak cough flow) value.

Table 1. Participants characteristics

	n (%)	Mean (SD)
Age		30,1 (3,6)
Gender		
Male	16 (36,4)	
Female	28 (63,6)	

Body weight (kg)		62,8 (12,6)
Body height (m)		1,6 (0,1)
Education level		
≥ Bachelor	44 (100)	
Maximum heart rate		176 (12)
RPE		16 (1)
IMT		23,5 (3,3)
IPAQ		330 (120 – 594)*
FEV1		2835 (1830 – 4550)*
FVC		3050 (1980 – 5250)*
PFR		478,8 (90,2)
PCF		469,6 (78,3)

*median (minimum – maximum)

On the first training session, the median value of lactate level in the participants was 6.8 (3-20) mmol/L, as compared to the 12th session with median value of lactate level was 5.5 (3-13) mmol/L (**Table 2**).

Table 2. Lactate level and RPE outcomes in 1st and 12th session

Outcome parameter	1st exercise session	12th exercise session	p-value*
Lactate level	6.8 (3-20)b	5.5 (3-13)[b]	<0.0001
Rate of perceived exertion (Borg scale)	12.3 (1.4)[a]	10.5 (6-13)[b]	<0.0001

[a]Outcome is reported in mean (SD) if considered to have normal distribution
[b]Outcome is reported in median (min-max) format due to abnormal distribution
*Wilcoxon Signed Ranked Test; p-value of <0.05 is considered significant

The graph in **Figure 1** also reports decreasing mean lactate level from 8.03 to 6.00 in the 1st and 12th exercise session. The comparison of lactate measurement in the first and final session is deemed significant (p-value <0.0001).

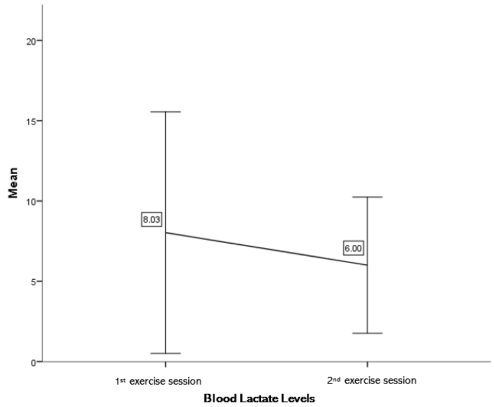

Figure 1. The difference of lactate levels on the 1st and 12th session. There is a decrease of mean blood lactate levels of 8.03 to 6.00 mmol/L.

Similar results can also be inferred from the physical exertion rate used by participants with 12.3±1.4 on the first session and 10.5 (6-13) on the final session with significant difference (p-value <0.0001) as seen in **Figure 2.**

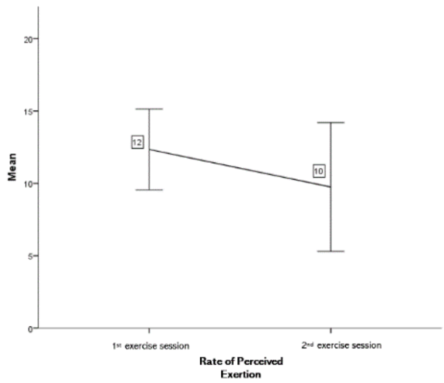

Figure 2. The difference of rate of perceived exertion (RPE) on the 1st and 12th session, with a decrease of two score in the Borg Scale.

DISCUSSION

Despite not being the first study of HIIT effect on plasma lactate or RPE, the study might be the first in evaluating the output in sedentary individuals. Our research has revealed the effect of HIIT on sedentary individuals with significant decrease of blood lactate level of 1.1 mmol/L and decrease of RPE on Borg scale with difference of two. The result has concluded the beneficial effect of HIIT on sedentary individuals.

The study's inclusion criteria are set to the age range of 18 to 40 years, based on the previous research conducted by Cardoso et al (2012) in Brazil with ages between 18-40 years and based on the definition of young adults by Hurlock (2001).[15] With such criteria, 44 participants of 18-40 years old with a mean age of 30 years old was included. The average body mass index of subjects in this study was 23.5 (3.3) kg/m2 of which classified as overweight. Physical inactivity or sedentary has a large contribution to the occurrence of excess weight and obesity.[16] The weight gain itself is a significant risk factor for metabolic and heart disease.[17]

The overall level of education of the subject is the bachelor's degree, which ease the process of filling out English questionnaires and further assistance in providing explanations for the training to be given as well as motivation to follow the exercise program up to twelve times. Out of all 44 participants, there were no drops out in this study.

In this study, the results of the electrocardiogram record of all participants showed no change from all the recorded leads. The examination of lung function described from spirometry results also stated no signs of obstruction or restrictions adjusted to the value of pneumomobile results. The peak cough flow (PCF) value obtained was of 469.6 ± 78.3 L/minute. This result is in line with previous research which stated the normal susceptibility of peak cough flow in sedentary young adult individuals is between 310 - 645 L/minute.[18] All participant is trained to then get intensity to undergo an exercise program, should all of their examination results (ECG, spirometry, and PCF) be considered normal.

The participants of this study were sedentary individuals, where sedentary itself is defined as the unfulfilled threshold of moderate and vigorous intensity physical activity.[19–23] A study by Tudor-Locke and Meyer (2001) concluded that sedentarism is a low energy use, both for distance and walking time, climbing stairs, and/or low participation in strenuous-intensity activities for either recreation or exercise.[24] Based on the IPAQ results, All the study participants had low levels of physical activity with a middle value of 330 METs per week and a range between 120 - 594 METs. A person falls into the category of low activity if it does not meet the criteria of at least a total of 600 METs in a week either light, moderate or heavy activities.[16,25] The statement are also supported as sedentary lifestyle, according to ACSM and the American Heart Association, does not fulfill the recommended physical activity of at least 30 minutes at moderate intensity as much as 5 days a week, or even 20 minutes of strenuous activity as much as 3 days a week.[26] The causes of the high sedentary numbers from the participants can be reviewed from various aspects. The use of transportation, work, recreational time, homework are aspects that can play a role in a person's sedentary behavior.[27]

A widely used training test for individuals with low activity levels or sedentary is the modified Bruce protocol. This protocol has also been considered safe for overweight and obese individuals.[28–30] The duration of training test conducted is around 10 to 12 minutes. The participants stopped the training test if they had met one of the criteria of achieving the maximum training test, namely if there was no increase in heart rate by increasing workload, blood lactate level after the training test were >8.0 mmol / L, the perceived exertion rate has reached >17 on the rate perceived exertion scale (RPE) 6 - 20, or Respiratory Exchange Ratio (RER) ≥ 1.10. In this study, the average perceived exertion rate by the subjects was 16 ±1 which according to ACSM had reached the maximum training test criteria.

The result of this study has shown significant reduction of serum lactate level.

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The results are in line with previous study, which shown changes in blood lactate concentration which were observed in 10 healthy men, not exercising regularly, who had been given exercise at a 90% intensity interspersed with a resting phase. The exercise is divided into 5 meetings with ergo cycle and each exercise lasts for 20 minutes. After given a 20-minute exercise, there was a noticeable change in lactate from the blood lactate sampling in the 20th minute of the exercise from 18.3 mmol to 10.2 mmol. In another study conducted by Macedo, similar trend was found on blood lactate concentration after high-intensity exercise with a phase interval of 30 seconds by 120 seconds.[31] The significant decrease in post-workout lactate production might occur due to decreased glycolysis or increased lactate clearance from contracting muscles.[30] The process might be explained with Ca (2^{+}) -mediated modulation of glycogenolysis which supplies substrates to glycolytic during the resting phase, thus inactivation of glycolysis is reflected in the cessation of contractile activity.[32] The study did not differ the sex nor age group for the analysis. Despite being a limitation, several studies have mentioned there are no significant differences on blood lactate level between both sexes.[33,34] Significant differences are only found in age group after 70 years old.[35]

The rate of perceived exertion is an effective measuring tool in measuring weights and fatigue during exercise.[36] The rate of perceived exertion are closely related to the concepts of exercise intensity, exercise motivation, emotional states and diseases that can expand the scope of factors that affect the level of effort itself. In healthy individuals, the definition of perceived exertion emphasizes the subjective response of an intensity of exercise and the sensory experience of the perceived stimulus.[37]

Blood lactate levels and rate of perceived exertion decreased simultaneously during 12 sessions of high-intensity interval training, which was in line with Alkahtani's research.[5] In the study, a significant decrease in blood lactate levels occurred in the ninth exercise, and a decrease in the rate of effort occurred in the ninth exercise as well. The decreased lactate levels are associated with decreased perceived exertion after high-intensity interval training reflecting the metabolic adaptations in peripheral tissues. According to Bonnila (2020), a positive correlation is seen in the changes of lactate levels and perceived exertion.[36] Such adaptations include decreased glycogenolysis and decreased lactate accumulation in healthy, untrained individuals undergoing high-intensity exercise.[32] The difference between sex on rate of perceived exertion might not be seen in this study, however several studies have contradicting result. RPE is found to be lower in female group compared to male with higher endurance as shown with $\%VO_2$ max and estimation time limit.[38] Females are also observed to have lower respiratory exchange ratio in maximum lactate state as compared to male.[33] However, Rascon et al. stated there are no significant differences between both sexes.[34]

This study is the first to use laboratory training tests to determine the dose of an exercise program. Therefore, the strength of this study is its objectiveness and accuracy which can be inferred as the gold standard for dosage determination in an exercise program applied to healthy individuals to improve cardiorespiratory fitness.

However, the study is not without limitation. Laboratory training tests can’t be applied daily where there is no CPET tool for dosage determination. The diversity of physical activity level on all subjects also not controlled prior to the study, thus the high levels of lactate post-exercise is also possible due to the high intensity of activities shortly before doing the exercises. One of the most notable limitations is also the lack of control group on this study, thus the predisposing factor on the decrease of blood lactate and RPE that might be attributable to the result is not considered. However, the nature of this study to reveal the beneficial effect of HIIT on the population is objectively analyzed.

CONCLUSION

High intensity interval training is observed to reduce the blood lactate level and rate of perceived exertion after 12 sessions. Further research is needed to elaborate the findings of this study, including the need for field test to properly implement the training regimen without CPET device. Further research to evaluate the training effects on people with cardiopulmonary comorbidities. Due to our limitation, we also suggest the need for basic lactate measurement before the training regimen to objectively observe the lactate threshold of each subject.

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