Published in final edited form as:

J Am Geriatr Soc. 2009 November ; 57(11): 2055–2061. doi:10.1111/j.1532-5415.2009.02495.x.

Prediction of Cardiorespiratory Fitness in Older Men Infected with the Human Immunodeficiency Virus: Clinical Factors and Value of the Six-Minute Walk Distance

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Abstract

OBJECTIVES—To investigate factors related to cardiorespiratory fitness in older human immunodeficiency virus (HIV)-infected patients and to explore the utility of 6-minute walk distance (6-MWD) in measuring fitness.

DESIGN—Cross-sectional study in clinic-based cohort.

SETTING—Veterans Affairs Medical Center, Baltimore, Maryland.

PARTICIPANTS—Forty-three HIV-infected men, median age 57 (range 50–82), without recent acquired immunodeficiency syndrome–related illness and receiving antiretroviral (ARV) therapy.

MEASUREMENTS—Peak oxygen utilization (VO₂peak) according to treadmill graded exercise testing, 6-MWD, grip strength, quadriceps maximum voluntary isometric contraction, cross-sectional area, muscle quality, and muscle adiposity.

RESULTS—There was a moderate correlation between VO₂peak (mean ± SD; 18.4 ± 5.6 mL/kg per minute) and 6-MWD (514 ± 91 m) ($r = 0.60$, $P < .001$). VO₂peak was lower in subjects with hypertension (16%, $P < .01$) and moderate anemia (hemoglobin 10–13 gm/dL; 15%, $P = .09$) than in subjects without these conditions. CD4 cell count (median 356 cells/mL, range 20–1,401) and HIV-1 viral load (84% nondetectable) were not related to VO₂peak. Among muscle parameters, only grip strength was an independent predictor of VO₂peak. Estimation of VO₂peak using linear

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Data presented in part at the Gerontological Society of America Annual Scientific Meeting, San Francisco, November 16 to 20, 2007.

Author Contributions: All authors were involved with the study concept and design, acquisition of subjects and data, analysis and interpretation of data, and preparation of manuscript.

Conflict of Interest: The editor in chief has reviewed the conflict of interest checklist provided by the authors and has determined that the authors have no financial or any other kind of personal conflicts with this paper. Dr. Oursler's effort on this research was supported by National Institutes of Health (NIH) grant K23 AG024896. Dr. Scott's effort on this research was supported by a NIH T32 grant. The research was supported by National Institute on Aging (NIA) University of Maryland Claude D. Pepper Older Americans Independence Center P60-AG12583 (Drs. Oursler, Katzel, Russ, and Sorkin), University of Maryland General Clinical Research Center (M01 RR 16500), National Center for Research Resources, National Center for Rehabilitation Research T32 HD041899-01A1 (Dr. Scott), and Baltimore VA Geriatric Research, Clinical and Education Center (Drs. Katzel and Sorkin).

regression, including age, 6-MWD, grip strength, and hypertension as independent variables, explained 61% of the variance in $\text{VO}_{2\text{peak}}$.

CONCLUSION—Non-AIDS-related comorbidity predicts cardiorespiratory fitness in older HIV-infected men receiving ARV therapy. The 6-MWD is a valuable measure of fitness in this patient population, but a larger study with diverse subjects is needed.

Keywords

HIV; AIDS; cardiorespiratory fitness; physical function

Human immunodeficiency virus (HIV)-infected patients who receive antiretroviral (ARV) therapy are surviving into older age and are more likely to die from age-associated comorbid conditions than acquired immunodeficiency syndrome (AIDS).^{1–3} Deterioration in physical function is a consequence of chronic infection and sarcopenia in older adults.⁴ Aging, HIV infection, and ARV therapy have an additive effect on metabolism, pharmacokinetics, and immune function in older HIV-infected patients,⁵ but the combined effect on physical function is unknown.

Physical function encompasses many parameters, including fitness, strength, balance, and flexibility. In the current treatment era, difficulty with vigorous activities is the predominant functional limitation of HIV-infected patients regardless of their age.^{6–8} Exercise testing that shows a 42% reduction in cardiorespiratory fitness in adolescent⁹ and older (mean age 56)¹⁰ HIV-infected patients when measured as oxygen consumption during peak exercise performance ($\text{VO}_{2\text{peak}}$).

Before effective therapy was available, asymptomatic HIV infection frequently progressed to AIDS, resulting in generalized wasting and loss of muscle mass in young adults that was associated with shorter 6-minute walk distance (6-MWD)¹¹ and weaker hand-grip strength.¹² Similarly, laboratory markers of HIV disease progression, CD4 cell count, and HIV-1 viral load, were important predictors of physical function.^{6,13} More recently, in a large cohort of HIV-infected adults that included 447 subjects aged 50 and older it was found that self-reported physical function is associated with cardiac and pulmonary disease, independent of HIV stage and CD4 cell count.⁸ Although self-reported function provides important insight into physical disability, there may be limitations unique to older HIV-infected adults. Older HIV-infected patients, who represent a survival cohort, could have a different threshold for reporting functional limitations than younger HIV-infected patients or older noninfected patients. Exercise testing offers a laboratory-based measure to investigate the clinical and physiological factors underlying limitations in vigorous activities. 6-MWD is an estimate of submaximal exercise capacity that is easy to administer and predicts physical function and mortality in older adults with congestive heart failure (CHF)¹⁴ and chronic obstructive pulmonary disease (COPD)¹⁵ but has not been studied in older HIV-infected adults. In particular, the accuracy of the 6-MWD as a surrogate for treadmill testing has not been validated in this population.

The objective of the study was to investigate the association between age-associated comorbidity and cardiorespiratory fitness ($\text{VO}_{2\text{peak}}$) in older HIV-infected adults receiving ARV therapy. It was hypothesized that cardiac and pulmonary disease contribute to poorer fitness and that current effective HIV treatment minimizes the effects of AIDS and wasting. The secondary goal was to provide objective evidence that the 6-MWD could be used as a safe, easily administered, low-cost alternative to treadmill testing to assess fitness in older HIV-infected adults.

METHODS

Study Population and Design

The 43 subjects included in this study were part of a larger study of 67 HIV-infected men and women enrolled from the Baltimore Veterans Affairs (VA) Medical Center Infectious Disease Clinic between 2004 and 2007. Based on the Centers for Disease Control and Prevention definition of older HIV-infected adults,¹⁶ subjects aged 50 and older were included in the present report. Eligibility criteria included absence of AIDS-defining illness (ADI) and maintenance on ARV therapy for at least 6 months. These criteria were used to select subjects representative of patients with chronic stable HIV infection. Exclusion criteria included conditions that increase risk of exercise treadmill testing (e.g., poorly controlled hypertension (systolic blood pressure >180 mmHg or diastolic blood pressure >105 mmHg), class III or IV CHF, and severe anemia (hemoglobin <10 g/dL). Subjects who participated in structured exercise three or more times a week were excluded to minimize confounding from training effects. All subjects were men, except for two women and one transgender person, who were excluded from the present report. Written informed consent was obtained from all subjects and was approved by the University of Maryland, Baltimore institutional review board and the Baltimore VA Medical Center Research and Development Committee.

Fitness

Cardiorespiratory fitness was assessed by measuring oxygen consumption during a modified Bruce treadmill protocol.¹⁷ Subjects walked on a motorized treadmill that started at a speed of 1.7 mph and 0% incline. Every 3 minutes, the workload increased, by incline only at first, then by incline and speed. Subjects stayed on the treadmill until voluntary exhaustion. Breath-by-breath oxygen utilization, carbon dioxide production, and minute ventilation values were averaged at rolling 20-second intervals using a SensorMedics Vmax 29C series metabolic cart (Yorba Linda, CA). Maximum heart rate and time on the treadmill were also recorded. Peak oxygen utilization (VO₂peak) was calculated as the average of the last two oxygen utilization values during exercise. VO₂peak has been used to measure cardiorespiratory fitness in many populations, including healthy adults, where it declines with age at a rate of approximately 1% per year¹⁸; patients with age-associated comorbid conditions, such as coronary heart disease¹⁹; and younger HIV-infected patients (aged 20–50).^{9,20,21} The 6-MWD test was conducted according to the guidelines of the American Thoracic Society.²² Subjects were instructed to walk at their fastest comfortable pace on an even surface between two cones for 6 minutes, and the total distance covered was measured.

Skeletal Muscle Testing

Grip strength was quantified as the average of three trials of the dominant hand (Lafayette hand dynamometer (Lafayette, IN)). Lower extremity testing was added later to the study, and data are available on 30 subjects. Quadriceps muscle strength was measured as the average force generated by the knee extensors during three trials of maximum voluntary isometric contraction with the subject sitting and the knee in 90° of flexion (KinCom dynamometer, Chattanooga, TN). Quadriceps cross-sectional area and adiposity were determined from a single mid-thigh computed tomography (CT) slice (Medical Imaging Process Analysis and Visualization software (MIPAV), version 2.7.47 (Bethesda, MD)). Muscle attenuation according to CT was measured in Hounsfield units; lower values were indicative of higher muscle adiposity. Muscle quality was calculated for each subject as strength per cross-sectional area (specific force, N/cm²).

Additional Data

Lung tidal volume was measured as the average of three expirations measured using a handheld peak flow meter. Details on ARV therapy and comorbid conditions were extracted from the VA Computer Patient Record System (CPRS) for 1 year before enrollment and were confirmed according to subject self-report. Subjects who did not have laboratory data (CD4 count, HIV-1 viral load, hemoglobin) available in CPRS in the previous 3 months provided blood samples as part of the research protocol. Anemia was treated as a dichotomous variable (hemoglobin 10–13 g/dL) because hemoglobin values had a bimodal distribution.

Statistical Analyses

Analysis of variance was used to determine the association between VO_2peak , 6-MWD, and demographic and clinical characteristics. VO_2peak was plotted against 6-MWD and muscle testing parameters, and Pearson correlation coefficients were calculated. To investigate independent predictors of VO_2peak , relevant variables were included in age-adjusted linear regression models. Given the known association between zidovudine and anemia and mitochondrial oxidative dysfunction,²³ zidovudine therapy was included in the model for anemia. Multivariate analysis was performed to generate a predictive model for VO_2peak . Variables (clinical characteristics, 6-MWD, and muscle parameters) were entered stepwise into the model. Variables that improved the proportion of the variance explained by the model (coefficient of determination (R^2) adjusted for the number of independent variables in the model) were retained. Analyses were performed using Stata software (v9.0, StataCorp, College Station, TX). All analyses were two tailed.

RESULTS

Subjects

Of 97 patients who met ARV and AIDS illness eligibility criteria, 67 were enrolled in the larger study. Common reasons for exclusion were cardiac disease (arrhythmia, CHF, poorly controlled hypertension) and severe anemia. With the additional exclusion of three women and 21 younger men (<50) the analytical sample for this study was 43 men, aged 57.5 ± 6.5 . Eighty-eight percent of the subjects were African American. Immunological and virological markers of HIV disease reflected the subjects' treatment status. Median CD4 cell count was 356 cells/mL (range 20–1,401). HIV-1 viral load was below level of detection (<50 copies/mL) in 84% of the subjects. Of those with viremia, median viral load was 10,136 copies/mL (range 604–332,000). Age was not significantly associated with markers of HIV disease progression or ARV therapy ($P > .20$, data not shown). Most subjects were current or prior smokers and had a history of hepatitis C infection (Table 1). Despite the high prevalence of hepatitis C infection, only 51% of the subjects acknowledged history of injection drug use. Common co-morbid conditions were hypertension, COPD, asthma, dyslipidemia, and anemia (Table 1). Only one subject was taking a beta-blocker antihypertensive medication. Ten of the 16 subjects with anemia (63%) had a history of zidovudine use. Other comorbid conditions included diabetes mellitus ($n = 5$), chronic renal insufficiency ($n = 2$), and stroke ($n = 1$).

Fitness

Results from treadmill testing showed a mean VO_2 peak $\pm$ SD of 18.4 ± 5.6 L/Kg/min. Median time on the treadmill was 12 minutes (range 4–15). VO_2peak values qualified as a measure of maximum oxygen utilization in 46% of the subjects (20/43) based on reaching 90% or greater of their predicted maximum heart rate or a respiratory quotient of 1.1 or greater. Mean 6-MWD was 514 ± 91 m. There was a moderate correlation between

VO₂peak (mL/kg/min) and 6-MWD (correlation coefficient (r) = 0.60, P < .001, Figure 1). Lifestyle factors, smoking status, and obesity were not significantly associated with VO₂peak or 6-MWD (Table 1). Neither lung tidal volume nor pack-year smoking history predicted fitness (P > .50). Of the common comorbid conditions in this study population, only hypertension was significantly associated with VO₂peak (Table 1). The results remained unchanged in age-adjusted linear regression models that included smoking history, body mass index (BMI), or ARV therapy. Subjects with anemia (hemoglobin 10–13 g/dL, n = 16; P = .09) had 15% lower VO₂peak, which was unchanged after adjustment for zidovudine therapy and age (P = .09). Age confounded the large clinical difference in VO₂peak between subjects with and without hepatitis C infection (P = .06). Subjects in the hepatitis C–positive group were significantly younger than subjects in the hepatitis C–negative group (56 vs 71, P < .001). After adjustment for age, the association between VO₂peak and hepatitis C infection was not significant (P = .46). Neither VO₂peak nor 6-MWD was associated with markers of HIV disease progression or ARV therapy (Table 1). Results remained unchanged when CD4 cell count and log₁₀ HIV viral load were used as continuous variables rather than clinical categories. ARV therapy in the prior year was summarized according to history of zidovudine use, drug class (Table 1), and mean number of days per drug (P > .20, data not shown).

Muscle Testing

Results from hand-grip strength and lower extremity muscle testing are summarized in Table 2. There was a modest correlation between VO₂peak and grip strength (r = 0.41, P < .01) and quadriceps strength (r = 0.31, P = .09) (Figure 1). There was no significant correlation between VO₂peak and quadriceps muscle quality (specific force) (r = 0.08, P = .68), muscle attenuation (r = 0.13, P = .55) or muscle size (r = 0.23, P = .24) (Figure 1). In multivariate analysis predicting VO₂peak in which age and physiological tests were independent variables, the combination of 6-MWD and grip strength accounted for the greatest variance (R^2 = 0.56) (Table 3). Addition of several clinical variables (BMI, hypertension, and AIDS history) improved the predictive value and were included in the final multivariate model (R^2 = 0.63). Figure 2 shows a plot of VO₂peak predicted from the final multivariate model and VO₂peak observed from exercise testing.

DISCUSSION

This study, although small and limited to men, provides an initial examination of the clinical and physiological determinants of cardiorespiratory fitness in older HIV-infected adults. The hypothesis that cardiac and pulmonary disease, and not muscle wasting, are associated with reduced fitness in older HIV-infected men taking ARV therapy was tested. It was found that eligible subjects with hypertension had on average a 16% lower VO₂peak than those without hypertension. In contrast, subjects with a history of COPD or asthma did not have a significantly lower VO₂peak. The effect of anemia on VO₂peak is probably an underestimation given the small number of subjects with only moderate anemia (hemoglobin 10–13 gm/dL). Correlation of the 6-MWD with VO₂peak in older HIV-infected patients was similar to that in other older chronically ill patient populations.^{14,24} Furthermore, estimation of VO₂peak using linear regression including age, 6-MWD, and grip strength explained 61% of the variance in VO₂peak. Addition of clinical data (BMI, history of hypertension, and AIDS) improved the predictive value of the model (R^2 = 0.63).

Before the use of effective ARV therapy, it had been reported that hypertension was the only non-AIDS-associated medical comorbidity that independently predicted decline in self-reported ability to perform vigorous activities in young patients with AIDS (mean age 36).²⁵ Placed in clinical perspective, the drop in physical function score in patients treated for hypertension was similar to that in those diagnosed with new *Mycobacterium avium*

complex infection during the 8-month follow-up. The current study shows that older HIV-infected men with hypertension have a VO_2peak on average 0.25 L/min lower than those without hypertension. Although it is not surprising that hypertension is associated with poor cardiorespiratory fitness,²⁶ the findings of the current study have important implications for physical disability given the cumulative effect of aging²⁷ and HIV; 9-10 older HIV-infected patients with moderately well-controlled hypertension are performing vigorous activities²⁸ at close to their peak exercise tolerance. These findings also underscore that cardiac dysfunction needs to be investigated as a key mechanism for impaired fitness in older community-dwelling HIV-infected adults. Accumulating evidence suggests that HIV-infected patients have a greater risk of diastolic dysfunction. A recent cross-sectional study shows that HIV-infected patients had a 2.5 times greater risk of diastolic dysfunction than controls.²⁹ Risk for hypertension itself does not appear to be greater in HIV-infected adults than in uninfected adults and is not affected by HIV-related factors (CD4, viral load, ARV) when adjusted for BMI.³⁰ Together these reports and the results of the current study suggest that HIV infection may predispose older adults to loss of fitness through cardiovascular mechanisms. Research with in-depth physiological testing and cardiac imaging is needed to further investigate this question.

There is a well-established relationship between anemia and fatigue and self-reported physical function in patients with HIV infection and AIDS.^{31,32} The exercise testing in the current study supports this data with performance-based measures of function and further provides evidence that an important mechanism underlying symptomatic anemia may be poorer exercise capacity. However, with regard to insight into the peripheral determinants of VO_2peak , these results are limited. The negative effect of ARV therapy on muscle mitochondrial oxidative function and VO_2peak has been shown in younger patients.³³ Because the majority of subjects with anemia in this study were taking zidovudine the effect of low oxygen carrying capacity from reduced muscle mitochondrial oxidative function cannot be differentiated. The finding of a lack of an association between fitness and lower extremity skeletal muscle characteristics and quadriceps muscle quality, adiposity, and size is preliminary given the small sample size and noninvasive assessment techniques. The effect of HIV and ARV therapy on skeletal muscle is complex and diverse³⁴ and requires further evaluation to understand the additive effect of aging. Yet these results suggest that muscle wasting is no longer a primary determinant of fitness in patients surviving with HIV, even if they are older.

The secondary objective was to demonstrate the utility of the 6-MWD as a low-cost measure of fitness in older HIV-infected patients. Evidence was sought to support further research in this area given the possibility of accelerated aging in this growing group of chronically ill older adults who traditionally would be considered middle-aged. In younger men with AIDS and wasting, 6-MWD is associated with lower extremity muscle strength and size¹¹ and VO_2peak ($r = 0.57$).³⁵ The current study found a correlation between 6-MWD and VO_2peak in older HIV-infected adults taking ARV therapy ($r = 0.60$), which is comparable with patients with COPD ($r = 0.48$)²⁴ and advanced CHF ($r = 0.64$).¹⁴ Performance of less than 300 to 350 m on the 6-MWD has been used to reliably predict all-cause mortality in patients with COPD¹⁵ and CHF.¹⁴ Cardiovascular and pulmonary disease are now common causes of death in adults infected with HIV.³ Although a larger study with diverse subjects is needed, the findings of the current study support the use of the 6-MWD to measure fitness in older HIV-infected adults and investigate the role of fitness in mortality.

Walking speed and quadriceps strength are reliable predictors for disability in elderly adults³⁶ but may not apply to current older HIV-infected adults who are still, on average, 20 to 30 years younger than older cohorts not infected with HIV and whose primary deficit appears to be fitness. Results from this multivariate analysis help identify the physiological

and clinical factors that affect cardiorespiratory fitness. The approach was similar to a previous study of patients with CHF.¹⁴ The predictive value of the 6-MWD alone was similar in HIV-infected patients ($R^2 = 0.43$) and CHF patients ($R^2 = 0.42$), but by using precise measures of central parameters (radionuclide cardiac angiography and catheterization and pulmonary function tests) the capacity of the previous study's final multivariate model to predict VO_{2peak} ($R^2 = 0.72$) exceeded that of the current study ($R^2 = 0.63$). However, the clinical and physiological parameters in the model in the current study are practical for larger observational studies or randomized trials to investigate the differential effects of HIV, aging, and specific ARV regimens on fitness.

Characteristics of the study population limited this study. Because women have lower VO_{2peak} than men and were not well represented in the VA clinic, they were not included in the analysis. Patients with recent AIDS-related illness were not included to minimize confounding by active opportunistic infections. Therefore, the findings are limited to men without recent AIDS-related illness on stable ARV therapy; any conclusions outside this population should be drawn with caution. However, 26% of the subjects had a prior history of AIDS-related illness, and 21% had current CD4 cell count less than 200 cells/mL, which classifies their HIV infection stage as AIDS. The paucity of nonsmokers and hepatitis C–negative subjects limits the study's ability to investigate the association between these factors and fitness. The effect of injection drug use is unclear because only 9% admitted to current use. It was not found that COPD or asthma was a significant predictor of fitness. Although peak lung flow was not associated with VO_{2peak} or 6-MWD, it is likely that the lack of association between pulmonary disease and fitness was due to exclusion of patients with severe lung disease.

CONCLUSION

These findings demonstrate that non-AIDS comorbidity is an important predictor of cardiorespiratory fitness in older HIV-infected adults taking ARV therapy. Given the strict study eligibility criteria, the effect of comorbidity on fitness and the degree of impairment in these patients is probably an underestimation. Cardiorespiratory fitness is a significant predictor of all-cause mortality in adults aged 60 and older that is independent of lifestyle factors.³⁷ Given the significantly poorer fitness in mid-aged HIV-infected adults,¹⁰ the effect on mortality may be greater. The 6-MWD offers a measure of fitness in older HIV-infected patients that is safe, feasible, and inexpensive, but study of a larger, diverse, HIV patient population is necessary for validation of it as a prognostic indicator. This study highlights the need for longitudinal physical function testing toward the goal of understanding the effect of biological aging and age-associated comorbidity on disability within the setting of chronic HIV infection.

Acknowledgments

We thank Mary Bowers-Lash, RN, and Walter Williams, CGNA, for their dedication to study implementation; Andrew Goldberg, MD, for intellectual and material support; Alice Ryan, PhD, for compiling and interpreting radiological data; and Christopher Gallagher, PharmD, for compiling medication data.

Sponsor's Role: The sponsors had no role in the design, methods, subject recruitment, data collections, analysis, or preparation of this manuscript.

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Figure 1.

Correlation between peak oxygen utilization ($\text{VO}_{2\text{peak}}$) and 6-minute walk distance, hand-grip strength, quadriceps strength, and cross-sectional area. MVC = maximum isometric voluntary contraction.

Figure 2. Plot of measured peak oxygen utilization ($\text{VO}_{2\text{peak}}$; L/min) according to model-predicted $\text{VO}_{2\text{peak}}$ (L/min) estimated using the final multivariate model (Table 3, model 7). The diagonal line represents the line of perfect agreement.

Table 1

Demographic and Clinical Characteristics of 43 Human Immunodeficiency Virus (HIV)-Infected Men and Association with Fitness Measured According to Peak Oxygen Utilization (VO₂peak) and 6-Minute Walk Distance(6-MWD)

Characteristic	n (%)	Mean ± Standard Deviation	
		VO ₂ peak (L/min)	6-MWD (m)
Age			
50–54	19 (44.2)	1.45 ± 0.46	511 ± 92
55–59	11 (25.6)	1.59 ± 0.22	531 ± 67
60+	13 (30.2)	1.30 ± 0.48	504 ± 112
Race			
African American	38 (88.4)	1.42 ± 0.43	510 ± 95
Caucasian	5 (11.6)	1.57 ± 0.35	545 ± 54
Body mass index, kg/m ²			
≥30	7 (16.3)	1.48 ± 0.41	465 ± 84
<30	36 (83.7)	1.43 ± 0.50	523 ± 36
Smoking			
Current smoker	27 (62.8)	1.46 ± 0.32	522 ± 85
Prior smoker >1 year ago	12 (27.9)	1.35 ± 0.56	498 ± 110
Never smoker	3 (7.0)	1.56 ± 0.32	493 ± 104
CD4 count, cells/mL			
≤200	9 (20.9)	1.49 ± 0.29	494 ± 58
>200	34 (79.1)	1.43 ± 0.45	519 ± 98
HIV-1 viral load, copies/mL			
>50	7 (16.3)	1.32 ± 0.31	524 ± 94
≤50	36 (83.7)	1.46 ± 0.44	512 ± 92
Antiretroviral regimen in prior year			
Any nucleoside reverse transcriptase inhibitor	42 (97.7)	1.42 ± 0.41	510 ± 88
Any protease inhibitor	37 (86.0)	1.44 ± 0.44	507 ± 92
Any non-nucleoside reverse transcriptase inhibitor	12 (25.6)	1.31 ± 0.41	500 ± 90
Zidovudine	21 (48.8)	1.44 ± 0.40	526 ± 76
History of acquired immunodeficiency syndrome–defining illness			
Diagnosed >6 months prior	11 (25.6)	1.33 ± 0.46	534 ± 76
Never diagnosed	32 (74.4)	1.48 ± 0.41	507 ± 96
Hypertension			
Present	19 (44.2)	1.30 ± 0.44*	492 ± 96
Not present	24 (55.8)	1.55 ± 0.38	532 ± 86
Chronic lung disease [†]			
Present	11 (25.6)	1.38 ± 0.28	539 ± 79
Not present	32 (74.4)	1.46 ± 0.46	505 ± 94

Characteristic	n (%)	Mean ± Standard Deviation	
		VO ₂ peak (L/min)	6-MWD (m)
Dyslipidemia			
Present	13 (30.2)	1.45 ± 0.53	501 ± 109
Not present	30 (69.8)	1.43 ± 0.38	520 ± 84
Anemia (hemoglobin 10–13 g/dL)			
Present	16 (37.2)	1.30 ± 0.40	475 ± 85
Not present	27 (62.8)	1.52 ± 0.44	524 ± 91
Chronic hepatitis C [‡]			
Present	39 (90.7)	1.48 ± 0.40	520 ± 87
Not present	4 (9.3)	1.06 ± 0.51	455 ± 132

* $P < .05$ according to analysis of variance.

[†] Chronic obstructive pulmonary disease and asthma.

[‡] Seropositive and detectable viral load.

Table 2

Summary of Exercise Testing Results

Parameter	Value
Peak oxygen utilization, mean $\pm$ SD *	
L/min	1.4 $\pm$ 0.4
mL/kg per minute	18.4 $\pm$ 5.6
Metabolic equivalents, median (range) *,†	7 (3–10)
6-minute walk distance, m, mean $\pm$ SD	514 $\pm$ 91
Grip strength, kg, mean $\pm$ SD	39.6 $\pm$ 7.4
Quadriceps strength, N, mean $\pm$ SD	560.8 $\pm$ 132.9
Quadriceps size, cm ² , mean $\pm$ SD	68.0 $\pm$ 12.5
Quadriceps muscle quality, N/cm ² , mean $\pm$ SD	8.4 $\pm$ 2.0
Quadriceps muscle attenuation, Hounsfield units, mean $\pm$ SD	54.8 $\pm$ 8.9

* Graded exercise treadmill test.

† Calculated according to treadmill workload.

SD = standard deviation.

Table 3

Coefficients from Multivariable Linear Regression Predicting Peak Oxygen Utilization in Older Human Immunodeficiency Virus–Infected Men Receiving Antiretroviral Therapy

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Age	−0.019*	−0.010	−0.008	−0.006	−0.007	−0.006	−0.007
6-minute walk distance, m		0.003 [†]	0.002 [†]	0.002	0.002 [†]	0.002 [†]	0.002 [†]
Grip strength, kg			0.023 [†]	0.017	0.021 [†]	0.021 [†]	0.019 [†]
Quadriceps maximum voluntary isometric contraction, N				0.001	—	—	—
Body mass index, kg/m ²					0.017	0.016	0.0120
History of hypertension						−0.120	−0.147
History of acquired immunodeficiency syndrome							−0.167
Constant	2.5	0.61	−0.02	−0.03	−0.55	−0.47	−0.22
Model adjusted R ²	0.07	0.40	0.53	0.45	0.55	0.56	0.57
Model R ²	0.09	0.43	0.56	0.53	0.59	0.61	0.63

* $P < .05$;

[†] .01.

R² = coefficient of determination.