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Aerobic Fitness Levels and Validation of a Non-Exercise VO_{2max} Prediction Equation for HIV-Infected Patients on HAART

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Abstract

Background—Non-exercise (N-EX) questionnaires have been developed to determine maximal oxygen consumption (VO_{2max}) in healthy populations. There are limited reliable and validated N-EX questionnaires for the HIV+ population that provide estimates of habitual physical activity and not VO_{2max} .

Objectives—To determine how well regression equations developed previously on healthy populations, including N-EX prediction equations for VO_{2max} and age-predicted maximal heart rates (APMHR), worked on an HIV+ population; and to develop a specific N-EX prediction equation for VO_{2max} and APMHR for HIV+ individuals.

Methods—Sixty-six HIV+ participants on stable HAART completed 4 N-EX questionnaires and performed a maximal graded exercise test.

Results—Sixty males and 6 females were included; mean (*SD*) age was 49.2 (8.2) years; CD4 count was 516.0 ± 253.0 cells·mm⁻³; and 92% had undetectable HIV PCR. Mean VO_{2max} was 29.2 ± 7.6 (range, 14.4–49.4) mL·kg⁻¹·min⁻¹. Despite positive correlations with VO_{2max} , previously published N-EX VO_{2max} equations produced results significantly different than actual VO_2 scores ($P < .0001$). An HIV+ specific N-EX equation was developed and produced similar mean VO_{2max} values, $R = 0.71$, when compared to achieved VO_{2max} ($P = .53$).

Conclusion—HIV+ individuals tend to be sedentary and unfit, putting them at increased risk for the development of chronic diseases associated with a sedentary lifestyle. Based on the level of error associated with utilizing APMHR and N-EX VO_{2max} equations with HIV+ individuals, neither should be used in this population for exercise prescription.

Keywords

HIV; nonexercise questionnaires; prediction equation; validation; VO_{2max}

Exercise has been shown to reduce cardiovascular disease (CVD) risk factors and to diminish the prevalence of complications associated with HIV and HAART.^{1–6} It has been reported that HIV-infected individuals respond to exercise in the same manner as healthy individuals.^{1,4,5} Supervised, moderate-intensity aerobic exercise has been shown to be safe and effective for medically stable, HIV-infected individuals and will not negatively impact immunological function. Although concerns that high-intensity exercise may decrease immune function in HIV-infected individuals have been raised in the literature,^{7,8} subsequent research has shown that these concerns may be unwarranted.⁹ However, caution is advised when specific exercise intensities are prescribed to individuals infected with HIV, especially those with severely impaired immune function.^{9–11}

Exercise regimens should focus on creating improvements in cardiovascular fitness using prescribed intensities based on maximal oxygen consumption (VO_{2max}). Although VO_{2max} can be obtained through a maximal graded exercise test (MGXT),¹² it may not be safe or practical to administer a MGXT depending on available resources.¹³ Non-exercise (N-EX) questionnaires have been developed to estimate VO_{2max} in healthy populations without having them engage in exhaustive physical activity, and therefore they offer a practical and convenient alternative to MGXT.¹⁴ These questionnaires, when validated within the population being tested, offer reasonable estimations of VO_{2max} (standard error of the estimate [SEE] ranging from 9%–15%^{15,16}), are less time consuming, do not require expensive equipment or a trained individual to administer, and do not put physical stress on the participant. Unfortunately, the N-EX questionnaires that have been previously validated within the HIV-infected population only provide estimates of habitual physical activity and not VO_{2max} .^{17–19} The generalized N-EX equation developed by Jackson et al²⁰ was previously tested in a small cohort of HIV+ individuals ($n = 12$) and resulted in a correlation of $r = 0.82$ between actual and predicted VO_{2max} ,²¹ suggesting that N-EX equations may be a valid tool for assessing VO_{2max} clinically in this population. However, currently there are no validated N-EX questionnaires for assessing VO_{2max} in the HIV-infected population.

In the absence of validated N-EX questionnaires for HIV-infected individuals, the only option for determining prescribed exercise intensity without performing MGXT is the use of submaximal exercise tests, which have been shown to underestimate predicted VO_{2max} for untrained individuals.²² Additionally, the use of submaximal tests requires accurate prediction of maximal heart rate.¹² However, the ability to predict maximal heart rate is highly variable (± 11 beats per minute [bpm]), even in a healthy population and when controlling for age and training status.²² The accuracy of established equations for predicting maximal heart rate is unclear for HIV-infected individuals on HAART. Due to the inaccuracies in predicting maximal heart rate, errors of 10% to 15% may be expected when predicting VO_{2max} from submaximal exercise tests.²²

The purpose of this study was (1) to determine the effectiveness of regression equations developed previously on healthy populations, including N-EX prediction equations for

VO_{2max} and age-predicted maximal heart rates (APMHR), when applied to an HIV-positive population, and (2) to investigate development of specific N-EX prediction equations for VO_{2max} and APMHR for HIV-infected individuals receiving stable HAART.

METHODS

Participants

Participants included 68 medically stable HIV-infected patients (62 males, 6 females), ranging in age from 22 to 63 years, who were recruited from an ongoing study at the Hawaii Center for AIDS (HICFA). Two participants were excluded; one did not meet criteria for maximal effort during the MGXT and another was identified as an outlier using the least median of squares method.²³ The final sample size was 66 patients (60 males, 6 females). All participants were treated with HAART as outlined by the US Department of Health and Human Services guidelines for at least 6 months prior to data collection. Participants were cleared for participation by a physician and were subject to exclusionary criteria, including exercise contraindications as outlined by the American College of Sports Medicine (ACSM) or the stated inability to complete the exercise protocol.¹² Informed consent was obtained from all participants. Prior to study entry, all participants read and signed the informed consent form and medical history forms. This study was approved by the university's Institutional Review Board, Human Studies Program.

Instruments

Participants completed 4, independently validated, N-EX questionnaires that were scored according to methods described previously by the creators: (1) Baecke Questionnaire,¹⁷ (2) Modified George N-EX Questionnaire by Bradshaw et al,^{14,15} (3) Jackson N-EX Questionnaire,²⁰ and (4) International Physical Activity Questionnaire (IPAQ).^{18,24} Data from the questionnaires were used in an attempt to develop an accurate N-EX prediction equation of VO_{2max} for HIV-infected individuals on HAART.

Maximal oxygen consumption was assessed with a Max IIa metabolic cart (AEI Technologies, Naperville, IL) using standard open-circuit spirometry techniques. Standardized measurements of respiratory exchange ratio, volume of oxygen consumed per minute (VO₂), and volume of carbon dioxide produced per minute (VCO₂) were calculated directly by the metabolic cart. The instrument was calibrated prior to each testing session. Heart rate (HR) was monitored by a Polar Sensor (Polar Electro, Lake Success, NY), compatible with the built-in interface of the metabolic system.

Body composition was assessed using dual-energy X-ray absorptiometry (DEXA) (GE Lunar Prodigy Advance, Encore 2004 software version 8.10.027, Waukesha, WI). Blood lactate levels were determined using a Lactate Plus Lactate Meter (Nova Biomedical Co., Waltham, MA).

Procedures

All VO_{2max} and questionnaire data were collected in one 1 ½-hour session or two 45-minute sessions (less than 7 days apart) at the HICFA clinical laboratory – Clint Spencer Clinic.

Participants were given standardized written and verbal instructions prior to the initiation of all tests. All participants then completed the Baecke, Modified George N-EX, Jackson N-EX, and IPAQ questionnaires. Anthropometric measurements including height, body mass, blood pressure (BP), and resting HR were collected. Body composition (% body fat) was assessed via DEXA. Current (within 3 months of the study) CD4+lymphocyte counts and viral loads were obtained from clinic medical records.

Participants were connected to a 3-lead electrocardiogram (EKG) and were monitored by a physician for the duration of the MGXT. Blood lactate levels were obtained prior to and 7-minutes after the MGXT via a capillary digit puncture. Participants warmed up on a mechanically braked Monarch 834 cycle ergometer (Monarch, Stockholm, Sweden) for a minimum of 5 minutes at a self-selected pace prior to the initiation of the $\text{VO}_{2\text{max}}$ graded cycling protocol. Workload for the testing protocol began at 50 Watts (W) and increased by 12.5 W every minute.²⁵ Participants were instructed to exercise to volitional fatigue with active encouragement from investigators. Perceived exertion and local muscular fatigue, as determined by the Borg Ratings of Perceived Exertion (RPE) scale, EKG output, and BP, were recorded in 2-minute intervals at the completion of every other stage.²⁶ Maximal effort was based on ACSM criteria for maximal exercise testing, including a plateau in oxygen uptake or failure to increase oxygen uptake by 150 mL/min, a respiratory exchange ratio (RER) > 1.15, postexercise venous lactic acid concentration > 8 mmol, and/or an RPE > 17.¹² Upon termination of the exercise test, participants completed a cycling cool-down for at least 5 minutes at a self-selected pace.¹² ACSM's guidelines for contraindications and termination of exercise testing were strictly followed.^{12,27} Absolute maximal oxygen uptake ($\text{L}\cdot\text{min}^{-1}$) was then ratio scaled using body mass ($\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and allometrically scaled ($\text{mL}\cdot\text{kg}^{-0.67}\cdot\text{min}^{-1}$) as proposed by Heil et al.¹⁶

Statistical Analyses

Data were analyzed using Statistical Analysis Software (SAS) Version 9.1 English software package (SAS Institute Inc., Cary, NC). Descriptive data were generated. Functional aerobic impairment was determined using gender-specific formulas as described by Hand et al.²⁸ Relationships between variables were examined using Pearson's product moment correlation coefficients. Predicted $\text{VO}_{2\text{max}}$ was calculated using the Modified George¹⁵ and Jackson²⁰ N-EX questionnaires. Differences between actual and predicted values were analyzed using 2-tailed, paired *t* tests. Multiple linear regression analyses to predict APMHR and $\text{VO}_{2\text{max}}$ were performed using the maximum R^2 procedure. Regression diagnostics were used to identify data points (outliers) that would skew the regression formula. Specifically, the least median of squares was used to identify outliers with a potential to leverage the resulting regression equations for possible removal.²³ Prediction equation results were cross-validated using the predicted residual sum of squares (PRESS) method.²⁹ The alpha level was set at $P < .05$. The constant error (CE) was calculated using the following formula: $\text{CE} = (\text{actual} - \text{predicted})$. The total error (TE) or pure error was calculated using the following formula:

$$\text{TE} = \sqrt{\frac{\sum (\text{predicted} - \text{actual})^2}{n}},$$

where n is the sample size.

RESULTS

Male and female data for current study participants were combined, and demographic and anthropometric data are displayed in Table 1. All but one participant subsequently met at least one of ACSM's criteria for exerting maximal effort during the MGXT, and 85% of study participants met 2 or more of ACSM's maximal effort criteria.

Participant's $\text{VO}_{2\text{max}}$ values were considered to be within acceptable limits of normal distribution with a $Z_{\text{skewness}} = 0.01$ and $Z_{\text{kurtosis}} = 0.06$. However, based on age- and gender-controlled rankings, 86.4% of study participants were categorized at or below the 50th percentile for $\text{VO}_{2\text{max}}$ according to ACSM's allometrically scaled oxygen uptake percentiles, with 40.9% scoring below the 10th percentile rank.³⁰ Allometric $\text{VO}_{2\text{max}}$ scores were assessed for ACSM's fitness percentile ranks in order to control for participant's body mass. The weighted mean $\text{VO}_{2\text{max}}$ of 12 studies, published since the year 2000,^{6,21,31–40} was $27.3 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, which was similar to the $\text{VO}_{2\text{max}}$ achieved by subjects in the present study ($29.2 \pm 7.6 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$).

Maximal graded exercise tests lasted an average of 8.3 ± 3.2 minutes and participants reached an average max workload of $154.3 \pm 39.4 \text{ W}$. Functional aerobic impairment for participants in the current study was $23.1\% \pm 21.4\%$ (range, -37.2% to 59.21%). Study participants achieved a mean peak heart rate (HR_{peak}) of $157.5 \pm 20.0 \text{ bpm}$. Correlation between age and HR_{peak} was significant at $r = -0.32$ ($P = .005$); however, attempts to predict HR_{peak} from age in the present study resulted in $R^2 = 0.10$. Generation of Pearson's correlation coefficients resulted in positive, weak correlations between achieved HR_{peak} and previously established APMHR equations. The Fox³¹ and Gellish I³² equations demonstrated the highest correlation with achieved HR_{peak} , both with an $r = 0.32$ ($P < .01$). The Gellish III equation demonstrated the weakest correlation, $r = 0.25$. Two-tailed, paired t tests demonstrated that all 4 APMHR equations produced estimated maximal heart rates that were significantly higher than those achieved ($P < .0001$) (Table 2).

Multiple linear regression analysis resulted in a 4-variable prediction equation (Equation 1) that included N-EX and anthropometric variables: body mass (kg) ($P < .0001$), percent total body fat-squared ($P < .0001$), physical activity rating score (PA-R) from the Jackson Questionnaire ($P < .0001$), and moderate leisure activity score (Lm) from the IPAQ ($P < .05$). Equation 1 positively correlated with achieved $\text{VO}_{2\text{max}} \text{ L}\cdot\text{min}^{-1}$ values with an $R = 0.71$ ($P < .0001$). Equation 1 produced mean $\text{VO}_{2\text{max}} \text{ L}\cdot\text{min}^{-1}$ values similar to achieved mean $\text{VO}_{2\text{max}} \text{ L}\cdot\text{min}^{-1}$ values; a t test showed no significant difference between actual and predicted means ($t = -0.55$; $P = .58$).

$$\text{VO}_{2\text{max}}(\text{L}\cdot\text{min}^{-1}) = 0.462501 + (0.024335 \times \text{BM}) - (0.000477 \times \% \text{Body fat}^2) + (0.105978 \times \text{PA-R}) - (0.009941 \times \text{Lm}) \quad \text{Eq 1}$$

Comparisons between Equation 1 and those previously published are found in Table 3. The Bradshaw¹⁵ and Jackson (BMI) N-EX²⁰ prediction equations resulted in lower correlations with achieved $\text{VO}_{2\text{max}}$ values, with $r = 0.69$ and 0.66 , respectively. The Jackson (%fat)

equation demonstrated a correlation with $\text{VO}_{2\text{max}}$ ($r = 0.71$) similar to that of Equation 1. Despite the relatively strong correlations with $\text{VO}_{2\text{max}}$, the Bradshaw¹⁵ and the 2 Jackson²⁰ prediction equations yielded mean results that were significantly different than actual VO_2 scores ($P < .0001$). Attempts to improve the R^2 when predicting $\text{VO}_{2\text{max}}$ by using ratio or allometric scaling were not successful.

Equation 1 was cross-validated using the PRESS method.²⁹ The standard error of the estimate for the current sample population ($\text{SEE} = 0.47 \text{ L}\cdot\text{min}^{-1}$) was similar to the SEE developed from the PRESS method ($\text{PRESS SEE} = 0.48 \text{ L}\cdot\text{min}^{-1}$). The R^2 value generated from the PRESS method ($\text{PRESS } R^2 = 0.42$) was lower than the R^2 value reported from regression analysis for the current sample population ($R^2 = .50$) (Table 4).

DISCUSSION

The most important finding of the present study was that the existing N-EX equations for predicting $\text{VO}_{2\text{max}}$ were not clinically effective in the present sample of HIV+ patients, with the best performing equation only predicting 33% of subjects within $\pm 10\%$ of the achieved $\text{VO}_{2\text{max}}$ and 45.5% within $\pm 15\%$. Attempts to develop an N-EX equation for predicting $\text{VO}_{2\text{max}}$ specific to HIV+ patients resulted in smaller prediction errors but produced a similarly limited ability to predict $\text{VO}_{2\text{max}}$ within $\pm 10\%$ or 15% of achieved $\text{VO}_{2\text{max}}$. Existing APMHR equations produced significantly higher estimates of maximal HR compared to peak HR attained during maximal exercise testing in HIV+ patients. The best performing equation (Table 2) only placed 63.1% of subjects within $\pm 10\%$ of actual peak HR. Attempts to develop APMHR prediction equations specific to HIV+ patients in the present study were not successful. Therefore, the use of N-EX prediction equations for $\text{VO}_{2\text{max}}$ and APMHR equations is not appropriate in HIV+ patients, and the clinical use of these equations for development of exercise prescriptions in this population is contraindicated.

The current study confirmed that stable HIV-infected individuals on modern HAART regimens tend to be sedentary and relatively unfit, which puts them at increased risk for the development of chronic diseases associated with a sedentary lifestyle.^{10,33–36} This study evaluated a sample of HIV-infected individuals ($n = 66$) who achieved a mean $\text{VO}_{2\text{max}}$ of $29.2 \pm 7.6 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ($2.3 \pm 0.7 \text{ L}\cdot\text{min}^{-1}$). The mean $\text{VO}_{2\text{max}}$ value was similar to those presented by previous authors.^{6,21,28,37–41} The mean maximal workload for the current study participants, $154.3 \pm 39.4 \text{ W}$ ($2.0 \pm 0.5 \text{ W/kg}$), was somewhat lower than those reported by Roge et al (171 W) and Duong et al ($2.1 \pm 0.4 \text{ W/kg}$; $n = 27$).^{39,42} Participants in the current study displayed similar mean predicted functional aerobic impairment to those previously reported by Hand et al²⁸ (mean = 23.1% and 24.6%, respectively), however they had a lower percentage of mean predicted functional aerobic impairment values than those reported by Oursler et al (41%) and Cade et al (30.1%).^{37,38} Therefore, participant data in the present study were considered to be a reasonable representation of the HIV+ population.

Despite the functional aerobic impairment observed in the current study, participants were capable of producing maximal efforts that were consistent with ACSM's MGXT guidelines. Sixty-six participants met at least one of ACSM's criteria for MGXT maximal effort. Thirty

percent of participants achieved a plateau in oxygen uptake, which contradicted the 1% reported by Hand et al²⁸; this difference may be attributed to the different MGXT protocols used. Sixty-six percent of participants achieved an RER 1.15. The mean RER value of 1.21 ± 0.19 was similar to the mean RER value reported by Cade et al (1.21 ± 0.02 ; $n = 27$).³⁸

Participant's $\text{VO}_{2\text{max}}$ data were allometrically scaled to remove the influence of the participant's body mass (BM). Unsealed VO_2 values ($\text{L}\cdot\text{min}^{-1}$) tend to correlate positively with BM as seen in the present study ($r = 0.39$, $P < 0.001$); therefore $\text{VO}_{2\text{max}}$ has commonly been ratio scaled ($\text{mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) in an attempt to control for BM. However, ratio scaling over corrects for the influence of BM resulting in a negative correlation as seen in the present study ($r = -0.14$, $P = .254$).⁴³ Therefore data in the present study were converted into allometric scores ($\text{mL}\cdot\text{kg}^{-0.67}\cdot\text{min}^{-1}$) resulting in a correlation between BM and allometric $\text{VO}_{2\text{max}}$ scores that approached zero ($r = .04$, $P = .738$), indicating that the effect of BM had been removed from the resulting variable.

Utilizing allometrically scaled $\text{VO}_{2\text{max}}$ values, participants were ranked according to ASCM's oxygen uptake percentiles. Mean percentile ranks for $\text{VO}_{2\text{max}}$ (mean = $25.6\% \pm 22.5\%$) confirmed that the current study participants had low $\text{VO}_{2\text{max}}$ values and were relatively unfit for their age and gender. Although allometrically scaled VO_2 eliminated the effect of an individual's BM, it did not produce a significant prediction equation.

Although achievement of predicted maximal heart rate is age-specific, highly individualistic, and not included as one of ACSM's criteria for achieving $\text{VO}_{2\text{max}}$, participants in the current study achieved a mean HR_{peak} of 157.5 ± 20.0 bpm, similar to those reported previously in HIV-infected cohorts.^{39,40} Attempts to predict HR_{peak} from age in the present study resulted in an $R^2 = 0.10$. Therefore, results of the regression analysis did not provide enough predictive ability to justify creation of a new APMHR equation specific to HIV+ individuals. Previously established APMHR equations of Fox, Gellish I, Gellish II, and Gellish III significantly overestimated HR_{max} for this population (Table 2). The Fox and Gellish I equations demonstrated the highest correlation with achieved HR_{peak} ; however, paired sample t tests confirmed a significant difference between achieved HR_{peak} and all 4 APMHR equation means.

The error of overestimating HR_{max} for the HIV-infected population will affect intensity-specific HR-based exercise prescriptions.^{10,12} For example, using actual HR_{peak} and a resting HR of 72 bpm, we calculated the training zone using Karvonen's equation to be between 123 and 145 bpm.⁴⁴ Using the Fox equation to estimate HR_{peak} , the training zone was calculated to be between 131 and 156 bpm. Thus the prescribed training intensity would be too high using the APMHR formulas. It is unclear whether the lower HR_{peak} values are result of HIV infection, HAART regimens, or low fitness levels. Regardless, previously established APMHR equations do not provide accurate estimations of HR_{peak} for this or other samples of HIV-infected individuals.

Three previously published prediction equations were evaluated for accuracy in predicting $\text{VO}_{2\text{max}}$ for HIV-infected subjects in the present study. The previously established N-EX $\text{VO}_{2\text{max}}$ prediction equations of Jackson et al²⁰ and Bradshaw et al¹⁵ significantly

overestimated oxygen uptake for HIV-infected individuals ($P < .0001$) when compared to actual $\text{VO}_{2\text{max}}$ values. Although predicted $\text{VO}_{2\text{max}}$ values and actual $\text{VO}_{2\text{max}}$ values were significantly correlated, the 3 previously established prediction equations produced significantly different means than the actual $\text{VO}_{2\text{max}}$ values ($P < .0001$). Therefore, the N-EX prediction equations of Jackson et al²⁰ and Bradshaw et al¹⁵ were ineffective for estimating $\text{VO}_{2\text{max}}$ for the HIV-infected participant's in this study. These results were not unexpected, as all 3 prediction equations were validated using large healthy populations and because of the relatively high percentage of functional aerobic impairment occurring in subjects in the current study.

Multiple linear regression was used in attempt to develop a new prediction equation (Equation 1) specific to HIV-infected individuals using activity scales from previously established N-EX questionnaires and demographic data. Equation 1 produced mean $\text{VO}_{2\text{max}}$ scores that were not significantly different than achieved $\text{VO}_{2\text{max}}$ values. This was expected, because regression equations are specific to the population from which they were derived. Equation 1 placed 52% of the participants within $\pm 15\%$ of their achieved $\text{VO}_{2\text{max}}$. However the R^2 was 0.50 with a SEE of $0.47 \text{ L}\cdot\text{min}^{-1}$ and a SEE% of 20.5% (percentage of subjects within $\pm 1 \text{ SEE}$). Cross-validation using the PRESS statistic resulted in shrinkage of the R^2 to 0.42 and a slight increase in the SEE to $0.48 \text{ L}\cdot\text{min}^{-1}$ and the SEE% to 21.3%, indicating that Equation 1 is unlikely to yield satisfactory results when applied clinically.

A limitation of the present study was that the sample size may have been inadequate for developing an N-EX prediction equation, although Equation 1 was generated from a larger sample of HIV+ subjects than previous studies investigating aerobic fitness in this population since the year 2000. When compared to previous studies, the $\text{VO}_{2\text{max}}$ participants in the current study was judged to be representative of the fitness levels of HIV+ subjects. However, the sample size may have contributed to a narrow range in $\text{VO}_{2\text{max}}$ values, thus restricting the amount of variance accounted for by Equation 1. The inclusion of male and female subjects into a single generalized prediction equation may also be viewed as a limitation of the present study. However, the inclusion of female subjects allowed for an increased sample size while only affecting the mean ratio-scaled $\text{VO}_{2\text{max}}$ by $0.58 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ compared to inclusion of male subjects alone. An additional limitation was the use of DEXA to determine percent body fat; if other methods are applied, results may be skewed.

CONCLUSIONS

The current study evaluated the $\text{VO}_{2\text{max}}$ of a sample of HIV-infected individuals ($N = 66$). The predicted functional aerobic impairment and $\text{VO}_{2\text{max}}$ values were consistent with those previously reported in the literature,^{6,21,28,37–41,45} therefore participants in the current study were determined to reasonably represent the aerobic fitness levels of HIV-infected patients. When viewed in the context of other studies, results of the current study emphasize the extent to which HIV+ individuals may possess markedly impaired aerobic fitness levels and may be at significant risk for the development of chronic diseases associated with a sedentary lifestyle. There is an overriding need for regular physical activity to increase aerobic fitness and decrease cardiovascular disease risk in this population.

Results from this study addressed several concerns regarding HIV-infected individuals that may affect the accuracy of exercise prescriptions. It was concluded that established APMHR equations did not provide accurate estimations of HR_{peak} in the current sample of HIV-infected individuals and should be not utilized to prescribe intensity-specific exercise regimens for HIV-infected individuals.

It was also concluded that previously established N-EX VO_{2max} prediction equations inadequately predicted VO_{2max} for this population and therefore should not be used. Equation 1 produced better prediction of actual VO_{2max} values for this HIV+ sample than previously published N-EX equations; however the failure to predict VO_{2max} within $\pm 10\%$ for an acceptable percentage of the population suggests the clinical use of these equations to predict VO_{2max} or for the development of exercise prescriptions in this population is contraindicated.

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Table 1

Participants' anthropometric and demographic data

Variables	Mean (SD)	Range
Age, years	49.2 (8.2)	22.0–63.0
Height, cm	171.2 (9.7)	143.5–193.7
Body mass, kg	78.2 (12.5)	55.0–115.6
BMI, kg·m ⁻²	26.4 (3.5)	20.8–36.3
Years since HIV diagnosis	16.0 (8.1)	1.0–30.0
CD4 count, cell·mm ⁻³	516.0 (253.0)	66.0–1,168.0
Viral load, ^a copies·mL ⁻¹	19.4 (83.0)	0.0–532.0
VO _{2max} , mL·kg ⁻¹ ·min ⁻¹	29.2 (7.6)	14.4–49.4
VO _{2max} , L·min ⁻¹	2.3 (0.7)	0.9–4.1
VO _{2max} , mL·kg ⁻¹ ·min ⁻¹	122.5 (32.2)	56.4–212.0
Resting lactate, mmol·L ⁻¹	1.4 (0.7)	0.4–3.6
Resting systolic BP, mm Hg	132.5 (12.1)	98.0–170.0
Resting diastolic BP, mm Hg	83.0 (10.1)	61.0–106.0

Note: N = 66; 60 males, 6 females. BMI = body mass index; BP = blood pressure; VO_{2max} = maximal oxygen consumption.

^aThere were 61 of 66 (92%) participants who had an HIV RNA viral load <48 copies/mL (undetectable). Only 2 of the remaining 5 subjects had a HIV RNA viral load >300 copies/mL.

Participants' age-predicted maximum heart rate (APMHR) from published equations ($N = 66$)**Table 2**

Equation	Predicted, bpm Mean (SD)	Constant error, bpm Mean (SD)	Total error, bpm	Correlation (r) with HR _{peak}	t test	$\pm 10\%$ bpm	$\pm 15\%$ bpm
Fox ^a	170.8 (8.2)	-13.2 $\pm$ 19.0	23.4	0.32 ^{**}	-5.6 [*]	63.1	78.5
Gellish I ^b	172.5 (5.7)	-14.9 $\pm$ 18.9	24.0	0.32 ^{**}	-6.4 [*]	56.9	76.9
Gellish II ^c	174.1 (5.4)	-16.5 $\pm$ 19.1	25.1	0.30 ^{***}	-6.9 [*]	53.8	75.4
Gellish III ^d	175.3 (4.6)	-17.7 $\pm$ 19.4	26.2	0.25 ^{***}	-7.4 [*]	49.2	72.3

Note: Mean peak heart rate (HR_{peak}) = 157.5 ± 20.0 beats per minute (bpm).

^a APMHR = $220 - \text{age}$.

^b APMHR = $207 - (0.7 \times \text{age})$.

^c APMHR = $191.5 - (0.007 \times \text{age}^2)$.

^d APMHR = $163 + (1.16 \times \text{age}) - (0.018 \times \text{age}^2)$.

* $P < .0001$.

** $P < .001$.

*** $P < .05$.

Table 3

Comparison of participants' predicted VO_{2max} using Equation 1 and previously published equations with percent of participants within 10% and 15% of achieved VO_{2max} (L·min⁻¹)

Equation	Predicted Mean (SD)	CE Mean (SD)	TE	Correlation (r) with VO _{2max}	t test	±10%	±15%
Equation 1 ^a	2.3 (0.5)	-0.03 (0.45)	0.45	0.71 [*]	-0.55	30.3	51.5
Jackson (% fat) ^b	2.5 (0.65)	-0.26 (0.5)	0.56	0.71 [*]	-4.25 [*]	31.8	42.4
Jackson (BMI) ^c	3.5 (0.88)	-1.21 (0.7)	1.20	0.66 [*]	-14.78 [*]	3.0	9.1
Bradshaw ^d	2.6 (0.52)	-0.37 (0.5)	0.60	0.69 [*]	-6.26 [*]	33.3	45.5

Note: Participants' actual achieved maximal oxygen consumption (VO_{2max}) = 2.3±0.7 L·min⁻¹, CE = constant error; BMI = body mass index; Lm = moderate activity during leisure from the International Physical Activity Questionnaire; PA-R = Jackson et al physical activity rating; TE = total error.

^{*} P< .0001.

^aEquation 1 = 0.462501 + (0.024335×BM) – (0.000477×%fat²) + (0.105978×PA-R) – (0.009941×Lm).

^bJackson [%fat] = 50.51 + (1.59×PA-R) – (0.29×age) – (0.55×5fat) + (5.86×gender^e).

^cJackson [BMI] = 56.363+ (1.92×PFA) – (0.38×age) – (0.75×BMI) + (10.987×gender^e).

^dBradshaw = 48.07+ (6.18×gender^e) – (0.25×age) – (0.62×BMI) + (0.71×PFA) + (0.67×PA-R).

^eGender: male = 1, female = 0.

Table 4

Multiple linear regression results for Equation 1 and predicted residual sum of squares (PRESS)

Variable	
Intercept	0.462501
Body mass	0.024335 **
% Total body fat ²	-0.000477 **
PA-R	0.105978 **
Lm	-0.009941 *
<i>R</i>	0.71
<i>R</i> ²	0.5
SEE, L·min ⁻¹	0.47
SEE %	20.5
PRESS	
<i>R</i> ²	0.42
SEE, L·min ⁻¹	0.48
SEE%	21.3

Note: PA-R = Jackson et al physical activity rating; Lm = moderate activity during leisure from the International Physical Activity Questionnaire; SEE% = (SEE / mean actual VO_{2max}) × 100; VO_{2max} = maximal oxygen consumption.

* *P* < .001.

** *P* < .0001.