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Effects of changes in volume and intensity of exercise training on $VO_{2\ MAX}$ in young females

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ABSTRACT

The Aim of this research was to survey effect of exercise training intensity and volume changes on Maximal Oxygen Uptake ($\dot{V}O_{2\ max}$) and resting HR. For this purpose 45 non athletic health undergraduate students with means 25±1.87 year, weight 71±1.95 Kg and height 175±2.30 voluntarily contributed at this research. Subjects randomly divided into four groups that were included group of moderate (50-55% HRR, N=12, group 1), Low vigorous (60-65% HRR, N=12, group 2), high vigorous intensity (70-75% HRR, N=12, group3) or a non-exercising control group (N=10, group 4). In first six weeks, group 1 run on treadmill for 30 minutes and with intensity of 70 % heart rate reserve (HRR), group 2 run for 30 minutes and with intensity of 60% HRR and group 3 run for 30 minutes and with intensity of 50% HRR, and in two last weeks, group 1 run on treadmill with intensity of 75% HRR, group 2 with intensity of 65% HRR, and group 3 with intensity of 55% HRR. For analysis of findings used ANOVA test and Tukey test (P=0.05). Findings showed that there is significant difference in $\dot{V}O_{2\ max}$ change in group 1 and group 3. Also Group 3 made more reduction in resting heart rate than group 1. Base on findings of current research, it deducted that for raise of $\dot{V}O_{2\ max}$, three sessions training in week with intensity of 50-55% HRR has more effects rather than one session training in week with intensity of 70-75% HRR.

Keywords: Cardiovascular Physiological Phenomena, Physical Education and Training, Physical Exertion, Physical Fitness, Time Factors.

INTRODUCTION

Cardio respiratory endurance has long been recognized as one of the fundamental components of physical fitness [1]. $\dot{V}O_{2\ max}$ is probably the single most important factor determining success in an aerobic endurance sport [1, 2]. Cardio respiratory fitness is increased by exercise training, regardless of age, gender, race, and initial fitness level [3, 4]. Every US adult should accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week'' , to maintain cardiovascular well-being according to the American College of Sports Medicine and the American Heart Association ‘recommendation [5]. The report also stated that a greater amount or a greater intensity of exercise confers greater benefits, but specifics for intensity were not provided [6]. Although the dose-response relation was acknowledged in the 1995 recommendation, this fact is now explicit. Very few studies have been conducted to examine the effects of intensity, duration, or frequency of physical activity independent of their contribution to the total amount of physical activity. Based on recent data, there is some indication that vigorous-intensity activities confers greater cardio protective health benefits than moderate-intensity exercise, including a lower incidence of coronary heart disease that may be related to lower risk [7, 8]. Other Current guidelines suggest that changes in cardio respiratory fitness are similar in high-intensity interventions and in moderate-intensity interventions of longer duration if the energy cost of exercise is similar [5]. Because of this dose-response relationship, it is important that exercise guidelines explain how cardio respiratory fitness is optimized.

Research suggests that vigorous-intensity exercise (60–84% oxygen consumption reserve ($\dot{V}O_2R$) results in greater increases in aerobic capacity than moderate-intensity exercise (40–59% $\dot{V}O_2R$) [8]. On the other hand, other guidelines suggest that changes in cardio respiratory fitness are similar in high and moderate-intensity interventions if the energy cost of exercise is similar [5]. However, those randomized controlled trials that have compared interventions of equal energy cost have concluded that high-intensity training is more effective in improving cardio respiratory fitness [9,10,11].Moreover, several similar studies found no difference between groups performing continuous exercise at different intensities [12,13, 7, 14].

Epidemiologic studies (Seccareccia, 2001; Diaz A, 2005; Fox K, 2008; Tverdal A, 2008;) have demonstrated that elevated resting HRs increase the risk of mortality, from cardiovascular disease [15, 16, 17, 18]. Resting heart rate can decrease significantly following training in a previously sedentary individual [19]. However, few studies have evaluated the potential role of exercise intensity in reducing resting HR. Six studies that have controlled exercise volume between two groups exercising at different intensities measured resting HR [20, 6, 9, 14, 21, 22]. Of these, only one found an intensity effect, in that women training at 64% $\dot{V}$O2R decreased resting HR, whereas those training at 41% $\dot{V}$O2R did not [21]. Men in neither intensity group decreased resting HR; however, there were few men in the study. One study that did not control the volume of exercise found that training at 72% of $\dot{V}$O2R resulted in a significant decrease in resting HR, whereas training at 50% $\dot{V}$O2R did not [23]. Gormley found that there are no significant differences in the resting HR between four groups after training when he evaluated intensity. Further research is warranted to fully examine the question of whether higher-intensity exercise is more effective at lowering resting HR than lower-intensity exercise [6].

The current study aimed to confirm whether continuous exercise at a vigorous intensity in one and two session per week is more effective than continuous exercise at a moderate intensity in three sessions in week in healthy young for improving aerobic capacity. Some studies that have compared vigorous and moderate intensities of continuous exercise found that vigorous-intensity is more effective, but other studies have not. Moreover, research comparing one and two sessions in week with vigorous-intensity training is limited. A secondary purpose of the study was to determine whether resting HR changes in three groups after training. It was hypothesized that there would be significantly difference in $\dot{V}O_{2\ max}$ in the four groups. It was also hypothesized that there would be significantly difference in resting HR in the four groups after an 8-week training period.

MATERIALS AND METHODS

Subjects: Female undergraduate students were recruited from the branch of science and research of Islamic Azad University of Tehran, Iran through the advertisements on the board of university according to these selection criteria: (1) between the ages of 20–30 years, (2) in good health, with no known diseases including diabetes, cancer or heart disease, (3) a body mass index less than 25kg.m^2, (4) not currently on exercise program (<3 moderate to vigorous aerobic sessions per week of >20 minutes. session), (5) not using cigarettes. Before being included in the study, subjects had to agree to be randomized to any one of the four groups (moderate, low vigorous and high vigorous intensity, and control), and not participate in any formal exercise outside of that provided during the study. Subjects signed a statement of informed consent. During the training period, 4 subjects dropped out of the study because of illness and injuries not related to the study.

Measurements of cardio respiratory fitness and HR were conducted in all subjects before and after an 8-week exercise. Data analyzed using a 4 (moderate, low vigorous and high vigorous intensity, and control) x 2 (pre- and post-study) repeated measures design

Testing procedures and material: After screening, subjects were randomly assigned to a moderate-intensity exercise group, a near low vigorous-intensity exercise group, a near high-vigorous intensity exercise group or a non-exercising control group. Subjects were instructed to refrain from caffeine, heavy meals, or heavy exercise 3 h before testing. All participants were instructed not to change their dietary or lifestyle habits other than prescribed. The subjects were familiarized with treadmill running (30 min) twice before the start of the study. They started with a warm-up period and terminated with a cool-down of 5 min at approximately 50% of predicted $\dot{V}O_{2\ max}$. The intensity levels for training were chosen because they are in keeping with those recommended for the improvement of cardio respiratory fitness [5]. Exercise testing and training took place at the exercise laboratory of the Medical Federation. Subjects were recruited by the principal investigator but were assigned to four groups by a fourth party using computer-generated sequences of random numbers.

Height and mass were measured (Jackson AS, 1985), and body mass index (BMI) was calculated. For HR measurement, subjects were fitted with a chest strap monitor (Polar CIC Inc [24]. Port Washington, Ny) and lay supine quietly for 15 min. HR was measured at 14 and 15 min and averaged to report resting values. Maximal aerobic power ($\dot{V}O_{2\ max}$) was determined utilizing the Bruce graded maximal treadmill protocol [25]. Testing was terminated when the subject was no longer able to continue. Calibration of the treadmill was completed before initiation of the study and at 1-month intervals.

To reduce potential sources of variability, the pretests and the posttests were administered at the same time of day for each subject. The testing procedures of the posttest matched those of the pretest. Post testing occurred the 48 hours after the completion of the 8-wk experimental period.

Training protocol: Subjects randomly assigned to one of four groups: 1) moderate intensity (~55% HRR), 2) low vigorous intensity (~65% HRR), 3) high vigorous intensity (~75% HRR) 4) or a non-exercising control group. Age was not used in the assignment process, because the age range of the subjects was relatively narrow.

The training protocol varied in intensity (%HRR), and frequency(sessions per week).During exercise, intensity was controlled by establishing target HR at the equivalent percentages of HR reserve (HRR) based on the resting and the maximum HR values measured during testing [8]. Training intensity during the first 6-wk experimental period was performed on the same intensity as mentioned above but two last weeks were different. However, duration and frequency weren't changed. Each session contained a 5-min warm-up and a 5-min cool-down period not included in the training duration. Subjects were informed that they must complete at least 90% of all training sessions to fulfill the requirements of the study. Each training session was supervised to ensure that the target HR was maintained.

For first 5-wk, moderate-intensity group run at 50% HRR for 30 min, three times a week, low vigorous-intensity group run at 60% HRR for 30 min, two times a week, near high vigorous-intensity group run at 70% HRR for 20 min, after that walked for 20 min and finally run at 70% HRR for 20 min once a week, and non-exercising control group didn't have any training.

During week 6, intensity in any groups increased 5%, moderate-intensity group run at 55% HRR with the same duration and frequency, low vigorous-intensity group run at 65% with the same duration and frequency HRR, high vigorous-intensity group run at 75% HRR with the same duration and frequency.

For the remaining 2 wk of exercise (7 and 8 wk), subjects were exercising at their final levels of duration, frequency, and intensity. Intensity in any groups increased about 2-3%, moderate-intensity group run at near but less than 60% HRR with the same duration and frequency, moderate-intensity group run at near but less than 70% with the same duration and frequency HRR, high-intensity group run at near but less than 80% HRR with the same duration and frequency.

Statistical analysis: All data were analyzed using SPSS for Windows, version 11.0 (SPSS, Chicago, IL). Descriptive statistics are presented as mean and SD. Effects of training on the principal dependent variables ($\dot{V}O_{2\ max}$, and resting HR) were analyzed using a 4 (four levels corresponding to the four training groups) x 2 (pre and post-study) repeated measures ANOVA. For significant F-ratios, a post hoc Turkey's test was used to determine which group means differed from each other. To evaluate percent changes in variables, a one-way ANOVA with post hoc Tukey's test was used. One-way ANOVA was also used to determine whether the work performed on the treadmill during any given week was different between the three training groups, and whether the physical activity performed outside of the study during any given week was different between the four subject groups. For all tests, Statistical significance was set at the $P < 0.05$ level and values are expressed as mean ± SE.

RESULTS

The baseline descriptive characteristics of the subjects are presented in Table 1. The age range was narrow because all of the participants were first year students of university. There were no significant differences observed at baseline between any of the groups for age, height, mass, BMI, or percent body fat. Further, there were no significant changes for any of the anthropometric variables after training. During the 8-week study, subjects in the exercise groups were required to attend the exercise sessions: all attended at least 90% of the training sessions: mod erate (95.1 ± 1.9%), low vig (94.5±3.3%), and high vig (93.7 ± 3.5%). Actual attendance was 84%, with make-up sessions increasing this to 94%.

Table 1. Subject characteristics.				
	Age (yr)	Height (cm)	Mass (kg)	BMI (kg.m^{-2})
control				
Pretest (N = 10)	20±3	161±6	58.3±8.4	22.6±3.4
Posttest (N = 10)		161±6	58.1±8.4	22.4±3.4
moderate				
Pretest (N = 12)	21±2	159±7	60.9±9.9	24.1±2.5
Posttest (N = 12)		159±7	60.9±9.7	24.1±2.3
low vig				
Pretest (N = 12)	22±3	161±8	60.3±10.1	23.3±3.5
Posttest (N = 12)		161±8	60.3±10.1	23.3±3.7
high vig				
Pretest (N = 11)	21±2	162±6	61.4±8.8	23.3±2.6
Posttest (N = 11)		162±6	61.3±8.8	23.3±2.6

Although intensity and the number of days exercised per week differed among groups, the energy expenditure per week had a little difference between the 3 training groups (P=.66) because the moderate-intensity group used about 150 Mets per session, or 450 Mets per week for the first 6-wks and 550 Mets for the 6,7, and 8 wks. Low vig used about 220 Mets per session, or 450 Mets per week for the first 6-wks and 530 Mets for the 6, 7, and 8 wks. High vig used about 430 Mets per session or week for the first 6-wks and 520 Mets for the 6, 7, and 8 wks.

Table 2 and Fig 1 summarize the $\dot{V}O_{2\ max}$ and heart rate data. There were no significant differences in the baseline $\dot{V}O_{2\ max}$ between three groups. $\dot{V}O_{2\ max}$ significantly increased from pre to post training in moderate and low vig groups. There were no significant differences in the post training in high vig and control groups.

Table 2. Changes in V˙O2max (mL.min^{-1}Ikg^{-1}) after the 8-wk training protocol.

Intensity Group	Initial V˙ O2max	Final V˙O2max	Net Change in V˙ O2max
control	32.5±6.4	32.9±7.7	0.4±2.7
moderate	33.1±5.5	39.2±6.3	6.1±2.9†,a,b
low vig	32.5±7.6	37.6±7.6	5.1±2.7†,a,b
high vig	33.8±7.1	35.6±7.9	1.8±3.3

† Significant increase versus baseline using two-way ANOVA (P < 0.05).
a Significantly greater increase than control group using two-way ANOVA (P < 0.05).
b Significantly greater increase than near high group using two-way ANOVA (P < 0.05).

There were no significant differences in the baseline resting HR between control, moderate, low vig and high vig groups. Resting HR significantly reduced from pre to post training in moderate group than the control, low vig, and high vig groups.

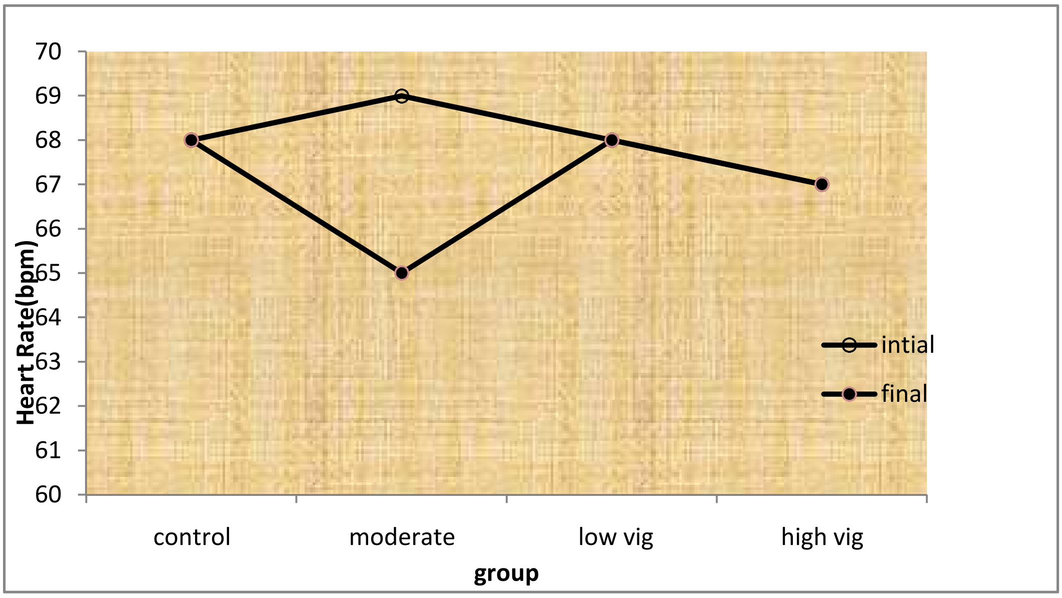

Fig 1. Changes in heart rate (beat.min^{-1}) after the 8-wk training protocol

DISCUSSION

The major findings of this study were that low-vigorous intensity has the same training effect as moderate intensity, and low-vigorous intensity and moderate intensity are significantly more effective than high-vigorous intensity in improving $\dot{V}O_{2\ max}$ during a training period of 8 wk in healthy, young female. Furthermore, moderate intensity elicits greater improvement in HR than other groups.

Our study had two limitations. First, three subjects in the moderate-intensity continuous training group did not come regularly during of the training period to the laboratory so they extracted from this study for Statistical analysis. In addition, four of the subjects in moderate-intensity group were overweight, that is, their Mean BMI was approximately 26.Thus, it is possible these limitations may be affected the main outcomes of the study. However, these limitations weren't important. On the other hand, this research had some advantageous such as high number of participant, female, near range of age, moderately fit and similar energy expenditure per week.

According to ACSM guidelines, using METs as an indicator of activity intensity allows generally healthy adults to accumulate credit for the various moderate or vigorous intensity activities they perform during the week. When combining moderate and vigorous intensity activity to meet the current recommendation, the minimum goal should be in the range of 450 to750 $MET.min.wk^{-1}$. At this study, training groups used about 520 MET.min for the sessions of training at week. Therefore volume of exercise was the similar in three exercise groups. Thus, each group performed the same amount of exercise relative to her aerobic capacity. Three exercise groups performed different intensity and different duration per week. Many individuals say that they haven't enough time to do exercise so we decided to design kind of protocol that one group performed it with the same volume once a week.

As mentioned earlier, Current guidelines suggest that changes in cardio respiratory fitness are similar in high-intensity interventions and in moderate-intensity interventions of longer duration if the energy cost of exercise is similar (2).Of course, this research and many studies are consistent with ACSM [12, 26, 27, 28, 29, 30, 31, 32, 33]. King concluded that the high-intensity groups exercised for 40 min at 73–88% of peak exercise heart rate, and the low-intensity group exercised for 30 min at 60–73% of peak exercise heart rate. After 12 mo of exercise training, all exercise groups significantly improved ($P < 0.03$) $\dot{V}\dot{V}O_{2\ max}$ relative to those in the control group. [34]**.** Branch showed that during graded exercise testing, with no significant differences between the groups in post training values. Women participating in moderate intensity exercise training as recommended in basic public health guidelines demonstrate an increase in cardio respiratory fitness similar to that elicited by vigorous training. [13]. However, at the study, high-vig training group didn't have any improvement in $\dot{V}O_{2\ max}$, several possible explanations for this discrepancy are that training performed once a week, subjects were a bit overweight, 27 % of subjects excluded from the results and this short duration in one session isn't enough to increase $\dot{V}O_{2\ max.}$ Helgerud et al. has noted that it is important to know how different training intensities influence adaptations in physiological parameters when selecting an optimum training regimen for a specific sport or for improving fitness in the general community [7]. Bunc and Heller (1989), Helgerud (1994), and Helgerud et al. (2001, 2007) have shown the individual variations in gross oxygen cost of activity at a standard running velocity[35, 7, 36]. In addition, it is often suggested that the genetic factors (Bouchard C, 1999) and level of aerobic fitness (Laukkanen JA, 2002, O'Donovan G 2005) also are important [11, 37, 3].

The results of this research are in disagreement with the some results. A study recently published by Gormley et al. examined the effects of various intensity of aerobic training on $\dot{V}O_{2\ max}$ during 6 wk in healthy young adults. Groups performed exercise on a stationary bicycle ergo meter with a moderate [50% $\dot{V}O2$ reserve ($\dot{V}O_2R$) for 60 min], vigorous [75% ($\dot{V}O_2R$) for 40 min], near-maximal-intensity [95% ($\dot{V}O_2R$)], or a non-exercising control group. Exercise volume (and thus energy expenditure) was controlled across the three training groups by varying duration and frequency. $\dot{V}O_{2\ max}$ significantly increased in all exercising groups by 7.2, 4.8, and 3.4 $mL.min.^{-1}.kg^{-1}$ in the near-maximal–, the vigorous-, and the moderate-intensity groups were all significantly different from each other ($P< 0.05$).This differences can be due to mode of exercise(cycling vs. running). Therefore, Gormley concluded when volume of exercise is controlled, higher intensities of exercise are more effective for improving $\dot{V}O_{2\ max}$ than lower intensities of exercise [6]. O'Donovan et al, investigated the effect of exercise intensity on cardio respiratory fitness and coronary heart disease risk factors. Maximum oxygen consumption ($\dot{V}O_{2\ max}$) was measured in sedentary men in a non-exercise control group, a moderate-intensity exercise group or a high-intensity exercise group with an equal energy cost. After 24 wk, $\dot{V}O_{2\ max}$ increased by 0.38 ± 0.14 l.min in the moderate-intensity group and by 0.55 ± 0.27 l.min in the high-intensity group, indicating that $\dot{V}O_{2\ max}$ responded differently to moderate- and high-intensity exercise(O'Donovan 2005). Other researcher randomized controlled trials that have compared interventions of equal energy cost have concluded that high-intensity training is more effective in improving cardio respiratory fitness [9, 10]. Wenger et al observed higher training responses at higher intensities. All of these studies differed from the current study because they were performed interval at higher intensity. A major strength of this study was the all exercise groups were performed only continuous and the subjects had similar age and moderately fit and all were woman [38, 20, 7, 39, 26, 40, 41, 42].

Resting HR. A strong, graded, independent relationship between RHR and incident CVD was demonstrated in healthy men and women [43]. Increased HR is universally associated with greater risk of death. Given the remarkable correlation between HR and lifespan, resting HR should be seriously considered as another possible cap on maximum lifespan [44]. Resting heart rate can decrease significantly following training in a previously sedentary individual [19]. Many studies examined the effects of training on resting HR but A few of them examined the role of training intensity on resting HR, , three found no change in resting HR in either group (Gossard D, 1986, Tashiro E. 1993, Gormley SE 2008), two found similar decreases in both groups (Braith RW1994, Leutholtz BC 1995), and one found that women, but not men, in the higher-intensity group decreased resting HR, whereas neither women nor men did in the lower-intensity group [21].Another found that a decrease of -3.49 bpm Sloan RP. 2009 and Zhang found the average resting HR decreased from 69.7 to 66.8 in the experimental group [45, 44]. Several behavioral and lifestyle factors are associated with RHR. These include increased resting HRs in the presence of psychological stress(Ohira T, 2008) or smoking(Felber Dietrich D 2007) and lower resting HRs in those who are physically fit(Jurca R, 2005) or consume greater amounts of oily fish or Ω-3 fatty acids.(Mozaffarian D. 2008; Mozaffarian D, 2006, Geelen 2005) [46, 47, 48, 49, 50, 51,52]. In the present study, there was significantly change in moderate group (from 69 to 65) than the exercising and control groups. This may be due to kind of exercise that performed in three days per weeks so a greater duration with moderate intensity of training may be needed to elicit the bradycardia. However, participants in moderate group had a higher resting heart rate.

CONCLUSION

The present randomized controlled study of exercise showed a significant increase in $\dot{V}O_{2\,max}$ in moderate intensity, and low-vigorous intensity groups and significant decrease in resting HR in moderate group over the 8-weeks study period. The study demonstrated a potential benefit of moderate continuous exercise to improve of cardio respiratory fitness in young females.

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