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HIV and the Athlete: Effects of Chronic HIV Infection and Antiretroviral Therapy on Physical Performance and Exercise Capacity

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Abstract

Background. Effective antiretroviral therapy (ART) has transformed HIV infection into a chronic condition compatible with long-term physical activity and sport. Nevertheless, chronic HIV infection, ART exposure, comorbidities, and changes in body composition may influence exercise capacity and physical performance.

Aim. To critically review evidence on the effects of chronic HIV infection and ART on cardiorespiratory fitness, muscular function, mitochondrial physiology, body composition, fatigue, and exercise responses, with emphasis on implications for competitive athletes.

Material and methods. This narrative review synthesizes evidence from HIV treatment guidelines, sports-medicine consensus statements, systematic reviews, meta-analyses, randomized controlled trials, observational studies, and selected mechanistic investigations. Earlier findings were interpreted in the context of historical ART regimens.

Results. People living with HIV (PLWH) may demonstrate lower aerobic capacity, muscular strength, and functional performance than HIV-negative populations, although findings are heterogeneous and based mainly on clinical cohorts. Historical ART was associated with mitochondrial and metabolic toxicity, whereas contemporary regimens have a different pharmacological profile. Exercise can improve physical capacity without evidence of adverse effects on virological control.

Conclusions. HIV status alone should not generally contraindicate sport participation in clinically stable individuals. However, athlete-specific evidence remains limited, particularly regarding high training volumes, repeated maximal exercise, recovery, overreaching, and long-term competitive performance with contemporary ART.

Key words: HIV; antiretroviral therapy; athlete; exercise capacity; physical performance; cardiorespiratory fitness

1. Introduction

The clinical course of HIV has changed profoundly with the development of effective combination antiretroviral therapy. Modern ART allows durable viral suppression in most appropriately treated individuals and has shifted the focus of HIV care well beyond the prevention and treatment of opportunistic disease [1]. Cardiovascular and metabolic health, body composition, musculoskeletal function, ageing, and quality of life have consequently become increasingly relevant components of long-term care. This change is also relevant to sports medicine. People living with HIV (PLWH) participate in recreational exercise, organized sport, and, in some cases, high-level competition. The practical question is therefore no longer simply whether physical activity is beneficial. Of greater interest is whether chronic HIV infection, previous treatment exposure, or contemporary ART may influence physiological systems involved in performance, training adaptation, and recovery. Physical performance is inherently multifactorial. Cardiorespiratory fitness, skeletal-muscle strength and power, body composition, neuromuscular function, metabolic efficiency, and recovery all contribute, but their relative importance varies considerably between disciplines. A modest change in relative VO_2peak, for example, may be particularly relevant to an endurance athlete while having less direct importance in a strength- or power-dominant sport. Findings obtained from clinical exercise testing therefore need to be separated carefully from conclusions about sport-specific performance. At the population level, comparative studies suggest that PLWH may have lower physical capacity than HIV-negative populations. Gomes-Neto et al. analyzed 30 studies involving 2,161 participants with HIV and 2,148 HIV-negative controls and reported lower aerobic capacity and muscular strength in the HIV group [2]. The pooled difference in aerobic capacity favored the control groups by 8.4 units (95% CI, 4.8-12.0), while lower-body strength was also reduced [2]. Such estimates are relevant to understanding the broader physiological phenotype associated with HIV, but they should not be interpreted as an expected performance deficit in every individual, and particularly not in a trained athlete. Several processes may contribute to the differences observed between populations. Cardiovascular and metabolic disease, altered fat and lean-tissue distribution, fatigue, pain, physical inactivity, and disease-related factors may all influence exercise capacity. Historical antiretroviral treatment introduced an additional concern, particularly mitochondrial toxicity associated with selected nucleoside reverse transcriptase inhibitors (NRTIs) [3,4]. How much these observations apply to athletes receiving contemporary ART is less certain because both HIV management and

the pharmacological profile of treatment have changed substantially. Treatment-associated weight gain represents a more contemporary issue. Large observational studies indicate that increases in body weight may differ between ART regimens and may be greater with some integrase strand transfer inhibitor (INSTI)-based combinations [5]. The implications for sport, however, cannot be inferred from body weight alone. Changes in fat mass and lean mass may have different consequences, and the relevance of either will depend on the physiological and mechanical demands of a particular discipline. Baseline fitness and trainability should also be considered separately. Aerobic, resistance, and combined exercise programs have produced measurable improvements in physical capacity in PLWH, including individuals receiving ART [6-9]. Thus, a group-level difference in baseline cardiorespiratory fitness or strength does not necessarily imply a proportionately impaired response to exercise training. The aim of this narrative review is to examine the effects of chronic HIV infection and ART on exercise capacity and physical performance, with particular attention to cardiorespiratory fitness, muscular function, mitochondrial physiology, body composition, treatment-related effects, fatigue, and recovery. A further objective is to examine how far findings obtained predominantly from general clinical populations can reasonably be extrapolated to competitive athletes.

2. Methods

This narrative review synthesizes evidence from contemporary HIV treatment guidelines, sports-medicine consensus statements, systematic reviews and meta-analyses, randomized controlled trials, comparative observational studies, and selected mechanistic investigations relevant to exercise physiology and physical performance in people living with HIV. Particular attention was given to studies reporting cardiorespiratory fitness, peak or maximal oxygen uptake, exercise tolerance, muscular strength, body composition, mitochondrial function, fatigue, cardiovascular and metabolic outcomes, CD4 cell count, HIV RNA, and exercise safety. Evidence from earlier treatment eras was interpreted in relation to the antiretroviral regimens used at the time rather than being assumed to represent contemporary ART. More recent studies were given particular relevance when considering current treatment strategies and treatment-associated changes in body composition.

3. Results

3.1. Cardiorespiratory Fitness

Cardiorespiratory fitness is among the most frequently investigated objective measures of exercise capacity in HIV. Peak oxygen uptake reflects the integrated ability to deliver and utilize oxygen during exercise and is particularly relevant to endurance performance. In the systematic review and meta-analysis by Gomes-Neto et al., aerobic capacity was significantly lower in PLWH than in HIV-negative controls. The analysis included 30 studies, 2,161 participants with HIV, and 2,148 controls. The pooled difference in peak VO_2 was 8.4 (95% CI, 4.8-12.0) in favor of the control groups. Lower-body strength was also lower in PLWH, with a pooled difference of 1.07 (95% CI, 0.29-1.84) [2]. The authors graded the evidence supporting these differences as moderate quality. The pooled estimates nevertheless arose from a heterogeneous evidence base. Exercise-testing procedures varied between studies, as did age, ART exposure, baseline activity, disease characteristics, and comorbidity burden. The meta-analysis therefore supports the presence of lower average fitness in studied HIV populations but cannot determine the expected magnitude of any difference in a trained competitive athlete. Vancampfort et al. examined cardiorespiratory fitness from a somewhat different perspective by assessing its level and potential moderators within HIV populations. Their meta-analysis included 21 studies and 1,010 PLWH, with a pooled fitness estimate of approximately 26.4 mL/kg/min (95% CI, 24.6-28.1). Older age, higher

body mass index, and lipodystrophy were associated with poorer cardiorespiratory fitness, whereas higher CD4 cell counts were associated with better fitness [10]. The authors also emphasized that the available evidence was insufficient for a reliable pooled comparison with HIV-negative controls [10]. This limitation is particularly relevant when moving from clinical exercise physiology to sport. A cohort of relatively inactive adults, some with chronic comorbidities, differs substantially from a highly trained population in baseline VO_2peak, body composition, training history, and physiological reserve. Group-level estimates from such cohorts should therefore not be converted directly into an expected percentage loss of performance in an athlete. Conversely, high baseline aerobic capacity should not lead clinicians to attribute every subsequent decline in performance to training alone. New exercise intolerance in an athlete with HIV may result from cardiovascular or pulmonary disease, anemia, musculoskeletal injury, inadequate recovery, sleep disturbance, medication-related effects, nutritional problems, or excessive training load. HIV status forms part of that clinical context but is not, by itself, an explanation.

3.2. Muscular Strength and Functional Performance

Muscular strength contributes to acceleration, sprinting, jumping, resistance exercise, collision tolerance, and repeated force production. Several studies suggest that deficits in muscle function can occur in PLWH, although the magnitude and even the presence of such differences depend strongly on the population and method of assessment. Oliveira et al. compared 44 adults with HIV receiving ART with 25 matched HIV-negative controls. Among men, total dynamic strength assessed by one-repetition maximum was lower in the HIV group than in controls (262.5 versus 357.2 kg), with lower values in the bench press, leg press, and arm curl. Comparable group differences were not observed among women, and lean body mass did not differ significantly between the HIV and control groups [11]. The cross-sectional design and relatively small sample do not allow a causal explanation for the lower strength observed among the male participants. The study is more appropriately interpreted as evidence that reduced muscular performance can be present in some ART-treated adults even when a clear difference in overall lean body mass is not detectable. Functional testing provides a related, but not identical, perspective. Richert et al. examined 324 adults with HIV from the ANRS CO3 Aquitaine Cohort. Median age was 48 years and 89% were receiving ART. Poor performance on the five-times sit-to-stand test was identified in 53% of participants. Longer duration since HIV diagnosis was associated with poorer performance, whereas ART use itself was not associated with this outcome [12]. For sports medicine, the distinction between functional limitation and athletic performance is essential. A sit-to-stand test evaluates an aspect of lower-limb functional capacity but does not measure sprint speed, maximal force, rate of force development, or sport-specific power. It nevertheless illustrates that measurable functional limitations can persist in some treated HIV populations. Body composition adds further complexity. In a systematic review and meta-analysis of 41 studies involving 5,532 PLWH and 2,986 HIV-negative participants, Guimarães et al. found that muscle mass was approximately 0.21 standard deviations lower in PLWH [13]. Estimates of sarcopenia prevalence varied markedly according to the definition used: 30.3% when low muscle mass alone was considered, compared with 4.5% when both low muscle mass and low strength were required [13]. This variation is particularly relevant in an athletic setting. Muscle mass, maximal strength, relative strength, muscular endurance, and power are related but distinct characteristics. None can be inferred reliably from another in isolation, and a single body-composition measure should not be treated as a surrogate for overall athletic capacity.

3.3. Mitochondrial Function and Oxidative Metabolism

Mitochondrial physiology has attracted particular attention in HIV because oxidative phosphorylation is central to sustained exercise and because several older antiretroviral agents were associated with mitochondrial toxicity. Gardner et al. reviewed laboratory, animal, and human evidence concerning mitochondrial pathology associated with HIV treatment. Selected NRTIs were linked with inhibition of mitochondrial DNA polymerase-γ, depletion of mitochondrial DNA, and a range of related abnormalities [3]. Clinically described manifestations included myopathy, neuropathy, and lipodystrophy. Treatment toxicity, however, does not provide a complete explanation. Maagaard and Kvale reviewed evidence of mitochondrial abnormalities in both untreated HIV infection and patients receiving ART [4]. Their analysis suggests that infection-related and treatment-related mechanisms may overlap, making a simple separation into exclusively "HIV-related" and "drug-related" mitochondrial dysfunction difficult to sustain. Direct physiological studies have produced a similarly mixed picture. Røge et al. examined eight HIV-positive patients receiving highly active ART who had lipodystrophy or elevated plasma lactate and compared them with eight HIV-negative controls. Maximum workload was lower in the HIV group (171 versus 235 W, $P = 0.05$). Maximum oxygen consumption was also numerically lower, but the difference did not reach statistical significance (2,136 versus 2,985 mL/min, $P = 0.11$). Several skeletal-muscle oxidative enzymes and metabolic substrates did not differ significantly between groups [14]. Given the small and clinically selected sample, these results cannot support a simple model in which antiretroviral mitochondrial toxicity alone explains reduced exercise tolerance. They instead illustrate the difficulty of linking cellular abnormalities directly to whole-body performance. Cade et al. examined another component of oxygen transport. In 45 physically active participants divided among HIV-positive individuals taking HAART, HIV-positive individuals not taking HAART, and HIV-negative controls, peak arteriovenous oxygen difference was lower in the HAART group. Peak VO_2 itself, however, did not differ significantly among the three groups [15]. The distinction matters. The study provides evidence of altered peripheral oxygen extraction under the conditions investigated, but it does not demonstrate that HAART produced a significant reduction in maximal whole-body oxygen uptake. Using it as direct evidence of reduced peak VO_2 would therefore exceed the reported findings. Ortmeyer et al. reported additional evidence of altered skeletal-muscle metabolism in 10 older HIV-positive men receiving ART compared with eight age-matched controls. β-hydroxyacyl-CoA dehydrogenase and citrate synthase activities were 38% and 77% lower, respectively, in the HIV group. Hydrogen peroxide and oxidized cardiolipin were 1.4-fold and 1.8-fold higher, while VO_2peak normalized to fat-free mass was approximately 33% lower. Aerobic capacity was also related to several mitochondrial enzyme and oxidative-stress measures [16]. These observations suggest an association between altered skeletal-muscle mitochondrial biology and aerobic capacity in the selected population studied. They cannot establish mitochondrial dysfunction as the principal cause of reduced exercise capacity, particularly given the small, cross-sectional sample restricted to older men.

3.4. Mitochondrial Response to Exercise Training

The identification of mitochondrial abnormalities raises a separate question: whether cellular responses to training are preserved to the same degree in people with HIV. Jankowski et al. evaluated skeletal-muscle mitochondrial responses before and after 24 weeks of exercise in 18 older adults with HIV receiving ART and 21 HIV-negative controls. Several measures related to mitochondrial adaptation, including citrate synthase, manganese superoxide dismutase, PGC-1α, and complex IV, showed greater exercise-associated changes in the

control group [17]. One interpretation is that selected molecular adaptations to exercise may be attenuated in some older adults with HIV. This should not be equated with failure to respond functionally to training. Cellular remodeling and changes in whole-body strength, fitness, or physical function occur at different physiological levels and need not change in parallel. The population studied also limits extrapolation to competitive sport. Participants were older and the samples were small. Whether younger, highly trained athletes receiving contemporary ART display comparable differences in mitochondrial adaptation remains unknown.

3.5. Contemporary Antiretroviral Therapy and Body Composition

Findings from the early ART era should not automatically be used to describe the physiological effects of treatment today. Current guidelines favor highly effective contemporary regimens, most commonly involving second-generation INSTIs in treatment-naïve adults [1]. These regimens differ considerably from combinations used in many early studies of mitochondrial toxicity. Weight gain after ART initiation has consequently emerged as a more contemporary area of interest. Bourgi et al. analyzed 32,514 treatment-naïve adults in North American cohorts. At two years, predicted mean weight gain was 4.9 kg among those initiating INSTI-based therapy, 4.7 kg among those receiving protease inhibitor-based therapy, and 2.7 kg among those receiving NNRTI-based treatment. Among the INSTIs assessed, predicted mean weight gain was highest with bictegravir at 6.9 kg and dolutegravir at 5.3 kg [5]. These observations concern body weight rather than athletic performance. The cohort did not evaluate VO_2peak, maximal strength, power, movement economy, or competition results. It would therefore be inappropriate to interpret the association between ART regimen and weight change as direct evidence that contemporary ART impairs sport performance. Even so, body composition can matter substantially in sport. Additional mass may alter relative aerobic capacity or movement economy in endurance and weight-bearing disciplines, whereas the same change may have different implications in strength, power, or collision sports. The composition of the gained mass is also relevant. At present, however, these remain physiologically plausible considerations rather than demonstrated consequences of ART-associated weight gain in athletes. The contribution of medication is unlikely to be isolated from other determinants. Guaraldi et al. followed 281 ART-experienced, INSTI-naive PLWH for approximately 4.2 years. The population-attributable fraction for significant weight gain was 45% for high baseline BMI and 32% for lower physical activity. The corresponding estimate for switching to an INSTI was 11% and was not statistically significant [18]. Rather than contradicting the broader literature on weight gain with contemporary ART, these findings emphasize its multifactorial nature. Medication exposure, baseline body composition, physical activity, energy intake, and other characteristics may interact in shaping long-term weight trajectories.

3.6. Resistance Exercise, Muscle Strength and Body Composition

Among exercise interventions, resistance training provides relatively consistent evidence of improvements in measurable muscular outcomes. Zanetti et al. conducted a systematic review and meta-analysis of seven randomized controlled trials involving 258 PLWH. Compared with no-exercise conditions, resistance training increased bench-press strength by 10.69 kg (95% CI, 3.44-17.93) and squat strength by 22.66 kg (95% CI, 7.82-37.50). Lean body mass increased by 2.96 kg (95% CI, 0.98-4.94), while fat mass decreased by 2.67 kg (95% CI, −4.95 to −0.39) [19]. These results indicate that PLWH can gain strength and improve body-composition measures in response to resistance exercise. They should not, however, be interpreted as evidence that resistance training necessarily normalizes performance relative to HIV-negative athletes. Participants were not specifically elite competitors, and protocols differed in duration, intensity, and exercise prescription. The meta-analysis also

reported an increase in CD4 cell count of approximately 100 cells/mm³ [19]. This is an immunological outcome rather than a measure of sport performance. It should therefore remain separate from conclusions about competitive capacity, and resistance training should not be presented as a substitute for effective ART.

3.7. Aerobic and Combined Exercise Training

Evidence that structured exercise can improve cardiorespiratory fitness in PLWH is relatively consistent across several forms of training. The updated Cochrane review by O'Brien et al. included 14 randomized trials and concluded that aerobic exercise, either alone or in combination with progressive resistance exercise, appears safe and may improve cardiopulmonary fitness, body composition, and psychological well-being in adults living with HIV [6]. At the same time, the authors highlighted limitations of the evidence base, including small samples and substantial withdrawal rates in several trials. Gomes-Neto et al. evaluated combined aerobic and resistance exercise in a systematic review and meta-analysis of seven controlled studies. Compared with no exercise, combined training increased peak VO_2 by 4.48 mL/kg/min (95% CI, 2.95-6.0). Knee-extensor strength improved by 25.06 kg (95% CI, 10.46-39.66), while elbow-flexor strength increased by 4.44 kg (95% CI, 1.22-7.67) [7]. A later network meta-analysis included 40 randomized trials involving 1,518 PLWH. Combined aerobic and resistance exercise ranked highest among the evaluated interventions for improvement in peak VO_2, with an estimated difference corresponding to 4.2 mL/kg/min (95% CI, 2.5-5.9) compared with usual care [8]. The ranking is informative but should not be treated as definitive proof that combined exercise is universally superior. Network meta-analysis incorporates indirect as well as direct comparisons, and the underlying interventions varied in frequency, duration, intensity, and supervision. Evidence from individual trials broadly points in the same direction. Pedro et al. investigated a 16-week concurrent training program in ART-treated PLWH, with aerobic and resistance exercise performed three times per week. Improvements in peak oxygen uptake and peak speed were reported, although only 33 participants were included in the final analysis [9]. The relatively small final sample limits precision, but the trial is consistent with the broader conclusion that ART-treated PLWH can improve cardiorespiratory fitness through structured exercise.

3.8. Exercise Intensity and High-Intensity Training

For competitive athletes, the question extends beyond whether exercise is beneficial. Training volume, intensity, repeated exposure to high workloads, and the ability to recover between sessions are equally important. Erlandson et al. studied sedentary adults aged 50-75 years with and without HIV. Following 12 weeks of moderate-intensity exercise, participants either remained at moderate intensity or progressed to a higher-intensity program for a further 12 weeks. Physical function improved among participants with HIV, and progression to higher intensity produced additional gains in selected measures of strength. Bench-press strength improved by approximately 6% more and leg-press strength by approximately 10% more than with continued moderate-intensity training [20]. The study shows that selected older adults with HIV were able to progress to a more intensive supervised exercise program and continue to improve selected functional and strength outcomes. Its implications should remain within those boundaries. The intervention does not establish either the safety or superiority of high-volume, high-intensity training in competitive athletes, whose training may involve repeated maximal efforts, substantially greater weekly loads, frequent competition, travel, and restricted recovery. Accordingly, the available clinical evidence is reassuring with regard to progressive exercise in appropriately selected individuals, but it does not define an upper physiological limit for training in athletes with HIV.

Exercise intensity should therefore be considered alongside symptoms, comorbidities, functional capacity, previous training exposure, and recovery rather than being inferred from HIV status alone.

3.9. Immune and Virological Control

Exercise-related physiological stress has historically raised concerns about immune function in people with HIV. Available evidence does not indicate that appropriately prescribed exercise worsens HIV control in clinically stable individuals. WHO guidelines on physical activity and sedentary behaviour recommend regular physical activity for adults living with chronic conditions, including HIV. The evidence reviewed in those guidelines supports improvements in physical fitness and mental health without indication of adverse effects on CD4 count, viral load, or disease progression [21]. The Cochrane review similarly concluded that aerobic exercise appears safe in adults living with HIV, while acknowledging the limitations created by heterogeneous methods, relatively small trials, and participant withdrawal [6]. Poton and Polito analyzed 12 randomized controlled trials involving 438 PLWH. Aerobic training was associated with improvements in VO_2max and CD4 cell count, whereas the metabolic outcomes examined did not show consistent significant effects [22]. CD4 cell count provides information about immune status but does not measure athletic performance. Likewise, maintenance of viral suppression does not demonstrate normal cardiorespiratory fitness, strength, or recovery. Exercise should therefore be viewed as complementary to HIV treatment. Sustained virological suppression depends primarily on effective ART and adherence rather than on exercise itself [1].

3.10. Cardiovascular and Metabolic Considerations

Cardiovascular risk and abnormalities of body-fat distribution have long been recognized as clinically relevant in people living with HIV. Earlier literature described interactions among HIV infection, antiretroviral exposure, altered fat distribution, metabolic abnormalities, and cardiovascular risk [23]. Although current treatment differs substantially from regimens used during that period, cardiovascular and metabolic assessment remains relevant when an athlete or physically active person develops otherwise unexplained exercise intolerance. A decline in sport performance should not automatically be attributed to HIV or ART. Cardiovascular and pulmonary disease, anemia, metabolic disorders, musculoskeletal injury, sleep problems, inadequate nutrition, and excessive training load can all reduce exercise capacity. The diagnostic approach should therefore remain broad. The distinction between surrogate physiological outcomes and clinical endpoints is similarly important. HIV-specific exercise studies commonly report VO_2peak, muscular strength, body composition, blood lipids, or other intermediate measures. Such variables may be clinically useful, but they are not equivalent to myocardial infarction, stroke, hospitalization, or mortality. An exercise-induced improvement in aerobic fitness, for example, should not be described as direct proof that cardiovascular events have been prevented. A comparable principle applies to body weight. The sporting consequences of additional mass may be minor in one discipline and meaningful in another. Without studies designed specifically around athletic outcomes, the direct effect of contemporary ART-associated weight gain on competitive performance remains uncertain.

3.11. Fatigue, Pain and Recovery

Fatigue remains a frequently reported barrier to physical activity among PLWH and may have particular relevance to competitive athletes, whose training depends on the ability to reproduce high-quality performance over repeated sessions. A systematic review of qualitative studies identified fatigue, pain, and broader health-related problems among barriers to participation in physical activity [24]. Fatigue itself is a nonspecific symptom. Depending on the individual, it may coexist with sleep disturbance, psychological symptoms, anemia,

medication effects, chronic disease, pain, nutritional inadequacy, or deconditioning. Recovery in competitive sport, however, is not identical to the ability to complete an isolated exercise session. An athlete may tolerate one demanding training bout but experience difficulty maintaining the same quality of performance when comparable loads are repeated across consecutive days or combined with competition. Direct evidence concerning recovery kinetics in athletes living with HIV is sparse. Most intervention studies involve a limited number of structured sessions per week over relatively short periods [8,20]. They therefore do not reproduce the accumulated stress of a full competitive training schedule. It remains uncertain whether chronic HIV infection or contemporary ART meaningfully modifies recovery from repeated maximal exercise, susceptibility to functional overreaching, or risk of overtraining syndrome. At present, these questions cannot be answered confidently by extrapolating from short-term clinical exercise interventions and require athlete-specific longitudinal research.

3.12. Ageing and Athletic Longevity

Ageing introduces an additional dimension to physical performance in HIV. Systematic evidence indicates that lower muscle mass and sarcopenia are relevant concerns in PLWH [13], while functional limitations have also been documented in clinical cohorts [12]. These issues may be especially relevant to masters athletes, in whom age-related physiological changes occur alongside long-term HIV infection and potentially prolonged exposure to different generations of ART. Importantly, older adults with HIV remain responsive to exercise. Structured programs can improve physical function and strength, and selected individuals have tolerated progression toward higher-intensity training [20]. At the cellular level, however, Jankowski et al. observed a less pronounced response in several markers of mitochondrial adaptation compared with HIV-negative controls [17]. These findings are not necessarily contradictory. Improvements in functional performance can occur even when selected molecular adaptations differ between groups. The available research simply does not establish how such cellular observations translate into long-term sport performance. Evidence concerning athletic longevity remains particularly limited. There are few direct data on masters athletes living with HIV who continue to compete at high levels in endurance, strength, power, or mixed-demand sports. Long-term conclusions about the interaction between HIV, ART, ageing, and sustained competitive performance therefore remain premature.

3.13. Home- and Community-Based Exercise

Structured exercise does not always require continuous specialist supervision, an issue with practical implications for rehabilitation, travel, and periods in which access to usual training facilities is limited. Aminde et al. reviewed minimally supervised home- and community-based exercise interventions involving 857 PLWH across 13 studies. These programs were associated with improvements in physical activity, step count, body fat, and the physical component of quality of life. No adverse events were reported in the included studies [25]. The findings support the feasibility of less intensively supervised exercise in the populations studied. They should not be interpreted as evidence of improved competitive performance, because participants were not selected as athletes and the interventions varied substantially. Their principal relevance to sports medicine lies in demonstrating that continuity of physical activity and exercise can be maintained outside highly supervised settings.

4. Implications for Competitive Athletes and Sports Medicine

Current evidence provides substantially more information about responsiveness to exercise than about the maximum performance potential of an athlete living with HIV. Most studies have enrolled clinically stable adults rather than competitive or elite athletes. This distinction is not trivial. Highly trained athletes differ in

baseline VO_2peak, muscle mass, training history, nutritional status, recovery strategies, and exposure to repeated high-intensity work. A physiological observation from a sedentary or moderately active clinical cohort cannot simply be transferred to professional sport. Evaluation of an individual athlete should therefore begin with the actual performance problem rather than HIV status alone. A decline in endurance, loss of strength, reduced repeated-sprint ability, unexplained weight change, or persistent fatigue may each have different underlying mechanisms. HIV infection and ART belong in the clinical history, but neither should automatically be assumed to account for the change. The choice of assessment should reflect the demands of the sport and the athlete's symptoms. Cardiopulmonary exercise testing may be particularly informative when unexplained exercise intolerance or loss of endurance is the main concern. Strength or power testing may be more relevant in other disciplines. When body weight has changed, assessment of body composition may help distinguish changes in adipose tissue from changes in lean tissue. Results need to be interpreted against the athlete's own longitudinal performance whenever such data are available. Training load deserves comparable attention. Competitive athletes may train on most days of the week, combine sport-specific work with strength and conditioning sessions, and compete under congested schedules. This environment differs markedly from most clinical exercise trials in HIV. There is therefore insufficient evidence to define an HIV-specific optimal relationship between training load, recovery, and performance. Persistent fatigue also requires a broad approach. Sleep, nutrition, psychological health, anemia, cardiovascular or pulmonary disease, musculoskeletal problems, medication-related effects, and overall training load may all be relevant. The presence of HIV should inform the assessment, not prematurely end it. Sport-specific physiology further complicates extrapolation. Endurance athletes may be more sensitive to changes in relative VO_2peak, body mass, and movement economy. Strength and power athletes rely more heavily on maximal force, rate of force development, and preservation of lean mass. Team- and racket-sport athletes combine aerobic requirements with repeated high-intensity efforts and short recovery periods. At present, direct evidence is insufficient to conclude that athletes in any of these categories consistently experience an HIV-specific performance disadvantage.

4.1. Exercise Intensity and Participation in Sport

Available evidence and current guidance do not support automatic restriction of exercise solely because an individual has HIV, provided that the person is clinically stable and otherwise suitable for the intended activity [20,21,26]. Erlandson et al. showed that selected older adults with HIV could progress toward higher-intensity exercise and continue to improve physical function and strength [20]. The limits of that evidence remain important. A supervised intervention in previously sedentary older adults is not equivalent to an elite training environment. The study does not validate unrestricted high-intensity or high-volume training in competitive athletes, nor does it define the amount of recovery required after repeated maximal efforts. Participation in sport itself is also addressed by sports-medicine guidance. The AMSSM position statement reports that confirmed transmission of blood-borne pathogens during sporting participation is exceedingly rare and that there are no well-documented reports of HIV transmission occurring during sport. Appropriate standard precautions remain recommended for health professionals and sports personnel [26]. Notably, the same position statement identifies the effects of long-term intense training and treatment therapies in athletes with blood-borne infections as areas in need of further investigation [26]. This reflects one of the central limitations of the present evidence base: participation in sport is much better supported than conclusions about the physiological consequences of many years of elite-level training.

5. Discussion

The available literature presents a more complex picture than a simple comparison between HIV-positive and HIV-negative individuals. At the population level, PLWH may show lower cardiorespiratory fitness, muscular strength, and functional performance in some cohorts, yet structured exercise can still produce clinically meaningful improvements in several of these domains [2,6-9]. The distinction between baseline capacity and trainability is therefore fundamental. Lower baseline VO_2peak does not imply an inability to improve with training. Similarly, reports of lower strength in selected HIV cohorts cannot be translated directly into an assumption that a competitive athlete with HIV will develop a performance-limiting strength deficit. The mechanisms underlying group-level differences in physical capacity remain incompletely defined and are unlikely to be explained by a single pathway. Disease-related factors, chronic immune and metabolic changes, body composition, cardiovascular health, physical inactivity, and historical ART toxicity may contribute to different degrees in different individuals. Mitochondrial research illustrates this uncertainty particularly well. Røge et al. observed lower maximal workload in a selected treated population, but maximum oxygen consumption did not differ significantly and several measures of skeletal-muscle metabolism were similar between groups [14]. Cade et al. reported lower peak peripheral oxygen extraction in HAART-treated participants while finding no significant difference in peak VO_2 [15]. Ortmeyer et al. demonstrated associations among altered mitochondrial enzyme activity, oxidative stress, and aerobic capacity, but their HIV group consisted of only 10 older men [16]. Together, these studies make mitochondrial physiology biologically relevant to the discussion of exercise capacity in HIV, but they do not support a straightforward causal sequence from ART exposure to mitochondrial dysfunction and then to impaired athletic performance. Interpretation of the ART literature requires similar caution. Mitochondrial toxicity associated with selected older NRTIs is well described [3,4], but current treatment regimens differ substantially from those used in many early physiological studies. More recent attention has shifted toward body-composition changes and weight gain associated with some contemporary regimens [5]. The importance of such weight changes for athletes is still uncertain. Body weight is not itself a performance outcome, and observational associations between ART regimens and weight trajectories cannot establish a causal effect on competition results. The findings of Guaraldi et al. also suggest that baseline BMI and physical activity contribute substantially to weight gain [18]. For clinical sports medicine, a change in weight is therefore more informative when considered together with body composition, aerobic fitness, muscular performance, and the requirements of the relevant discipline. The practical question is not simply whether body mass increased, but whether the underlying physiological change is meaningful for health, function, or sport performance. Evidence concerning exercise interventions is more consistent. Meta-analyses support improvements in peak VO_2, muscular strength, and body-composition outcomes after aerobic, resistance, or combined training [7,8,19], while randomized trial evidence provides broadly concordant findings [9]. Available studies also do not indicate that appropriately prescribed exercise worsens viral suppression or CD4 status in clinically stable individuals [6,21,22]. Higher-intensity exercise is somewhat less well characterized. Erlandson et al. demonstrated that selected older, previously sedentary adults with HIV could progress to more intensive training and achieve additional improvements in some strength measures [20]. This is encouraging but cannot establish either the safety or superiority of high-volume, high-intensity programs in competitive athletes. The distinction between an absence of demonstrated harm in available trials and evidence of safety under all

competitive conditions is important. Current literature supports participation in exercise for clinically stable PLWH, but it does not define the physiological limits of professional or elite sport. This remains the major evidence gap. Most exercise studies in HIV do not recruit elite competitors, use sport-specific performance endpoints, monitor full competitive seasons, quantify long-term external and internal training load, or measure recovery after repeated maximal exercise. Consequently, the literature tells us considerably more about health-related fitness and exercise responsiveness than about elite competitive performance. Surrogate outcomes must also remain conceptually separate. VO_2peak, muscular strength, body composition, and CD4 count each provide useful information, but they answer different questions. An increase in VO_2peak indicates improved aerobic fitness, it does not prove prevention of cardiovascular events. An increase in CD4 cell count does not establish improved athletic performance. Likewise, a reduction in fat mass cannot be assumed to improve competition results independently of the sport and athlete involved. An individualized approach therefore remains the most defensible. In a clinically stable athlete, training and competition decisions should reflect actual functional capacity, symptoms, cardiovascular and metabolic health, muscular performance, body composition, treatment exposure, training history, and recovery. HIV status is an important component of medical assessment but should not function as a substitute for it. Sports-medicine guidance is broadly consistent with this approach. The AMSSM position statement does not support routine exclusion from sport on the basis of blood-borne pathogen status and emphasizes standard precautions together with individualized assessment [26]. At the same time, it acknowledges the limited evidence concerning long-term intense training and treatment-related effects in infected athletes. Several research priorities follow. Prospective studies should recruit competitive and elite athletes receiving contemporary ART and follow them across full training and competition cycles. Sport-specific performance measures should be assessed alongside VO_2peak, maximal and explosive strength, body composition, training load, sleep, fatigue, and recovery. Longitudinal designs would also help distinguish stable between-person differences from true within-athlete changes over time. The central question has therefore evolved. There is substantial evidence that clinically stable PLWH can participate in structured exercise and improve multiple components of physical fitness. What remains unclear is how chronic HIV infection and contemporary ART interact with the much greater physiological demands of long-term high-level training and competitive sport.

6. Conclusions

At the population level, chronic HIV infection is associated in a number of studies with lower cardiorespiratory fitness, muscular strength, and functional performance. The magnitude and clinical relevance of these differences vary considerably between populations. Age, body composition, physical activity, comorbidities, duration and characteristics of HIV infection, and immunological status may all contribute. These observations should not be interpreted as evidence that HIV inevitably limits athletic performance. Historical antiretroviral regimens, particularly selected NRTIs, were associated with mitochondrial and metabolic toxicity. Such findings remain important when interpreting earlier cohorts but should not be generalized indiscriminately to athletes receiving contemporary ART. Modern treatment has a different pharmacological profile, although treatment-associated weight gain has emerged as a relevant clinical issue. At present, direct evidence linking contemporary ART-associated weight gain to impaired athletic performance is lacking. Aerobic, resistance, and combined exercise can improve several objective measures of physical capacity in PLWH. Available evidence does not suggest that appropriately prescribed exercise adversely affects HIV virological or immunological control. In

clinically stable individuals, current evidence and sports-medicine guidance do not support automatic restriction of exercise solely because of HIV status. This should not be interpreted as proof that every level of high-intensity or high-volume training has been specifically validated in athletes with HIV. Sports-medicine assessment should therefore remain individualized. Cardiorespiratory fitness, muscular performance, body composition, cardiovascular and metabolic health, symptoms, medication exposure, training load, and recovery should be considered when making decisions about training and competition. The principal unresolved questions are athlete-specific. Evidence remains insufficient concerning very high training volumes, repeated maximal exercise, recovery kinetics, overreaching, overtraining, and long-term sport-specific performance in competitive athletes living with HIV and receiving contemporary ART. Prospective research in athletic populations is needed before firm conclusions can be drawn about the interaction between chronic HIV infection, modern treatment, and elite sporting performance.

Disclosure

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References

1. Panel on Antiretroviral Guidelines for Adults and Adolescents. What to Start: Initial Combination Antiretroviral Regimens for People With HIV. Bethesda (MD): National Institutes of Health; 2024. Available from: https://clinicalinfo.hiv.gov/en/guidelines/hiv-clinical-guidelines-adult-and-adolescent-arv/what-start-initial-combination-regimens. Accessed September 9, 2026.
2. Gomes-Neto M, Rodriguez I, Lédo AP, Vieira JP, Brites C. Muscle strength and aerobic capacity in HIV-infected patients: a systematic review and meta-analysis. J Acquir Immune Defic Syndr. 2018;79(4):491-500. https://doi.org/10.1097/QAI.0000000000001835.
3. Gardner K, Hall PA, Chinnery PF, Payne BAI. HIV treatment and associated mitochondrial pathology: review of 25 years of in vitro, animal, and human studies. Toxicol Pathol. 2014;42(5):811-822. https://doi.org/10.1177/0192623313503519.
4. Maagaard A, Kvale D. Mitochondrial toxicity in HIV-infected patients both off and on antiretroviral treatment: a continuum or distinct underlying mechanisms? J Antimicrob Chemother. 2009;64(5):901-909. https://doi.org/10.1093/jac/dkp316.
5. Bourgi K, Bian A, Boyd L, Gupta SK, Cohen C, Lee JC, Sterling TR, Moore RD, Lesko C, Lake JE, Yendewa GA, Horberg MA, Silverberg MJ, Palella FJ Jr, Althoff K, Margolick J, Rebeiro PF, Koethe JR. Weight gain on contemporary integrase strand transfer inhibitors and tenofovir alafenamide in persons with HIV starting antiretroviral therapy in the United States and Canada. J Infect Dis. 2026 May 29:jiag271. https://doi.org/10.1093/infdis/jiag271.
6. O'Brien K, Nixon S, Tynan AM, Glazier R. Aerobic exercise interventions for adults living with HIV/AIDS. Cochrane Database Syst Rev. 2022;(3):CD001796. https://doi.org/10.1002/14651858.CD001796.pub3.
7. Gomes Neto M, Conceição CS, Carvalho VO, Brites C. Effects of combined aerobic and resistance exercise on exercise capacity, muscle strength and quality of life in HIV-infected patients: a systematic review and meta-analysis. PLoS One. 2015;10(9):e0138066. https://doi.org/10.1371/journal.pone.0138066.

8. Gomes-Neto M, Saquetto MB, Alves IG, Martinez BP, Vieira JP, Brites C. Effects of exercise interventions on aerobic capacity and health-related quality of life in people living with HIV/AIDS: systematic review and network meta-analysis. Phys Ther. 2021;101(7):pzab092. https://doi.org/10.1093/ptj/pzab092.
9. Pedro RE, Guariglia DA, Okuno NM, Deminice R, Peres SB, Moraes SMF. Effects of 16 weeks of concurrent training on resting heart rate variability and cardiorespiratory fitness in people living with HIV/AIDS using antiretroviral therapy: a randomized clinical trial. J Strength Cond Res. 2016;30(12):3494-3502. https://doi.org/10.1519/JSC.0000000000001454.
10. Vancampfort D, Mugisha J, Rosenbaum S, Firth J, De Hert M, Probst M, Stubbs B. Cardiorespiratory fitness levels and moderators in people with HIV: a systematic review and meta-analysis. Prev Med. 2016;93:106-114. https://doi.org/10.1016/j.ypmed.2016.10.001.
11. Oliveira VHF, Wiechmann SL, Narciso AMS, Webel AR, Deminice R. Muscle strength is impaired in men but not in women living with HIV taking antiretroviral therapy. Antivir Ther. 2018;23(1):11-19. https://doi.org/10.3851/IMP3159.
12. Richert L, Dehail P, Mercié P, Dauchy FA, Bruyand M, Greib C, Dabis F, Bonnet F, Chêne G. High frequency of poor locomotor performance in HIV-infected patients. AIDS. 2011;25(6):797-805. https://doi.org/10.1097/QAD.0b013e3283455dff.
13. Guimarães NS, Raposo MA, Greco D, Tupinambás U, Premaor MO. People living with HIV, lean mass, and sarcopenia: a systematic review and meta-analysis. J Clin Densitom. 2022;25(1):113-123. https://doi.org/10.1016/j.jocd.2021.03.004.
14. Røge BT, Calbet JAL, Møller K, Ullum H, Hendel HW, Gerstoft J, Pedersen BK. Skeletal muscle mitochondrial function and exercise capacity in HIV-infected patients with lipodystrophy and elevated p-lactate levels. AIDS. 2002;16(7):973-982. https://doi.org/10.1097/00002030-200205030-00003.
15. Cade WT, Fantry LE, Nabar SR, Shaw DK, Keyser RE. A comparison of $\dot{Q}T$ and a-vO_2 in individuals with HIV taking and not taking HAART. Med Sci Sports Exerc. 2003;35(7):1108-1117. https://doi.org/10.1249/01.MSS.0000074567.61400.93.
16. Ortmeyer HK, Ryan AS, Hafer-Macko C, Oursler KK. Skeletal muscle cellular metabolism in older HIV-infected men. Physiol Rep. 2016;4(9):e12794. https://doi.org/10.14814/phy2.12794.
17. Jankowski CM, Wilson MP, MaWhinney S, Reusch J, Knaub L, Hull S, Erlandson KM. Blunted muscle mitochondrial responses to exercise training in older adults with HIV. J Infect Dis. 2021;224(4):679-683. https://doi.org/10.1093/infdis/jiaa799.
18. Guaraldi G, Milic J, Bacchi E, Carli F, Menozzi M, Franconi I, Raimondi A, Ciusa G, Masi V, Belli M, Guaraldi S, Aprile E, Mancini M, Mussini C, Lake JE, Erlandson KM. Contribution of integrase inhibitor use, body mass index, physical activity and caloric intake to weight gain in people living with HIV. HIV Res Clin Pract. 2022;24(1):1-6. https://doi.org/10.1080/25787489.2022.2150815.
19. Zanetti HR, Lopes LTP, Gonçalves A, Soares VL, Soares WF, Hernandez AV, Tse G, Liu T, Biondi-Zoccai G, Roever L, Mendes EL. Effects of resistance training on muscle strength, body composition and immune-inflammatory markers in people living with HIV: a systematic review and meta-analysis of randomized controlled trials. HIV Res Clin Pract. 2021;22(5):119-127. https://doi.org/10.1080/25787489.2021.1975448.

20. Erlandson KM, MaWhinney S, Wilson M, Gross L, McCandless SA, Campbell TB, Kohrt WM, Schwartz R, Brown TT, Jankowski CM. Physical function improvements with moderate or high-intensity exercise among older adults with or without HIV infection. AIDS. 2018;32(16):2317-2326. https://doi.org/10.1097/QAD.0000000000001984.
21. World Health Organization. WHO Guidelines on Physical Activity and Sedentary Behaviour. Geneva: World Health Organization; 2020.
22. Poton R, Polito MD. The effects of aerobic training on the CD4 cells, VO_2max, and metabolic parameters in HIV-infected patients: a meta-analysis of randomized controlled trials. J Sports Med Phys Fitness. 2020;60(4):634-642. https://doi.org/10.23736/S0022-4707.19.10261-7.
23. Grinspoon S, Carr A. Cardiovascular risk and body-fat abnormalities in HIV-infected adults. N Engl J Med. 2005;352(1):48-62. https://doi.org/10.1056/NEJMra041811.
24. Song D, Hightow-Weidman L, Yang Y, Wang J. Barriers and facilitators of physical activity in people living with HIV: a systematic review of qualitative studies. J Int Assoc Provid AIDS Care. 2024;23:23259582241275819. https://doi.org/10.1177/23259582241275819.
25. Aminde JAAA, Burton NW, Thng C, Clanchy K. A systematic review and meta-analysis evaluating the effectiveness of minimally supervised home and community exercise interventions in improving physical activity, body adiposity and quality of life in adults living with HIV. Prev Med. 2024;189:108144. https://doi.org/10.1016/j.ypmed.2024.108144.
26. McGrew C, MacCallum DS, Narducci D, Nuti R, Calabrese L, Dimeff RJ, Paul S, Poddar S, Rao A, McKeag D. AMSSM position statement update: blood-borne pathogens in the context of sports participation. Br J Sports Med. 2020;54(4):200-207. https://doi.org/10.1136/bjsports-2019-100650.