Research Article **IJSMR (2021) 4:20**

International Journal of Sports Medicine and Rehabilitation
(ISSN:2637-5044)

Peripheral Neuropathy Impacts Gait Motor Components in Hispanic-Latinx living with HIV

Martín G. Rosario PT, PhD, CSFI, ATRIC[1*], Leah Jamison, PT, DPT[1], Gabriel Gines BS, MPH, CPT, CSFI[2]

[1]Texas Woman's University, Physical Therapy Program, Dallas Campus; Texas; [2]Sara Alert, Airport Surveillance System, Department of Health, Puerto Rico.

ABSTRACT

HIV can cause numerous health-related complications that can lead to disabilities and affect the quality of life. Some problems added with HIV, like peripheral neuropathy (PN), may develop additional impediments in this population.

Purpose: This study investigated PN's impact on the cardio-motor profile of Hispanic Latino living with HIV.

Methods: A submaximal cardiovascular test (Ross test) was conducted to obtain the study's cardiomotor results. Cardiomotor data were compiled from records of members enrolled at La Perla de Gran Precio Community Centre on HIV in San Juan, Puerto Rico.

Results: The motor profile included the speed and inclination of the treadmill. The cardiovascular data had blood pressure and heart rate at the time Ross's test was terminated. Two hundred and ninety-one participants were further designated as 225 in the non-PN and 66 in the PN group. Both groups average comparable amounts of CD4 counts. An ANOVA was used to determine variations in the PN group with a considerable ($P < 0.05$) increase in the time of HIV diagnosis and a reduction in gait velocity and treadmill inclination distinguished to counterpart. Conclusion: Hispanic Latino living with HIV and PN displayed distinctive motor gait deficiencies. Gait parameters, such as gait speed, were further impaired in those suffering from both conditions. We encourage healthcare providers to incorporate the specific cardio-motor items alluded to in this investigation to identify the process influencing gait that further alters the quality of life in those with HIV.

Keywords: Gait complications; HIV ; Peripheral Neuropathy; Ross Test; Hispanic Latinx; Motor Complicatio-ns

***Correspondence to Author:**
Martín G. Rosario
Texas Woman's University, Physical Therapy Program, Dallas Campus; 5500 Southwestern Medical Ave. Dallas, TX 75235-7299
https://linktr.ee/Dr.MartinRosario

How to cite this article:
Martín G. Rosario,Leah Jamison, Gabriel Gines. Peripheral Neuro-pathy Impacts Gait Motor Components in Hispanic -Latinx living with HIV. International Jour-nal of Sports Medicine and Rehabil-itation, 2021; 4:20

eSciPub LLC, Houston, TX USA.
Website: https://escipub.com/

Introduction

The human immunodeficiency virus (HIV) is a global pandemic that affects over 36.9 million people (http://www.unaids.org). HIV is currently a condition of higher population diversity, involving all ages, genders, and races. In the United States, considerable changes in the epidemiology perspective have greater involvement in young adolescents, white, middle-class men who have sex with men, and heterosexual contact in women from the early 1980s to the present (Moore et al., 2011). However, of the states and territories, Texas and Puerto Rico are among the top seven districts with the highest rate of HIV diagnosis (per 100,000 people), with 15.4 and 13.3, respectively. Hispanic and Latino men have four times more HIV infections than white men in these US territories (www.cdc.gov). According to the Center for Disease Control (CDC), Latinx represent 18% of the number of reported HIV since 1997 (http://hivinsite.ucsf.edu).

The problem is that most HIV cases have increased in the 25-34-year-old population, with men 4.8 times more infected than women. Unquestionably, HIV affects millions of people; the longer they live with this illness, the more profound the HIV-related complications evolve. That explained, some therapies can help reduce the risk of HIV-related complications, such as antiretroviral medications. Irrespective of the progress of HIV treatment, the considerations mentioned above make this condition a prime cause of attention in the United States and its territories (www.cdc.gov).

HIV is essentially an immunologic system disorder that can disturb the nervous system, leading to neurological disruptions and degeneration of the brain arrangements associated with motor alterations (MNAs) that directly impact everyday tasks (Sullivan E et al., 2011; Heinze B. et al., 2013). These neurological changes are attributed to the disruption of cerebral regions associated with motor function, such as the frontal lobe's motor cortex (Chang et al. 2004; Paul et al. 2007; Sclar et al. 2000; von Giesen et al. 2001).

Antiretroviral medications (ART) have gained much importance because of the success of expanding lifespan (Woods SP et al., 2009) and taming down the MNAs associated with HIV (Watkins CC et al., 2015) therefore improving the quality of life of this population (Erlandson K. et al., 2012). While antiretroviral therapy helps preserve a healthy immune system with normal CD4 cells, mild MNAs involving the central nervous system can be identified in HIV-positive individuals. As time and disease progress, inevitably, neurological motor impairments become more severe (Grant et al. 1987). These HIV-related MNAs can produce an alteration in several areas such as the cardiovascular system, gait, balance, vestibular, and lower limb musculature, all of which enhance the risk of falls, injury, and early death in these individuals (Erlandson K. et al., 2012, Cohen H. et al. 2012 & Heinze B. 2011).

Of particular concern is that most cases (>50%) of HIV-related MNAs show asymptomatic deterioration, characterized by neuropathological abnormalities that will undoubtedly increase the risk of early mortality. Other individuals encounter mild-to-severe MNAs at some point in their lives (Woods SP et al., 2009). Even in its mildest form, neurological alterations are still prevalent and negatively impact the individuals' quality of life (Havlik RJ et al., 2011; Cross S et al., 2013). Some MNAs are associated with the virus attacking the nervous system, provoking cardiovascular problems (Rosario MG et al., 2018) and peripheral neuropathy involving gait and posture (Bauer et al.,2005).

Peripheral neuropathy among people that are residing with HIV is rising worldwide because of the virus. The disease itself produces inflammation that can damage the sensory and motor nerves more commonly in the body's distal segments (Saylor D. et al., 2017). Therefore, people living with HIV could be more prone to peripheral neuropathy because of both illnesses, provoking unusual sensations (paresthesia), pain, and muscle weakness in this group (www.hopkinsmedicine.org).

Given the above clinical manifestations, individ-

uals experiencing HIV-neuropathic problems may have compromised balance or gait, increasing the risk of falls in this population. Previous investigations have highlighted gait and balance complications related to HIV sensorimotor issues. In their study, Bauer et al. observed increased postural sway when HIV participants were measured using a force-sensitive platform (Bauer et al., 2005). According to Bauer et al., there is clinical evidence of balance and gait disturbances in over 57% of symptomatic HIV cases and 25% of their asymptomatic peers.

Given that any of the above can manifest differently (moderate to severe) during the HIV timeline, and cardiovascular disorder and peripheral neuropathy are frequent occurrences in this population, we ask, what are the cardio-motor distinctions in people with peripheral neuropathy and HIV contrast to only the HIV diagnosis? We aim to further understand the implications on the cardiovascular and the gait motor system to prevent some HIV-related complications that might increase the risks of falls in those living with this disease.

II. METHODS

The current study compiled retrospective data from participants' records over the last 20 years (2000-2020). This research was approved by the La Perla de Gran Precio (LPDG) and fulfilled the establishment's privacy and confidentiality standards.

All participants in the current study were enrolled in a Community Based center (La Perla de Gran Precio) in San Juan, Puerto Rico. The LPGP is a community center specializing in wellness and promoting life quality for those living with HIV. In order to be part of the LPGP, all subjects signed informed consent, were cleared by a medical doctor, a physical therapist, and performed an exercise assessment by a certified personal trainer.

We compiled data related to age, cd4 values, sex, other medical conditions, and time since HIV diagnosis. Associated with the cardio-motor data, we used the outcomes from the Ross submaximal cardiovascular test. The Ross test measures the cardiovascular (blood pressure and heart frequency) and motor (treadmill speed and inclination) values during each participant's test.

Cardiovascular and Motor components:

First, before initiating the test, vitals were collected, blood pressure, and heart rate. The Ross treadmill test commenced at a speed of 2.0 mph with 0 inclination. Second, we adjusted the first 3 minutes of the tests for speed with constant inclination; 2.5 mph at minute 2, 3.0 mph at minute 3, and 3.4 mph at minute 4. Third, we modified the degrees of inclination every 3 min at a constant speed of 3.4 mph, reaching a maximal inclination of 15 ° at minute 21. Fourth, the examination was halted, and vitals re-assessed when the maximal cardiac frequency was achieved, cardiovascular/muscle fatigue was reported, or when reaching the intended 21 min of the test. Regardless of the reason to end the test, the cardio-motor data documented in this investigation were the values when the Ross test culminated.

Data Analysis

This study aimed to compare the implication of peripheral neuropathy (PN) on the cardio-motor profile in those living with HIV; thus, we allocated the data into two groups, PN and non-PN.

The specific two components collected and compared in the current report were cardiovascular and motor profiles. The motor factors included the treadmill's speed and inclination as values of interest. The cardiorespiratory components utilized the time of test completion and vitals (heart rate and blood pressure) when the Ross test ended. We performed an analysis of variance (ANOVA) with SPSS version 25 to compare the PN and non-PN groups. A p-value of 0.05 or less was considered statistically significant.

III. Results

As depicted in Table 1 (demographic data), this investigation collected data from 291 participants' records (mostly males) further divided into 66 PN and 225 non-PN groups. The PN group exhibited a higher cd4 count value (Cd4= 752.6+/-335.5) than (Cd4=598.6+/-351.3) non-PN. In addition, the PN group was older than the non-PN (PN 58 +/8.1 · years and non-PN 52+/-10.4 · years). Finally, both groups were analog-

ous in years of diagnosis (PN=20.2+/-7.6 and non-PN 18.4+/-8.7 years). Table 2 illustrates the comparison of cardio-motor factors between the groups. The PN group exhibited a decrease (P<0.05) in treadmill time and inclination compared to the non-PN group. The cardio components portrayed by BP and HR (Table 2) were equivalent among the groups (P>0.05).

Table 1: Demographic data of all participants. Results of ANOVA performed comparing Non-PN and PN groups Significance level set at p≤0.05.

Characteristics	Non-PN n=225	PN n=66	P value
Age (years)	M= 52+/-10.4 years	M=58 +/8.1years	P= 0.001
Gender	Male= 0 Female = 1 *M= 0.26+/-0.44	Male= 0 Female= 1 *M=0.27+/-0.45	P= 0.81
Year of Dx (years)	M= 18.4+/-8.7	M=20.2+/-7.6	P= 0.18
Cd4	M=598.6+/-351.3	M= 752.6+/-335.5	P= 0.01

PN=Peripheral Neuropathy
*In this study, for the purpose of comparison, we assigned 0 for each male and a 1 for each female.

Table 2 A Cardiovascular Component at the end of the Ross Submaximal Test. Results of ANOVA performed comparing Non-PN and PN groups Significance level set at p≤0.05.

Characteristics	Non-PN n=225	PN n=66	F Value	P value
Heart Rate (bpm)	M=140.04 +/- 18.55	M=135.63 +/- 19.04	11.6	P= .001
Systolic BP (mmHg)	M=123.4 +/- 15.8	M=126.9 +/- 19.8	1.8	P= .18
Diastolic BP (mmHg)	M=74.4 +/ 11.2	M=76.7 +/- 10.1	1.8	P= .18
Cardio test Time	M=10.7 +/- 4.8	M=9.2 +/- 4.2	4.9	P=0.05
Motor Component at the end of the Ross Submaximal Test				
Velocity	M=3.32 +/- .25	M=3.33+/- .34	1.5	P= 0.2
Inclination	M=5.8 +/-4.4	M=4.6+/- 3.5	4.7	P= 0.05
PN=Peripheral Neuropathy				

IV. Discussion:

This study intended to identify the impact of PN on the cardiomotor components in people with HIV. To establish the distinction related to PN, this study examined the comparison between the motor (speed and inclination on a treadmill) and cardiorespiratory (time, HR, and BP when the test ended) among PN subjects and HIV versus non-PN and HIV Hispanic Latinos.

In this regard, this project addresses the following question: Is there a cardio-motor difference in those living with HIV with an additional diagnosis of PN? In those suffering from both HIV and PN, cardiovascular values were parallel

among the groups. However, PN distorts the motor aspect by reducing speed and inclination when compared to the non-PN group.

The study's key feature is that the cardiovascular components compiled when the Ross test ended showed similarities between the two groups. Notably, cardiac dysfunction is common among people living with HIV and may contribute to reduced functional aerobic capacity (Prior, D. E., Song, N., & Cohen, J. A., 2018). The participants in the present investigation engaged in routine exercises in the LPDG. As a result, our findings suggest that regular exercise can halt or at least slow cardiovascular HIV-related problems even with PN's addition, hence the resemblances among groups. In the literature and supporting of our previous remark, substantial research had identified the benefits of continuous involvement in aerobic exercise to diminish cardiovascular impairments in this population (O'Brien KK et al., 2016; Jaggers JR, Hand GA., 2014; Hand GA, 2008; Prior, D. E., Song, N., & Cohen, J. A., 2018). In a review, O'Brien KK et al. (2017) showed that cardiorespiratory benefits could be achieved in HIV-positive individuals taking part in an aerobic and strengthening program. We suggested participation in a regular combined exercise program (cardio and strengthening) among people living with HIV, as it appears to have cardiovascular advantages regardless of the diagnosis of PN.

Another important discovery of the prevailing study was the altered motor components displayed in the PN group. The PN group exhibited a lower speed and inclination when they stopped the Ross test. We could associate a reason behind the previous result with the amount of time diagnosed with HIV. As shown in Table 1, the PN group had lived with the disease for far longer than the non-PN group. Although antiretroviral (ART) treatment alleviated some viral complications in the host, the fact remains that the longer individuals survive with HIV, the more health problems they encounter, such as chronic neuropathic pain (Madden, V. J., Parker, R., & Goodin, B. R., 2020). In our review, all participants used ART regularly, with CD4 values adequate for both groups. Therefore, we believe that the long-term use of ART and the extended period of living with HIV might be related to PN occurrence and, in turn, affect gait even further in this group. As our results compare, Oliveira et al. (2018) determined in their research that both strength deficits and neuropathies are frequent in those affected by HIV using ART.

Gait deterioration due to PN justifies our current findings. The PN group was diagnosed with HIV for a longer time, which led to a more significant decrease in walking, as represented in our study by reducing treadmill speed and inclination. Consistent with our findings, in a longitudinal study, Schrack et al. (2015) distinguished the rate of gait speed decline in men aged 40 years and older affected with HIV matched to non-HIV participants. The authors discovered that HIV-infected older men had a greater risk of developing clinically slow gait speed and established this to be predictive of advanced aging among this population, including a swifter rate of functional decline. Generally, as we age, walking speed decreases on average; however, studies confirm that walking speed decreases faster for men over 50 with HIV (Schrack et al., 2015). This study identified an additional potential factor affecting gait in people living with HIV based on the above.

PN could lead to an early onset of muscle weakness in people living with HIV, affecting gait. Previous reports have confirmed that HIV-infected males have considerably less dynamic muscular strength and a decrease in maximum torque in the lower limb musculatures, such as flexors and knee extensors. Muscular insufficiency attributed to HIV-related complications has already been studied. Richert et al. (2011), in a cross-sectional examination, assessed balance, walking ability, functional capacity, and lower limb muscle performance in non-PN subjects. Based on this review, one in two adults living with HIV had poor muscle performance in their lower limbs. Gait deterioration can be elicited by alterations to lower limb muscle strength and power, lessened in this population. We agree with the preceding research regarding lower limb and

gait alterations as an essential aspect considered in those living with HIV. Further, additional studies are required to single out the onset of these lower extremity and gait abnormalities before the history of falls and injuries in this community.

Another reason for the decrease in gait characteristics is that PN aggravates the nervous and neuromuscular systems, resulting in reduced walking speed, increased postural sway, and decreased postural reflexes. Berner et al. 's systematic review (2017) indicates that these deteriorations are more pronounced during challenging conditions and are connected to the effects that HIV has directly on the central nervous system (CNS) than to ART medications. Rosario MG reported disturbances in balance (Rosario MG. 2020a) and neuromuscular alterations in the lower limbs (Rosario MG. 2020b) in a community of people living with HIV. A crucial concept of the Rosario investigations is that all subjects took their ART regularly and had no history of falls. These earlier remarks underscore the importance of carrying out inquiries to assess the gait and balance of people living with HIV, however, at all stages of the disease.

As we have already mentioned, the consequence of further studies is that there are currently many HIV-related burdens that cause deterioration. For instance, a vast range of neuromuscular disorders and impairments are associated with HIV that can disturb the body's musculature and peripheral nerves (Prior, Song, & Cohen, 2018). Some conjectures on why people living with HIV are experiencing a decline in gait are presented in a review by Berner et al. (2017). One premise is that, although ART carries its advantages, the drugs could damage the mitochondria, in turn diminishing muscle function, contributing to musculoskeletal deterioration. Another inference applied to gait and lower limb strength impairments stem from leg muscles' inadequate coactivation, resulting in increased use of hip strategy and postural sway. Finally, HIV directly impacts the vestibular system, causing increased movement frequency and postural sway. Regarding the above statements, two concepts are indisputable: first, identifying the root of the problem will help avoid other complexities like falls and decrease the life quality. Second, PN's assessment, gait, and balance are essential when serving people living with HIV at any disease stage.

Conclusion

In this study, we intended to recognize PN's impact on cardio-motor components in people living with HIV. This examination ushers in identifying that HIV further disturbs the gait motor aspects of HIV and PN. Furthermore, this research favors the notion that even with a stable immune system, which means an average level of cd4, gait deterioration is possible. We presented gait alteration as a diminished speed and treadmill inclination during a gait submaximal cardiovascular assessment. Likewise, the participants with PN were significantly older than the non-PN group. This age difference between groups suggests that the longer people are affected by HIV live, the more challenges and disabilities will appear, as discussed in this study.

A limitation of this investigation was that BMI was not reviewed. Because we compiled data from files, most BMI measures were missing and therefore were not analyzed. In comparison with Bauer et al. (2011), we acknowledged the importance of BMI, especially in this population. Bauer et al. (2011) discussed the impact of the adverse effects of HIV/AIDS on balance and gait as an individual's body mass increases. As a result, we recommend exploring BMI's involvement in people with HIV and PN in future examinations.

We also advocate looking at the advancement of HIV and PN progression in this population. We propose to compare PN-induced deficits in the diagnosis of HIV with other PN-causing disorders, such as diabetes. Perhaps this correlation between conditions will shed some light on the similarity that will facilitate more targeted interventions. Finally, healthcare professionals working with people living with HIV should regularly assess their gait and peripheral neuropathic status.

Funding: N/A

Conflicts of interest: Authors report no conflict or competing interest.

Authors' contributions: All authors contributed to the study conception and design.

References

[1] Global HIV & AIDS statistics — 2018 fact sheet http://www.unaids.org/en/resources/fact-sheet Accessed [January 2019].

[2] Moore, R. D. (2011). Epidemiology of HIV infection in the United States: Implications for linkage to care. *Clinical Infectious Diseases, 52*(Suppl_2). doi:10.1093/cid/ciq044

[3] HIV in the United States by Region. https://www.cdc.gov/hiv/statistics/overview/geographicdistribution.html Accessed [January 2019].

[4] Comprehensive, up-to-date information On HIV/ AIDS treatment and prevention from the University of California San Francisco. (n.d.). Retrieved February 22, 2021, from http://hivinsite.ucsf.edu/InSite?page=pr-rr-03

[5] Sullivan E, Rosenbloom M, Rohlfing T, Kemper C, Deresinski S, et al. (2011). Pontocerebellar contribution to postural instability and psychomotor slowing in HIV infection without dementia. NIH Public Access. 5(1),12-24.

[6] Heinze B, Swanepoel D, Hofmeyr L. (2011). Systematic review of vestibular disorders related to human immunodeficiency virus and acquired immunodeficiency syndrome. J Laryngol Otol. 125, 881-891.

[7] Chang, L., Tomasi, D., Yakupov, R., Lozar, C., Arnold, S., Caparelli, E., et al. (2004). Adaptation of the attention network in human immunodeficiency virus brain injury. Annals of Neurology, 56, 259–272.

[8] Paul, R. H., Yiannoutsos, C. T., Miller, E. N., Chang, L., Marra, C. M., Schifitto, G., et al. (2007). Proton MRS and neuropsychological correlates in AIDS dementia complex: Evidence of subcortical specificity. Journal of Neuropsychiatry and Clinical Neuroscience, 19(3), 283–292.

[9] Sclar G, Kennedy CA, Hill JM, McCormack MK. Cerebellar degeneration associated with HIV infection [letter] Neurology. 2000;54:1012–1013.

[10] von Giesen HJ, Wittsack HJ, Wenserski F, Koller H, Hefter H, Arendt G. Basal ganglia metabolite abnormalities in minor motor disorders associated with human immunodeficiency virus type 1. Archives of Neurology. 2001;58:1281–1286.

[11] Woods, S.P., Moore, D.J., Weber, E. et al. Neuropsychol Rev (2009) 19: 152. https://doi.org/10.1007/s11065-009-9102-5

[12] Watkins CC, Treisman GJ. Cognitive impairment in patients with AIDS - prevalence and severity. HIV AIDS (Auckl). 2015;7:35-47. Published 2015 Jan 29. doi:10.2147/HIV.S39665

[13] Erlandson KM1, Allshouse AA, Jankowski CM, Duong S, Mawhinney S, Kohrt WM, Campbell TB. Comparison of functional status instruments in HIV-infected adults on effective antiretroviral therapy. HIV Clin Trials. 2012 Nov-Dec;13(6):324-34. doi: 10.1310/hct1306-324.

[14] Grant, I., Atkinson, J. H., Hesselink, J. R., Kennedy, C. J., Richman, D. D., Spector, S. A., et al. (1987). Evidence for early central nervous system involvement in the acquired immunodeficiency syndrome (AIDS) and other human immunodeficiency virus (HIV) infections. Studies with neuropsychologic testing and magnetic resonance imaging. Annals of Internal Medicine, 107(6), 828–836.

[15] Cohen HS, Cox C, Springer G, et al. Prevalence of abnormalities in vestibular function and balance among HIV-seropositive and HIV-seronegative women and men. *PLoS One*. 2012;7(5):e38419. doi:10.1371/journal.pone.0038419

[16] Heinze B, Swanepoel DW, Hofmeyr LM. Systematic review of vestibular disorders related to human immunodeficiency virus and acquired immunodeficiency syndrome. *The Journal of Laryngology & Otology*. 2011;125(9):881-890. doi:10.1017/s0022215111001423.

[17] Havlik RJ, Brennan M, Karpiak SE. Comorbidities and depression in older adults with HIV. Sex Health. 2011;8(4):551–559.

[18] Cross S, Onen N, Gase A, Overton ET, Ances BM. Identifying risk factors for HIV-associated neurocognitive disorders using the international HIV dementia scale. J Neuroimmune Pharmacol. 2013; 8(5):1114–1122.

[19] Rosario, MG and Gonzalez-Sola M (2018). Autonomic nervous system assessment in people with HIV: A cross-sectional study [version 1; referees: awaiting peer review]. *F1000 Research*., doi: 10.12688/f1000research.14685.1.

[20] Bauer, L. O., Ceballos, N. A., Shanley, J. D., & Wolfson, L. I. (2005). Sensorimotor dysfunction IN HIV/AIDS: Effects of antiretroviral treatment AND comorbid psychiatric disorders. *AIDS, 19*(5), 495-502. doi:10.1097/01.aids.0000162338.66180.0b

[21] Saylor, D., Nakigozi, G., Nakasujja, N., Robertson, K., Gray, R. H., Wawer, M. J., & Sacktor, N. (2017). Peripheral neuropathy in HIV-infected and uninfected patients in Rakai, Uganda. Neurology, 89(5), 485–491. https://doi.org/10.1212/WNL.0000000000004136

[22] McNamara, L. (2015, October 05). Hiv neuropathy. Retrieved February 22, 2021, from

https://www.hopkinsmedicine.org/neurology_neurosurgery/centers_clinics/peripheral_nerve/conditions/hiv_neuropathy.html

[23] Prior, D. E., Song, N., & Cohen, J. A. (2018). Neuromuscular diseases associated with Human Immunodeficiency Virus infection. *Journal of the Neurological Sciences*, *387*, 27–36. doi: 10.1016/j.jns.2018.01.016

[24] O'Brien KK, Tynan AM, Nixon SA, Glazier RH. Effectiveness of aerobic exercise for adults living with HIV: systematic review and meta-analysis using the Cochrane Collaboration protocol. *BMC Infect Dis*. 2016;16:182. doi:10.1186/s12879-016-1478.

[25] Jaggers JR, Hand GA. Health Benefits of Exercise for People Living With HIV: A Review of the Literature. *Am J Lifestyle Med*. 2014;10(berner3):184-192. doi:10.1177/1559827614538750.

[26] Hand GA, Phillips KD, Dudgeon WD, Lyerly GW, Durstine JL, Burgess SE. Moderate intensity exercise training reverses functional aerobic impairment in HIV-infected individuals. *AIDS Care*. 2008;20(9):1066-1074. doi:10.1080/09540120701796900.

[27] O'Brien KK, Tynan AM, Nixon SA, Glazier RH. Effectiveness of Progressive Resistive Exercise (PRE) in the context of HIV: systematic review and meta-analysis using the Cochrane Collaboration protocol. *BMC Infect Dis*. 2017;17(1):268.

[28] Madden, V. J., Parker, R., & Goodin, B. R. (2020). Chronic pain in people with HIV: a common comorbidity and threat to quality of life. Pain management, 10(4), 253–260. https://doi.org/10.2217/pmt-2020-0004

[29] Oliveira VH, Wiechmann SL, Narciso AM, Webel AR, & Deminice R. Muscle strength is impaired in men but not in women living with HIV taking antiretroviral therapy. *Antiviral Therapy*. 2018; *23*(1), 11-19. doi: 10.3851/IMP3159

[30] Schrack JA, Althoff KN, Jacobson LP, et al. Accelerated Longitudinal Gait Speed Decline in HIV-Infected Older Men. *J Acquir Immune Defic Syndr*. 2015;70(4):370–376. doi:10.1097/QAI.0000000000000731

[31] Richert L, Dehai, P, Mercié P, Dauchy FA, Bruyand M, Greib, & Groupe d'Epidémiologie Clinique du SIDA en Aquitaine. High frequency of poor locomotor performance in HIV-infected patients. *AIDS*. 2011; *25*(6), 797-805.

[32] Berner K, Morris L, Baumeister J, Louw Q. Objective impairments of gait and balance in adults living with HIV-1 infection: a systematic review and meta-analysis of observational studies. *BMC Musculoskeletal Disorders*. 2017;18(1). doi:10.1186/s12891-017-1682-2.

[33] Rosario, M. (2020)a. Early signs of standing postural instability in asymptomatic people living with HIV. HIV & AIDS Review. International Journal of HIV-Related Problems, 19(3), 193-198. https://doi.org/10.5114/hivar.2020.99680

[34] Rosario MG. (2020)b. Gastrocnemius and tibialis anterior neuromuscular modification recruitment during postural standing in people living with HIV. HIV & AIDS Review. International Journal of HIV-Related Problems. ;19(4):260-266. doi:10.5114/hivar.2020.101633.

[35] Bauer LO, Wu Z, Wolfson LI. An obese body mass increases the adverse effects of HIV/AIDS on balance and gait. *Phys Ther*. 2011;91(7):1063–1071. doi:10.2522/ptj.20100292