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Original Research

The Effects of Elliptical Cross Training on VO_2max in Recently Trained Runners

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ABSTRACT

Int J Exerc Sci 4(1) : 4-12, 2011. This study examined the effects of elliptical cross training on VO_2max in recently trained runners. 12 female and 8 male participants (mean ± SD; age = 23.70 ± 6.33 years, body mass index = 24.85 ± 5.89 kg/m^2) completed an initial four-week run training program, exercising four days/week, 30 minutes/day, at 80% maximal heart rate. VO_2max was predicted based on the duration of a Bruce graded-maximal treadmill test (GXT) prior to and after the run training. After initial training phase and post-test, subjects volunteered for the detrain group (n = 6) or were assigned to the run (n = 7) or elliptical (n = 7) based on a matched-pair design. Elliptical and run groups exercised three weeks under same prescription as initial program. GXT again performed after mode-specific training phase. VO_2max (ml/kg/min) increased ($p < 0.001$) from the pre-training (39.89 ± 10.74) to post-training (41.66 ± 10.90) after the initial run training program. Although not statistically significant, VO_2max declined (0.8% running, 1.5% elliptical, and 4.8% detraining) for all groups following the additional mode-specific program. Despite declines, repeated measures ANOVA showed no significant differences within or between groups before and after the mode-specific training phase. However, dependent sample t-test did reveal a decline ($p < 0.05$) in GXT time (minutes) for the detrain group from before (11.01 ± 2.80) and after (10.54 ± 2.72) their detrain phase. Future research should determine if elliptical exercise maintains VO_2max when away from running for longer periods.

KEY WORDS: Elliptical, VO_2max, Run, Cross Train

INTRODUCTION

The risks and incidence of injuries due to distance running have been well established (13, 16, 20). Research indicates that overuse is the most common cause of running injury (26). Many injuries, such as stress fractures, may prevent an individual from running until completely recovered. Because a decline in physiological fitness and running performance will occur in the absence of running, cross training exercise is an option to attempt to maintain fitness while injured (8, 15). While different modes of cardiovascular exercise have been compared to running in the past, little research exists on the benefits of an elliptical exercise training program.

Elliptical exercise machines provide an upright, non-impact, weight bearing form of aerobic exercise, similar to the running motion, as the lower body moves in a smooth, elliptical path on a set track (2).

The impact forces on the lower extremity, while elliptical training, were found to be equivalent to walking and less than half that of running (23). The low impact forces of elliptical exercise may make it a feasible training option for many running injuries. Several studies (2, 3, 5, 6, 7, 11, 12, 21, 23, 24, 25, 27) have looked at the effects of an individual bout of elliptical exercise compared to treadmill running, but few studies (9) have looked at elliptical exercise as part of an actual training program.

Cardiorespiratory endurance, determined by an individual's maximum ability to consume oxygen (VO_2max), is a significant health component to fitness because it is inversely related to premature death (17). Additionally, a high VO_2max increases physical work capacity or the ability to produce a large quantity of energy over a prolonged period of time. Furthermore, VO_2max is significantly correlated with running performance, especially in heterogeneous groups of people (18). The purpose of this study was to determine the effectiveness of an elliptical exercise-training program in maintaining cardiorespiratory fitness, particularly VO_2max, in recently trained runners.

It was hypothesized that an initial 4-week run-training program would significantly improve VO_2max in the first phase of the study. In the second 3-week phase of training, the elliptical and run training groups were expected to maintain or improve fitness in an equivalent manner, while a detraining group was expected to show a decline in fitness. This study furthered the knowledge base on the cardiorespiratory benefits of elliptical cross training exercise by determining the ability of elliptical training to sustain or improve maximal oxygen consumption in recently trained runners. These findings can be applied to healthy adults attempting to improve cardiorespiratory fitness, as well as beginning runners attempting to maintain or improve fitness through a cross-training program.

METHODS

Subjects

Twelve female and 8 male participants (mean ± SD; age = 23.70 ± 6.33 years, height = 1.71 ± .10 m, weight = 74.8.86 ± 20.34 kg, body mass index = 24.85 ± 5.89 kg/m², percent body fat = 21.37 ± 11.02%) completed all training and testing requirements. Subjects were recruited from kinesiology classes and the recreational sports facility at a regional university in the southwest. All subjects participated on a completely voluntary basis, and students from kinesiology classes were not offered class credit or extra credit for participation in the study. Qualified participants included individuals with access to the Recreational Sports Facility that also met ACSM guidelines for low risk, apparently healthy individuals (1). Participants completed a study application that

Table 1. Physical Testing Characteristics

(n = 20)	Pre-Test	Post-Test I
Weight (kg)	74.80 ± 20.34	74.55 ± 20.25
BMI (kg/m²)	24.85 ± 5.89	24.85 ± 5.97
Body Fat (%)	21.37 ± 11.02	20.66 ± 11.95
Bruce (min)	11.32 ± 2.69*	11.77 ± 2.69*
VO_2 (ml/kg/min)	39.89 ± 10.74*	41.66 ± 10.90*
Max HR (bpm)	189.75 ± 9.00	190.30 ± 8.43

Data shown as Mean ± SD.

* p value ≤ 0.001 between Pre-Test and Post-Test I

identified their current activity level and training availability. Subjects also completed a Physical Activity Readiness Questionnaire (PAR-Q), AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire, and signed an informed consent form. The study protocol was approved by the Protection of Human Subjects Committee at the University where the data was collected.

Testing Protocol
After subject selection, pre-testing included an initial body composition assessment with the BodPod (Life Measures Inc., Concord, CA). Additionally, cardiorespiratory endurance was evaluated with a graded maximal exercise test on a Quinton Treadmill (Cardiac Science Corp., Hannover, Germany) using the Bruce Protocol (4). All subjects attained a maximal heart rate within ten beats of their age predicted maximum to meet criteria for maximal volitional exhaustion. Due to malfunctions with the lab's metabolic cart at the time of the study, maximal oxygen consumption was estimated from the duration of the Bruce test by using the following predictive equation by Foster et al. (10): $VO_2max = 14.76 - 1.38 (time) + 0.451 (time)^2 - 0.012 (time)^3$. This was a generalized equation that was developed for use in cardiac patients as well as healthy, sedentary and active individuals, making it a good match for subjects in the present study. This equation was previously shown to have a correlation coefficient of 0.97 when compared with direct measurement of VO_2max (10). Additionally, maximal heart rate (Sigma Sport PC-14 Heart Rate Monitor: Sigma Sport USA, Batavia, IL) and total time were recorded from the maximal exercise tests. This testing protocol was repeated after four and seven weeks. Subjects were given 24-72 hours for recovery following their last training session prior to subsequent tests; however, there were no further controls on recovery within this given time range.

Training Protocol
The initial training phase lasted four weeks, and all subjects were directed to exercise at the same target training frequencies, relative intensities, and durations while running on a Precor 932i Series Treadmills (Precor Inc., Woodinville, WA). The training program consisted of 30 minutes of running for 4 days per week at an average intensity of 80% the maximal heart rate achieved during the initial Bruce test. Heart rate monitors were used to record the average heart rate for each training session over the 30-minute workout. Following each exercise bout, subjects recorded their average heart rate and the duration of the session, along with the distance ran.

Successful completion of the initial four week running program required the subjects to complete at least 75% of the prescribed workouts, which corresponded to at least 3 runs/week and 12 runs over the entire training phase. An increased frequency of weekly training sessions improves VO_2max, but there is a plateau in these gains beyond 3 days per week (22). For this reason, and in order to maximize the sample, subjects that completed 3-4 sessions per week were included. Subjects who did not complete 75% of the required workouts were dropped from the study. After subjects completed the initial four week running program, VO_2max and body composition were again assessed using the same protocol as the pre-test. Subjects were then placed into one of three training groups (run, elliptical, detrain) for the

Table 2. Phase I Training Characteristics

(n = 20)	Mean ± SD
Total Runs	13.80 ± 1.47
Duration (min)	29.91 ± 0.40
% Max HR	82.75 ± 4.23
Distance (miles)	2.64 ± 0.58
Pace (min/mile)	11.84 ± 2.59
Pace (miles/hr)	5.30 ± 1.13

Note. Data shown as Mean ± SD.

remainder of the study. Subjects volunteered to be in the detraining group (n = 6), while the remaining subjects were assigned to the elliptical (n = 7) and running (n = 7) groups based on a match pair design. Subjects who were to be assigned to the run or elliptical groups were ranked from highest VO_2max to the lowest, and every two individuals down the list were randomly assigned to either the elliptical or run group. All elliptical training was performed on Octane Pro4500 Ellipticals (Octane Fitness, Brooklyn Park, MN). The elliptical and run training groups continued to exercise for an additional three weeks at the same frequency (four days/week), relative intensity (80% maximum heart rate), and duration (30 minutes). The third group ceased all aerobic exercise training to serve as a sedentary control and demonstrate the effects of detraining. Following this second phase of training, all subjects completed a final assessment of VO_2max and body composition using the protocol performed during the pre-test and mid-test.

Statistical Analysis

Means and standard deviations for subjects' height, weight, body mass index, body fat percentage, age, duration of maximal Bruce Protocol test, predicted VO_2max, and maximum heart rate were reported for the pre-test and at four, and at seven weeks. After the initial phase of run training, pretest values for weight, body mass index, body fat percentage, duration of maximal Bruce Protocol test, predicted VO_2max, and maximum heart rate were compared to the four week assessment using a *t*-test for dependent samples. A p-value equal to or less than 0.05 was accepted as significant. These same values were compared within training groups (running, elliptical, and detraining) between the four week and seven week assessments. Between groups comparisons for the four week and seven week assessments were made using repeated measures analysis of variance (MANOVA). Average number of workouts for each training phase, relative heart rate intensities, duration, distance run, and running pace were reported for both phases of training. In the final three week training phase, these workout variables were compared between the elliptical and running groups using a *t*-test for independent samples. All statistical analyses were performed with the Statistical Package for the Social Sciences version 15.0 (SPSS Inc., Chicago, IL).

RESULTS

Phase I

Results of the pre-test measurements and the first post-test (four weeks) for the group as a whole are presented in Table 1. VO_2max was predicted based on total time (minutes) during the Bruce Protocol treadmill test (4). The following equation from (10) was used to predict VO_2max:

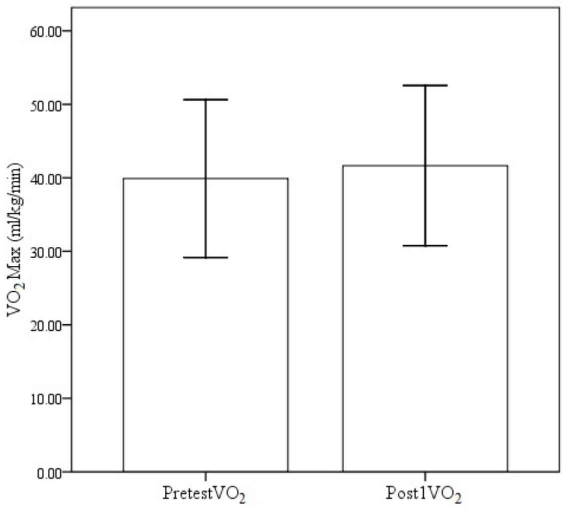

Figure 1. Mean VO_2max (± SD) before and after 4 weeks run training (n = 20).

$VO_2max = 14.76 - 1.38 (time) + 0.451 (time)^2 - 0.012 (time)^3$. There were significant improvements ($p \leq 0.001$) between the initial and Post-Test I assessments for both the duration of the Bruce treadmill test and for predicted VO_2max, which confirmed the researcher's hypothesis. VO_2max changes from Pre-Test to Post-Test I are also presented in Figure 1.

Table 3. Comparison of Post-Test I and Post-Test II

	Run (n = 7)		Elliptical (n = 7)		Detrain (n = 6)	
	PT-I	PT-II	PT-I	PT-II	PT-I	PT-II
BMI (kg/m²)	25.57 ± 6.95	25.43 ±6.60	23.57 ± 3.15	23.57 ± 3.15	25.50 ± 7.87	25.33 ± 7.87
Body Fat (%)	21.33 ± 11.10	22.34 ± 11.42	16.27 ± 10.20	17.62 ± 10.24	24.98 ± 14.84	22.32 ± 13.80
Bruce (min)	11.52 ± 2.83	11.46 ± 2.59	12.66 ± 2.63	12.49 ± 2.48	11.01* ± 2.80	10.54* ± 2.72
VO_2(ml/kg/min)	40.67 ± 11.50	40.34 ± 10.66	45.17 ± 10.89	44.50 ± 10.36	38.70 ± 11.02	36.82 ± 10.47
Max HR (bpm)	191.57 ± 9.43	191.57 ± 9.24	185.71 ± 6.26	183.00 ± 7.48	194.17 ± 8.16	195.17 ± 8.11

Note. Data shown as Mean ± SD.

PT-I (Post-Test I), PT-II (Post-Test II), * p value ≤ 0.05 within group.

Summary details of the initial four week run training phase are shown in Table 2. Subjects were required to complete at least 75% (12 of 16) of the prescribed runs over the four week period in order to advance to the post-test and second phase of training.

Phase II

A comparison of Post-Test I and Post-Test II is provided in Table 3. Following the three week phase of the mode specific training, there was a decline in VO_2max of 0.8%, 1.5% and 4.8% for the run, elliptical, and detraining groups, respectively. A *t*-test for dependent samples for each group did not reveal any significant changes, although the decline in predicted VO_2max for the detraining group demonstrated a trend towards significance ($p = 0.056$). There was a significant decline in Bruce treadmill time for the detraining group ($p = 0.045$).

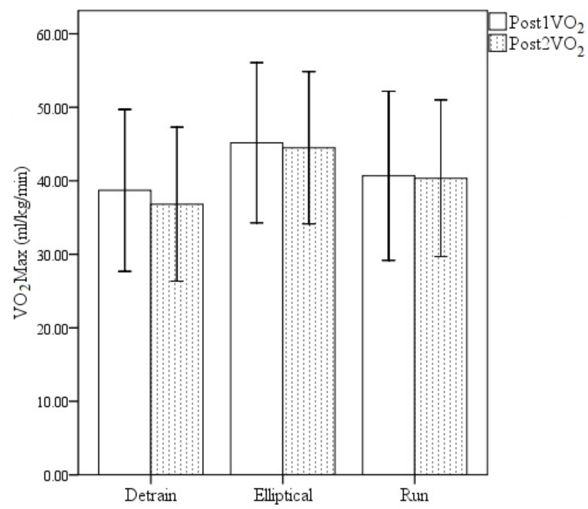

Figure 2. Mean VO_2max (± SD) in recently-trained runners before and after 3 weeks additional training.

A repeated measures ANOVA was used to analyze the change in means between Post-Test I and Post-Test II variables among the elliptical, run, and detraining groups. Thus, Post-Test I VO_2max to Post-Test II VO_2max was used as a within subjects factor and mode of exercise was used as the between subjects factor. When comparing changes in VO_2max between the three modes, the repeated measures ANOVA found no significant differences ($p = 0.296$, $df = 2$, $F = 1.307$). The changes in VO_2max between Post-Test I and Post-Test II for each group are displayed in Figure 2.

Tukey's Post-Hoc test also found no significant differences among one mode to any other for any of the measured variables. In summary, there was a significant decline in the Bruce treadmill time for the detraining group only. However, when comparing all three modes for each repeated measure variable in Post-Test I and Post-Test II, there were no significant differences found, which contradicted the researchers' initial hypothesis.

A summary of Training Phase II is provided in Table 4. Subjects in the training groups were required to complete at least 80% (10 of 12) of the prescribed workouts. There were no significant differences in training frequency, intensity, or duration between the elliptical and run groups when analyzed with a *t*-test for independent samples.

Table 4. Phase II Training Characteristics

	Run Group (n = 7)	Elliptical Group (n = 7)
Total Workouts	10.71 ± 1.11	10.71 ± 1.70
Avg. Duration (min)	29.44 ± 1.17	30.00 ± 0.00
% Max Heart Rate	81.05 ± 2.26	79.77 ± 5.30

Note. Data shown as Mean ± SD.

DISCUSSION

This study analyzed the effectiveness of an elliptical exercise-training program in maintaining cardiorespiratory fitness, particularly VO_2max, in recently-trained runners. The design of this training study intended to provide initial improvements in VO_2max for all subjects through a four week training program with a common modality (running). This allowed for application of the present study to beginner runners. The changes in cardiorespiratory fitness, following mode specific exercise (run, elliptical, detrain), were then analyzed in phase two of the study.

The initial four week training phase did yield significant improvements in VO_2max. Other training studies (9) comparing elliptical and running modes of training fail to account for the expected initial improvements in cardiorespiratory fitness that might occur with any aerobic training program that is recently introduced to a relatively sedentary group, regardless of modality. The present study accounted for this initial training stimulus by requiring all subjects to begin a run training program prior to comparing separate modes. This design allows for analysis of the ability to maintain or further improve fitness through various modes of training.

Phase two of the training resulted in no significant differences between the changes in VO_2max, or any other variable, across the three training groups from Post-Test I to Post-Test II. The detraining group did show a larger decline in VO_2max (4.8 %) compared to the running group (0.8%) and elliptical group (1.5%). While all groups declined in VO_2max, only the decline of the detraining group neared significant values ($p = 0.056$). These changes were expected based on previous detraining research by (14). As a whole, the repeated measures ANOVA yielded no significant changes in VO_2max due to mode of exercise. Given the PT-I VO_2max values, there were some concerns that the groups being compared were not identical. Despite the matched-pair design in assigning the elliptical and running groups, the elliptical group appeared to have a higher VO_2max (45.17 ml/kg/min) compared to the running group (40.67 ml/kg/min) and detraining group (38.70 ml/kg/min). A one-way ANOVA comparing the PT-I VO_2max values across groups was not significant ($p = 0.57$). Because all subjects underwent the same initial run training stimulus and were not significantly different at PT-I, the analysis for the second phase of training was carried out. With that said, more evenly matched groups and a larger sample (power analysis was not performed) might have led to significant findings at PT-II between groups. Nonetheless, an attenuation in the decline in VO_2max from 4.8% (detrain) to 1.5% (elliptical), still may have practical value for an injured runner hoping to maintain cardiovascular fitness through cross training.

Furthermore, it is likely that the changes from PT-I to PT-II would be more severe had the second phase of training lasted longer than three weeks. Ideally, each training phase would have lasted at least six weeks. The time constraints given the conclusion of the spring semester and inability to recruit subjects that would be available during summer break were a significant limitation to the current study. Future research can provide more clear results by improving on this and previously stated design flaws. However, the researchers believe the two training phase design, which includes an initial run phase, employed in the present study is a good model in order to make comparisons between alternate aerobic training modalities for application to injured runners.

When comparing the intensity of the second phase of training, the elliptical group exercised on average at 79.77% ± 5.30% of max heart rate and the running group at 81.05% ± 2.26%. While this was not a significant difference, there were anecdotal reports from the subjects in the elliptical group regarding the difficulty in attaining the target heart rate. Exercise prescription for both the elliptical and run groups was based on the subject's maximal heart rate achieved during a treadmill GXT, but maximal oxygen consumption and heart rate have been shown to be equal for treadmill and elliptical exercise (6, 7, 27). Looking specifically at rating of perceived exertion (RPE), some studies have shown equal RPE (21, 23) values for running and elliptical exercise at a given intensity, while others showed lower RPE (2, 12, 5) or higher RPE (25, 3) for a given intensity. This ambiguity is somewhat clearer when the distinction is made between whole body RPE and lower body RPE, in which case overall RPE was equivalent, but leg RPE was greater for the elliptical (11). In the present study, subjects exercising on the elliptical were directed to alter the cadence and resistance as they wished to attain the target heart rate. Subjects were also directed to move only in the forward direction. RPE was not measured in the current study and not believed to affect the results since both groups worked out at the same heart rate intensities relative to their treadmill maximum.

Runners who are injured or limited from running need alternative training options in order to maintain fitness. Cross training modalities such as cycling have been previously explored, but elliptical exercise is relatively new and less investigated, especially in terms of the chronic training effects. Simply by viewing the motions of elliptical, cycling, and running exercise, it seems that the elliptical motion may be more specific to running than is cycling. Whether or not this is true would require more measures than just VO_2max, but also need to look at other performance variables such as lactate threshold, running economy, and peak treadmill running velocity (19). However, given the present findings, elliptical exercise may be a viable cross training option for recently-trained runners attempting to maintain VO_2max in the short term. Studies comparing more physiological and performance measures for multiple cross training modalities can shed more light on which mode of training might be best for an injured runner.

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