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Recommended Citation
Hand, G.A., Phillips, K.D., Dudgeon, W.D., et al. (2008). Moderate intensity exercise training reverses functional aerobic impairment in HIV-infected individuals. *AIDS Care, 20*(9), 1066-1074

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AIDS Care
Vol. 20, No. 9, October 2008, 1066–1074

Moderate intensity exercise training reverses functional aerobic impairment in HIV-infected individuals

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(Received 14 August 2007; final version received 7 November 2007)

HIV infection and HIV drug therapies result in physical and psychological challenges to those living with HIV. These conditions contribute to decreased functional aerobic capacity (FAC). The aim of this study was to determine the effects of a combined moderate-intensity aerobic and resistance exercise intervention on the FAC of HIV-infected individuals. Forty HIV-infected individuals were randomized to an exercise group (EX) who completed six weeks of moderate-intensity exercise training, or to a control group (CON) that did not receive the exercise intervention. Twice weekly, the EX group completed 30 minutes of moderate-intensity aerobic training followed by moderate-intensity resistance training. Prior to, and following, the intervention the FAC for each subject was determined by graded exercise treadmill stress test (GXT). At baseline testing, the mean FAC as determined by treadmill time-based estimation of maximal oxygen consumption was 25% below age-predicted values, a level of reduction indicating the presence of functional aerobic impairment (FAI). Following the intervention, the EX had a significant increase in time to fatigue and estimated VO_2 max ($p < .001$). Further, FAI was eliminated (1% above age predicted values) during the exercise training. The EX group also experienced decreased heart rates during Stages 1 ($p = .02$), 2 ($p = .01$), 4 ($p = .05$) and 6 ($p = .02$) of the GXT. The CON had no significant changes during the intervention period. These data indicate that six weeks of combined moderate-intensity aerobic and resistance training can improve FAC and eliminate FAI in those with HIV. Results suggest that the functional limitations common in HIV-infected individuals are due in part to detraining that is reversible through moderate exercise adherence.

Keywords: VO_2; heart rate; functional aerobic capacity; graded exercise test

Introduction

People of all ages infected with HIV have been shown routinely to have abnormally low functional capacities, expressed as lowered capacity to utilize oxygen (VO_2) and perform physical work (Keyser, Peralta, Cade, Miller, & Anixt, 2000). The reduction of 25% or greater in age-predicted maximal capacity to use oxygen is termed functional aerobic impairment (FAI). Tests of an individual's ability to use oxygen, functional aerobic capacity (FAC), have shown those infected with HIV to have maximal VO_2 of 24–44% below their age-predicted normal values (Lox, MaCuley, & Tucker, 1996; MacArthur, Levine, & Birk, 1993). While it is likely that the etiology of this reduced work capacity is multifactorial, the sparse evidence available suggests that moderate to high intensity training is effective in improving the FAC of HIV-positive persons. Most training protocols have exercised subjects at 70% or greater of VO_2 max, typically three times a week for 60 minutes per session. Additionally, only three studies (Grinspoon et al., 2000; Robinson, Quinn, & Rimmer, 2007; Smith et al., 2001) have been conducted since the establishment of highly active antiretroviral therapy (HAART) as the standard of care, with six additional studies (Baigis et al., 2002; Lox et al., 1996; MacArthur et al., 1993; Perna et al., 1999; Stringer, Berezovskaya, O'Brien, Beck, & Casaburi, 1998; Terry et al., 2006) including subjects on some type of antiretroviral therapy. Given the potential negative impact of the drug side-effects on heart disease risk factors and cardiovascular function, the results from these early studies should be viewed cautiously and need to be revisited. Research has shown exercise to be safe in this population (Bopp, Phillips, Fulk, & Hand, 2003). Low to moderate-intensity exercise does not alter CD4 cell counts or viral load, nor does it increase the prevalence of opportunistic infections (Dudgeon, Phillips, Bopp, & Hand, 2004). Additionally, no reports of adverse side-effects to exercise interventions have been reported.

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ISSN 0954-0121 print/ISSN 1360-0451 online
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DOI: 10.1080/09540120701796900
http://www.informaworld.com

The effects of training in HIV-positive persons can include beneficial changes in body composition and muscular strength. Increases in lean tissue mass are positively correlated with slowed disease progression and decreased mortality in HIV disease (Wheeler et al., 1998). Thus, resistance training, resulting in lean tissue mass and muscular strength increases in healthy and diseased populations (Castaneda et al., 2001; Hakkinen, Sokka, Kotaniemi, & Hannonen, 2001; Hurley et al., 1995), has been prescribed to HIV-positive persons, with varying results. However, it appears that high-intensity resistance training may elicit favorable results in HIV-positive persons (Roubenoff et al., 1999; Roubenoff & Wilson, 2001). It is unknown if low- to moderate-intensity resistance training has similar effects.

Thus, studies of combined aerobic and resistance exercise training may result in both cardiovascular and musculoskeletal adaptations, making them more appealing than either mode alone. Three studies (Grinspoon et al., 2000; Rigsby, Dishman, Jackson, Maclean, & Raven, 1992; Robinson et al., 2007) have implemented resistance training along with aerobic exercise training in HIV-positive populations. Each reported increases in FAC similar to exercise regimens consisting of only aerobic training, and increases in strength greater than that produced by the aerobic regimens. However, these studies utilized high-intensity resistance training, which often results in poor exercise adherence due to muscle soreness and increased risk of injury in untrained individuals. By comparison to these previous studies, the aim of the present study was to determine the effects of a modest amount of moderate-intensity, resistance and aerobic exercise training on markers of FAC in HIV-positive persons. Another aim was to implement the current physical activity recommendations of the American College of Sports Medicine into a deconditioned population and to test its effectiveness in this population.

Methods

Sample

Forty HIV-infected men and women were recruited from local HIV/AIDS service organizations in the Columbia, SC metropolitan area. All HIV-infected individuals were over 18 years of age, free of any known opportunistic infections and physically able to complete the exercise intervention. No person was excluded based on ethnicity or gender.

Individuals were excluded from the study if: (1) their medical history revealed current opportunistic infection(s); (2) were currently using, or a past receiver of, hormone therapy; (3) scored five or greater on the Drug Abuse Screening Test (DAST) and/or the Michigan Alcohol Screening Test (MAST); (4) reported current involvement in a structured exercise program; or (5) any contraindications for testing, as specified by the American College of Sports Medicine (American College of Sports Medicine, 2000), were identified.

Procedure

All procedures, including testing and exercise training, were completed in the Clinical Exercise Research Center (CERC) in the Department of Exercise Science at the University of South Carolina. After signing the informed consent statement, subjects were assigned an identification number and then assisted in completing a demographic data sheet (age, race, gender, CDC-defined disease stage, current health status) and a cardiovascular risk factor survey addressing current medications (including HIV medications), family history of cardiovascular disease, smoking habits, physical activity habits, significant health concerns (other than HIV-infection) and other pertinent health information. Medical personnel reviewed the completed risk factor survey and obtained resting blood pressure (BP) and heart rate (HR) for each subject. If no contraindications for exercise stress testing were identified, subjects were cleared to receive a graded exercise treadmill stress test (GXT). Following successful completion of the GXT, subjects were randomized, via random number table, to either the intervention exercise (EX) group or a non-intervention control (CON) group. The screening survey and the GXT were repeated in the same fashion, two-to-four-days post-intervention. The Office of Research Compliance at the University of South Carolina approved the study and its procedures.

Graded Exercise Treadmill Stress Test

A trained exercise physiologist prepared eligible subjects for the GXT and a standard 12-lead electrocardiograph (ECG) was performed. Subjects sat quietly while medical personnel examined the real-time resting ECG, HR and BP. Once cleared for participation, the exercise physiologist administered the GXT using the Modified Bruce protocol on motorized Trackmaster treadmills (Full Vision, Inc., Newton, KS). All subjects exercised to volitional fatigue, followed by continued walking at a slow pace until HR and BP returned to baseline levels. Heart rate, BP, and treadmill total time were recorded at each stage of the protocol. Staff were blinded to group assignment.

The Modified Bruce GXT begins at a speed of 1.7 mph at 0% grade for three minutes then progresses to 1.7 mph at 5% grade for three minutes. After this stage, the protocol is identical to that of the Bruce Protocol. The Modified Bruce Protocol was used due to its lower initial intensity for this generally deconditioned population. Previous research has shown a high correlation between the Modified Bruce and Bruce protocols for HR responses ($r = 0.97$) and peak VO_2 measurements ($r = 0.72$) (McInnis & Balady, 1994).

Calculations for VO_2 peak and functional aerobic impairment

Estimated VO_2 peak was calculated from the treadmill total time. No universally accepted VO_2 peak calculation is available for the Modified Bruce Protocol, so 360 seconds (the equivalent of the first two stages that are absent from the Bruce protocol) were subtracted from each subject's treadmill total time. Total time on the treadmill in minutes was calculated from the total seconds (seconds/60). The time in minutes (T) was placed into the following gender specific equations that have been validated for estimating VO_2 peak from treadmill time during the Bruce Protocol (Foster et al., 1984):

- Males: $14.76\text{-}(1.379 * T) + (0.451 * T^2) - (0.012 * T^3)$
- Females: $(4.38 * T) - 3.9$

Predicted VO_2 max was calculated using the following age- and gender-specific formulas (Bruce, Kusumi, & Hosmer, 1973):

- Males: 69.7 – (0.612 * age in years)
- Females: 42.9 – (0.312 * age in years)

Functional aerobic impairment (FAI) was obtained with the following formula:

- $\%FAI = [(\text{predicted } V0_2 - \text{observed } V0_2)/\text{predicted } V0_2] * 100$

Aerobic exercise intervention

Exercise intervention subjects completed 30 minutes of aerobic exercise treadmill training in the intensity range of 50–70% of their age-predicted maximum HR (220-age in years) twice weekly, for six weeks. Heart rate was monitored using Polar Heart Rate Monitors. Each treadmill session consisted of a 5-minute warm-up period, followed by 30 minutes of training within the intensity range and then a 3–5 minute cool-down. Treadmill speed and grade were adjusted during each session to keep subjects within their prescribed intensity range.

Resistance exercise intervention

Following the aerobic training session, EX subjects completed upper-body and lower-body resistance training in approximately 20 minutes. Movements targeting the chest, upper back and triceps muscles were performed on plate-loaded Hammer Strength machines (Cincinnati, OH), the upper anterior and posterior legs on Life Circuit machines (Life Fitness, Irvine, CA) and the biceps brachii and deltoids using free weights. Subjects were given approximately one-minute recovery time between exercises. Resistance was adjusted so that each subject could complete one set of 12 repetitions for each exercise while maintaining proper form. As strength increased, resistance was changed to keep the subjects at their prescribed training intensity. Sessions were separated by at least 48 hours of recovery and lasted one hour in total duration.

Control group

Control group subjects came to the CERC for the same amount of time and weekly frequency as the EX subjects. The CON participants were allowed to read a book, talk or watch television. They were allowed to participate in the training regimen after completion of the CON protocol. Performance data from these subjects during the EX intervention are not included in the data analysis.

Statistical analysis

Sample size was based on previous studies of the same population. Repeated measures analysis of variance (ANOVA) was used to compare physiological and performance variables (HR, VO_2, time to fatigue) within groups. Variables at specific time-points were compared between groups using ANOVA. The significance level was set at $\alpha = .05$ and a Tukey post-hoc analysis of treatment means was used to identify differences between groups. All values are expressed as mean $\pm$ standard error (SE). No ancillary analyses were performed.

Results

Demographic data

Seventy-seven subjects were cleared for study participation and 11 subjects were excluded at screening based on the above mentioned criteria. With oversampling of the control group, forty-four subjects were randomly assigned to the control group and 30 subjects were randomized to the exercise group. Twenty-one subjects (seven women) in the EX intervention and nineteen subjects (three women) in the

Table 1. Self-reported demographic data of subjects who completed the 6-week study.

Variable	Exercise group	Control group
Age	41.2±2.3	42.4±1.4
Male	14	16
Female	7	3
African American	14	13
Caucasian	5	6
Other	2	–
ART yes	13	16
ART no	3	1
Did not answer	5	2
HIV-positive asymptomatic	15	13
HIV-positive symptomatic	1	1
AIDS	5	5

Note: HIV status is based on 1993 CDC criteria.
'ART Yes' refers to those subjects who reported taking at least one antiretroviral therapy during the study period.

CON group finished and completed all sessions in the study. Demographic data for each group is presented in Table 1. Thirteen EX group subjects were receiving HAART, three were not and five refused to answer. Sixteen individuals in the CON group were receiving HAART, one was not and two refused to answer. The mean age of the EX and CON group was not different (41.2±2.3 years and 42.4±1.4 years, respectively). The ethnic compositions of the groups were similar with the EX group having 14 African Americans and the CON group 13. Fifteen EX group subjects self-classified themselves as HIV-positive asymptomatic, according to the 1993 Centers for Disease Control and Prevention criteria, while 13 CON group subjects were self-classified as HIV-positive asymptomatic. No adverse events occurred to any of the subjects.

Functional aerobic capacity

Figure 1 illustrates the effect of training on estimated VO_2 max and treadmill time. Baseline analysis revealed that the estimated VO_2 peak of all 40 subjects, completing the study, was 30.5±1.8 ml/kg/min. The EX group had an estimated VO_2 peak of 31.6±2.1 ml/kg/min after spending 14.2±0.8 minutes on the treadmill, which was not different from the 29.4±0.3 ml/kg/min and 14.2±0.2 minutes of the CON group. There were no differences in estimated treadmill time or VO_2 peak between the 7 females (8.1±2.3 minutes; 31.2±0.3 ml/kg/min) and 14 males (9.1±3.0 minutes; 31.6±0.4 ml/kg/min) in the EX group. The male controls had a significantly higher treadmill time and estimated VO_2 peak (8.7±4.0 minutes; 30.4±0.8 ml/kg/min) than did the females (5.6±1.7 minutes; 20.5±0.1 ml/kg/min). There was no difference in baseline treadmill time or estimated VO_2 peak between those 30 subjects taking HAART (8.6±3.3 minutes; 30.3±0.6 ml/kg/min) and those 11 who were not or did not answer (8.3±3.6 minutes ; 30.6±0.7 ml/kg/min) .

Compared to pre-treatment values, the EX group increased treadmill time to 16.9±0.5 minutes ($p <$ .01) with a 21% increase in estimated VO_2 peak to 39.9±1.9 ml/kg/min ($p <$.01). The female exercisers improved by 24% (9.8 ml/kg/min increase) and increased treadmill time to 10.3±2.0 minutes, while the males improved by 20% (7.4 ml/kg/min) and increased treadmill time to 11.2±2.3 minutes. No difference ($p =$.72) was detected in response to training between those receiving HAART (7.6±1.0

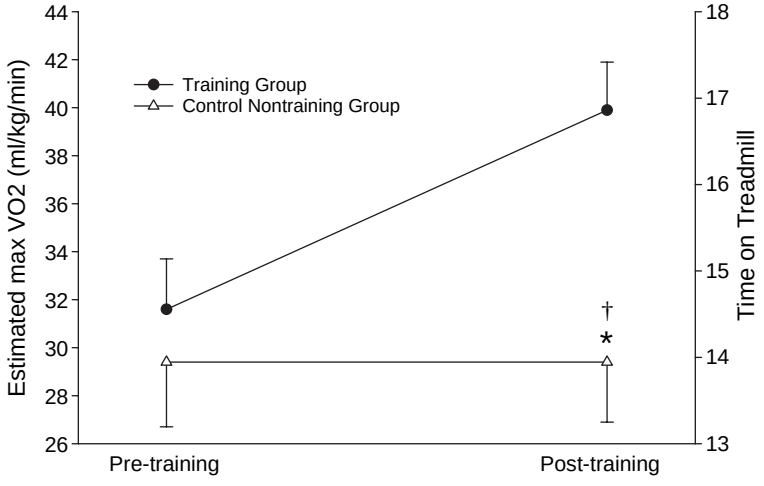

Figure 1. Effect of training on estimated VO2 and time on treadmill.
† = versus control and * = versus baseline.

ml/kg/min improvement and treadmill time of 9.4 ± 3.5 minutes) and those not (7.9 ± 1.1 ml/kg/min and 10.1 ± 3.0 minutes). No differences from pretreatment values were observed in treadmill time (14.8 ± 0.8 minutes) or estimated VO_2 peak (29.4 ± 2.7 ml/kg/min) in the CON group post-intervention.

Functional aerobic impairment

The age-predicted VO_2 peak for all the subjects was 40.5 ± 1.1 ml/kg/min, thus the subject pool had a baseline FAI of 24.6%, with the EX group a FAI of 20%, compared to CON group's 29.2% (Figure 2). The female exercisers exhibited no FAI at pretest (2.8% above predicted), while the males showed a 27% FAI. The CON group did not change FAC or FAI following the intervention. However, the EX group's improved FAC indicated a complete elimination of any FAI and raised the group's FAC to 1.2% above the predicted maximum at study conclusion. The female exercisers finished with a FAC 35% above predicted max, while the males improved to 11% impairment.

Heart rate

Heart rate was collected for each subject at rest, during each minute of the GXT and at peak workload. There were no differences between groups in percent of age-predicted maximum heart rate (APMHR) achieved during the pretests (EX: 87% ± 14% versus CON: 83% ± 15%) or during the posttest (EX: 86% ± 10% versus CON: 83% ± 12%). Figure 3's upper and lower panels illustrate changes in HR as GXT intensity increased from rest to peak exercise. Following the study, the EX group decreased HR at stages 1 ($p = .02$), 2 ($p > .01$), 4 ($p = .05$) and 6 ($p = .02$) and showed a trend for a decreased resting HR ($p = .07$). No HR changes were observed in the CON group. Percent of maximum HR achieved at baseline was not different between the men (83% ± 15%) and women (94% ± 9%) in the EX group, nor did it differ at post-testing (85% ± 11% versus 89% ± 7%, respectively). Additionally, no change was seen in maximum HR at the posttest for the EX group (154 ± 3 versus 154 ± 4) or the CON group (142 ± 7 versus 147 ± 6).

Discussion

The baseline estimated VO_2 peak for this sample was 30.5 ± 1.8 ml/kg/min, signifying FAI as the participants achieved only 75% age-predicted VO_2 max (40.5 ± 1.1 ml/kg/min). However, following the 6-week intervention, the EX group's VO_2 peak increased 26% (31.6 ± 2.1 ml/kg/min to 39.9 ± 1.9 ml/kg/min), abolishing the FAI present at pre-intervention, and placed them 1.2% above age-predicted values. This improvement was further demonstrated by a significant reduction in peak HR during four of the six GXT stages. Finally, the intervention was well tolerated, indicated by the EX group's 70% completion rate.

Research in HIV-positive populations has revealed estimated VO_2 max values below 30 ml/kg/min in untrained persons (Keyser et al., 2000; Prentiss, Power, Balmas, Tzuang, & Israelski, 2004; Stringer et al., 1998; Thoni et al., 2002), indicating low FAC. Higher-intensity aerobic exercise training (> 75% VO_2 max) has been effective at improving FAC, although most data were reported pre-HAART (LaPerriere et al., 1990; MacArthur et al., 1993; Stringer et al., 1998) many have erroneously reported peak measurements as maximal values. In most cases, VO_2 peak is the appropriate term as few tests achieve

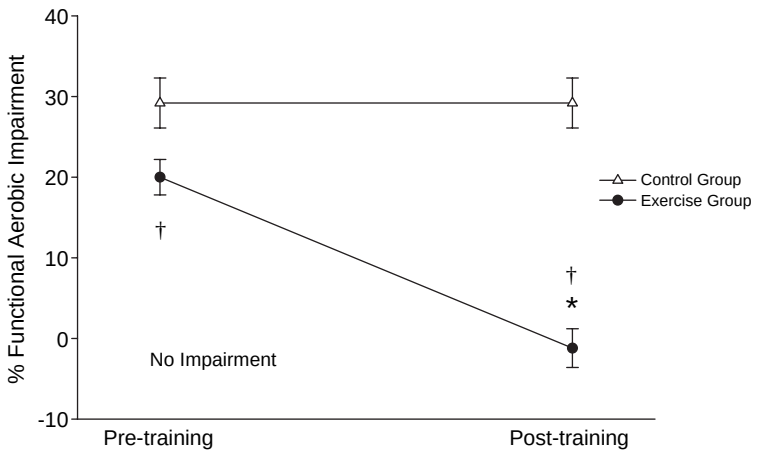

Figure 2. Effect of training on functional aerobic impairment.
† = versus control and * = versus baseline.

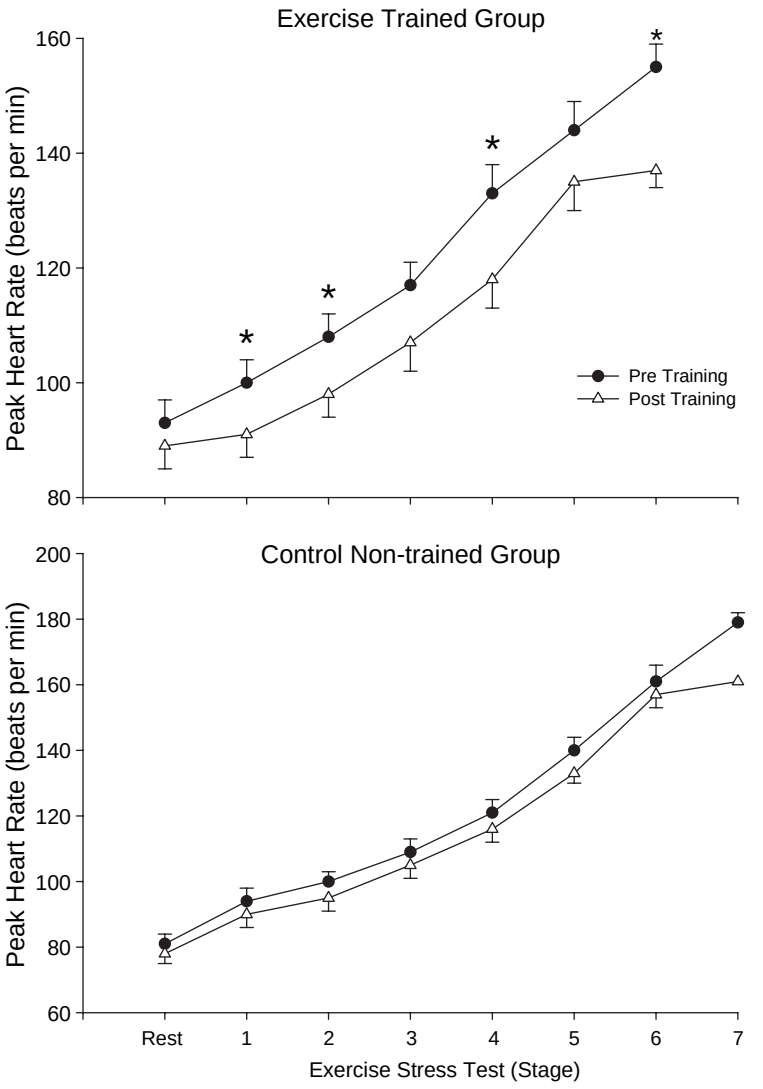

Figure 3. Effect of training on intensity-related peak heart rate.
* = versus control.

the criteria for a true maximal GXT. Our experience is that only perhaps 1% of the HIV-infected population can achieve a true maximal GXT (a VO_2 plateau with increasing workload), due to the severe physical deconditioning seen in this population.

The combined group's pre-training estimated VO_2 peak of 30.5 ± 1.8 ml/kg/min is comparable to other FAC values reported involving this population. Studies utilizing electrically braked cycle ergometers noted VO_2 max baseline values of 25.2 ml/kg/min to 30 ml/kg/min (Rigsby et al., 1992; Stringer et al.,1998; Thoni et al., 2002). Baseline VO_2 max estimates using treadmill protocols are comparable to bike tests and our results, and ranging from 26 ml/kg/min and 33.2 ml/kg/min (Cade, Fantry, Nabar, Shaw, & Keyser, 2003; MacArthur et al., 1993). Estimated VO_2 peaks were similar for both genders in our experimental group, though the females were above the gender and age-specific predicted values while males were below.

Although not specifically addressed, literature suggests significant FAI in the HIV-positive population. Stringer et al. (1998) reported that the 34 subjects in their study exhibited values at 85% predicted VO_2 max. Keyser et al. (2000) showed that a group of 17 young HIV-positive persons (18 ± 2 years old; 12 females) all had FAI, with VO_2 max values ($42 \pm 19\%$) less than predicted. Seventy-four percent (29 of 39) of the subjects in our study exhibited FAI, with a mean percent impairment of $25 \pm 1.2\%$. However, when examining only those with impairment, the mean was $36.7 \pm 0.2\%$. Interestingly, only 3 of the 10 females in our study exhibited FAI at

baseline, and were $2.7 \pm 0.8\%$ above predicted FAC as a group. Conversely, 26 of the 32 men had FAI, with a group mean of $29.1 \pm 2.4\%$. With a high level of confidence in the gender-specific functional capacity equations (Keyser et al., 2000), the data suggest that the female participants were either less affected by their infection (i.e. fewer symptoms or less severe) or their lifestyles facilitated a higher level of activity. This potential gender disparity demands further investigation.

A crucial question regarding exercise capacity in HIV-positive persons is their ability to adapt to training stimuli. Increasing evidence suggests that improved FAC can be expected with 12 weeks or more of training. MacArthur et al. (1993) found that 24 weeks of moderate- (50–60% VO_2 max) and high-intensity (75–85% VO_2 max) training improved FAC of HIV-positive persons in each group ($n = 3$) by 5.8 ml/kg/min and 10.1 ml/kg/min respectively. Also, subjects ($n = 19$) completing 45 minutes of training at ventilatory threshold (the upper limit of aerobic exercise) on a stationary cycle for 16 weeks (2x/week) saw a significant 2.6 ml/kg/min increase in VO_2 max (Thoni et al., 2002). Further, training one hour per day, three days per week for 12 weeks at 80% HR reserve (the difference between one's resting HR and maximum HR) on a stationary cycle resulted in a 5 ml/kg/min increase in 37 males (Rigsby et al., 1992). However, Smith et al. (2001) showed a non-significant 2.6 ml/kg/min increase in VO_2 max following 12-weeks of training (18 subjects; 20 min on treadmill and 10 min on stationary bike/stair stepper/ cross-country machines), three times per week at 60–80% VO_2 max.

Training durations less than three months have been used infrequently. Stringer et al. (1998) aerobically trained a group of HIV-positive subjects ($n = 9$) at 80% pre-intervention VO_2 max for 30–40 min, three times per week for six weeks, eliciting a $13 \pm 4\%$ increase in FAC, while a group ($n = 9$) training at 45% VO_2 max (six weeks) showed no improvement. Results from our low-volume, short-term (six weeks), moderate-intensity (50–70% APMHR) intervention using aerobic and resistance activities yielded a 26% increase in estimated VO_2 peak, which is greater than other studies of similar duration and comparable to higher-intensity interventions of longer duration.

In comparison to the other studies that utilized a combination of aerobic and resistance training, Robinson et al. (2007) trained subjects at an intensity between 70 and 80% VO_2 max for 20 minutes, 3 times a week for 16 weeks, but only saw an increase of 10% in VO_2. Robinson's study also utilized a resistance program of two times a week consisting of one set of 8–10 repetitions done at 80% of their one repetition maximum. Rigsby et al.'s (1992) study consisted of aerobic training, three days a week, for 12 weeks at a training intensity between 60 and 80% VO_2 max and a resistance regimen of three sets of repetitions, with repetitions varying from 6–18 repetitions per set. They showed a 17% increase in VO_2. Grinspoon et al. (2002) also completed a study utilizing a combination of aerobic and resistance training, but did not report any VO_2 values. When compared to our study's results, it can be suggested that improvements in FAC can be seen in HIV-positive persons at lesser intensities than have been tested previously, and can be experienced with programs including resistance training. The minimum duration of an effective exercise bout at different intensities remains to be determined.

Exercise training studies involving HIV-positive persons have generally not included HR data in their results. The change in HR during aerobic exercise is tightly coupled to increasing VO_2 as intensity rises. Therefore, HR is a useful measure when comparing results across studies not reporting VO_2 measurements. Additionally, a foundational marker of improved cardiovascular function is decreased HR at absolute submaximal work rates, the well-known training bradycardia effect. In this study, we report reduced HR changes in HIV-positive subjects during multiple stages of a GXT. We observed significantly decreased HR at GXT Stages 1, 2, 4, and 6. Only two other studies have recorded such decreases following training, and these were of longer duration (12–24 weeks), consisted of less subjects (6 and 13) and conducted pre-HAART (MacArthur et al., 1993; Rigsby et al., 1992).

This study also provided evidence that the Modified Bruce protocol is an appropriate GXT for the HIV-positive population. Prior to the study, this protocol was chosen over the Bruce protocol because it begins at a lower intensity and is less physically demanding. Buchfuhrer et al. (1983) suggested that FAC tests should last between 8 and 17 minutes, due to an increase in measurement error with tests lasting longer. Our average time of completion (14.5 ± 0.6 min) was within the 'optimal' range suggested by Buchfuhrer et al. with eight tests longer than 17 minutes, and one test less than eight minutes. Had the Bruce protocol been used, nearly half the subjects ($n = 19$) would have been below the optimal range.

A major limitation of many studies involving training in HIV-positive populations is small sample sizes (MacArthur et al., 1993; Rigsby et al., 1992). While the difficulty in retaining subjects is recognized, the lack of adequate sample sizes (resulting in low statistical power) is of concern and makes interpretation difficult. Due to this small sample

size, we did not perform an intent to treat analysis. Difficulties facing this population include inadequate transportation, poverty and opportunistic infections, possibly explaining high attrition rates in other studies. Our study achieved a 70% completion rate. Dropouts that were contacted reported no adverse signs or symptoms related to the exercise training and indicated that they voluntarily withdrew due to other factors. It should be noted that the twice-weekly sessions made this study less burdensome than studies using 3–5 sessions per week, perhaps explaining greater success in subject retention. Additionally, the moderate-intensity nature of this intervention would theoretically increase retention rates, as it would lessen the discomfort and fatigue associated with exercise of higher intensities. Another limitation was that we only asked if the subjects were on HAART therapy and not what type of specific classes of HAART medications they were taking.

Conclusion

This study confirmed the presence of decreased FAC in HIV-positive men and demonstrated a gender difference in HIV-associated FAI. Further, a training effect was apparent in both genders, showing enhanced FAC, decreased FAI and decreased HR at absolute submaximal workloads. The Modified Bruce protocol was appropriate for this population, given 80% of the subjects completed the GXT within an accepted 'optimal' range. Additionally, it appears that HIV-infected persons adhere well to low-volume, moderate-intensity training, as 73% of the exercising subjects completed this intervention. Finally, our findings suggest that HIV-infected persons can experience beneficial cardiovascular adaptations from short-duration training combining low-volume aerobic and resistance movements at moderate-intensity.

Acknowledgements

The authors would like to acknowledge the technical assistance of Raymond Thompson, Vernesha K. Brooks, Robert C. Bryant and Lateisha S. Tiller. We would also like to acknowledge Steven N. Blair, PED and Xuemei Sui, MD for their discussion on clinical trial research design. This research was supported by NIH/NCMHD EXPORT #MD001770–030003 (GAH KDP) and the American College of Sports Medicine's Gisolfi Research Fund (WDD).

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