

Gait-associated dynamic deviations during cognitive dual tasks in physically active adults living with HIV

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Abstract

Introduction: Among Human immunodeficiency virus (HIV) complications, individuals living with HIV experience cognitive deterioration that could influence gait and balance in this group. To identify gait variations during dual cognitive tasks equaled to single tasks in those living with HIV.

Material and methods: 11 females and 18 male adults (age, 60.31 ± 7.82) diagnosed with HIV were recruited for the current investigation. The study instructed participants to walk 7 meters (single tasks), and the same distance while counting backward from 100 by 3 (dual cognitive tasks). During the activity, parameters, such as gait speed, stride length, and postural sway were gathered with six motion analysis sensors.

Results: A significant reduction in cadence (single tasks: 108.6 ± 16.7 , dual tasks: 92.3 ± 25.9 ; $p < 0.001$), gait speed (single tasks: 0.98 ± 0.28 , dual tasks: 0.78 ± 0.31 ; $p < 0.001$), time during swing phase percentage (single tasks: 38.7 ± 3.9 , dual tasks: 35.3 ± 7.9 ; $p < 0.05$), single-limb support time (single tasks: 38.2 ± 3.9 , dual tasks: 35.4 ± 7.9 ; $p < 0.05$), and stride length (single tasks: 1.1 ± 0.2 , dual tasks: 0.95 ± 0.3 ; $p < 0.05$) were observed during dual cognitive tasks when compared to single tasks.

Conclusions: Gait-associated dynamic alterations were revealed as a compensatory strategy to adapt to the requirements of dual cognitive tasks for those living with HIV, even when physically active. We advise physicians to investigate the cognitive characters of all individuals with HIV, regardless of the status of the condition.

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Key words: HIV, AIDS, gait, walking, dynamic balance.

Introduction

According to UNAIDS statement, human immunodeficiency virus (HIV) affects 38 million people. In 2020 alone, there were 680,000 HIV-related deaths [1]. The disease pervades the individual's immune system and damages white blood cells, particularly CD4 lymphocytes, otherwise recognized as T cells. Infiltration of HIV can distort central nervous system (CNS) tissues, including the brain and spinal

cord [2]. Brain structure damage may prompt neuro-cognitive [2] and neuro-motor alterations [3, 4], and these motor-cognitive alterations could contribute to gait and balance deficits [5]. Motor-cognitive variations (MCNAs) involve motor speed, information processing, executive functions, awareness, new information, memory, recent information retrieval, standing balance, and gait parameters [4-7]. In initial stages of this condition with normal CD4 immune cells, even mild MCNAs that influence motor control, such

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as standing balance, can be identified in individuals with HIV [8]. Further, these motor-cognitive neurological modifications increase severity as they age [9], and the condition progresses [10].

Regularly, MCNAs are displayed as balance and gait changes [4, 9]. A research shows that asymptomatic HIV individuals exhibit higher postural instability than normal controls, leading to an increased fall risk [5]. Postural sway increase has been associated with a direct impact on the CNS and impairment of the lower limb muscle co-activation, notably from the leg musculature [11]. People living with HIV (PLHIV) could show an additional gait speed decline per year compared with healthy control groups [12]. HIV is also associated with a higher risk of developing slowed gait speed, a prognostic of accelerated aging in this population, including a faster rate of functional deterioration [12].

Several studies have reported cognitive deterioration associated with HIV. As previously mentioned, the virus destroys the immune and nervous systems. This injury leads to neurologic disorders and degeneration of brain networks associated with motor patterns and cognition, which affect daily activities [13, 14]. A solution to the development of MCNAs is antiretroviral drugs (ART). ART has been shown to slow the progression of motor cognitive changes associated with HIV [15], but these changes are still widespread and negatively affect the quality of life of people with HIV [16, 17].

The motor-cognitive changes are related to the involvement of frontal lobe, in particular the frontostriatal brain system [18]. Most of these MCNAs manifest themselves as gait deficiencies, standing balance problems, and perceived balance instability during everyday activities [4, 8, 9] in people with a previous history of falls or advanced stages of HIV. The aim of the study was therefore to describe the influence of cognitive tasks on gait parameters in PLHIV. We hypothesized that cognitive tasks would cause gait changes, such as reduced gait speed and the time percentage spent in single-limb support phases of gait in people with HIV.

Material and methods

Participants

Participants were recruited by word-of-mouth from a recreational community center specific for individuals with HIV, La Perla de Gran Precio Community Center (LPDG) in San Juan, Puerto Rico. The Institutional Review Board approved this study (approval No.: FY2020-32).

Detailed inclusion criteria were as follows: (1) participants must present with good health, (2) be between 18-65 years of age, (3) obtain an HIV diagnosis by a physician, (4) be physically able to walk more than 20 minutes with or without an assistive device, and (5) have a CD4 count of > 300 cells/ μ l. In addition, exclusion criteria were as follows: (1) severe balance impairments, (2) lower limb or back surgery within the last six months, (3) non-ambulatory status, and (4) pregnancy.

Interested participants were given a description of the study, including the protocol requirements, risks, and benefits of participating in the research. After agreeing to participate in the study, all participants signed an informed consent form before initiation of research data collection. In addition, demographic information, including age, gender, years since diagnosis, and CD4 levels, were obtained before the gait protocol. After participants provided their written consent, the inclusion and exclusion criteria were then evaluated by gathering data from medical records (CD4 count and HIV diagnosis confirmation). Then, vitals were gathered for each subject, such as heart rate (HR) and oxygen saturation (SaO₂) with a pulse oximeter. Participants were assessed for severe balance impairments via Fukuda balance protocol [19], and evaluated for levels of lower extremity strength using sit-to-stand assessment [20]. After ruling out any severe complications, which could endanger the subjects' safety, 30 participants were recruited for the study. Participants were allowed the use of corrective visual aids (glasses or contact lenses) if needed during testing administration.

The equipment employed to measure gait parameters was the MobilityLab: APDM's MobilityLab™ (APDM Inc., <http://apdm.com>). MobilityLab is a set of six accelerometer and gyroscope movement sensors used to capture temporal-spatial parameters of gait and movement, including gait speed, stride length, single/double limb support time, cadence, stance/swing percentage, sway, and turns. The mobility lab sensors were placed on the trunk, and lower and upper extremities. In this work, a member of the research team placed all six sensors on participants in the following body areas: bilateral wrists (2 sensors), bilateral ankles (2 sensors), lumbar spine (1 sensor), and thoracic spine (1 sensor).

Gait protocol

Gait protocol included single and dual tasks examinations. The protocol began with two trials of 7-meter ambulation at each participant's preferred walking speed. It ended with two trials of 7-meter ambulation, in conjunction with a cognitive task of counting backward from 100 by 3 aloud. The individuals were permitted to count in their native language, English or Spanish. A white line marked the 7-meter data collection area on the floor at the initiation point, followed by a cone at the turning point 3.5 meters away. The subjects were instructed to turn around at the cone and return to the initiation point.

Gait single tasks (two trials)

1. Participants were instructed to begin with their toes behind the white line in a static standing posture, then start walking at a self-selected pace when they heard a tone from the computer.
2. Upon reaching the cone 3.5 meters away, participants were instructed to walk around the cone and return to the starting point.

- Participants continued the path as described above until they heard a second computerized tone indicating they had completed a distance of 7 meters.

Gait dual cognitive tasks (two trials)

Participants repeated trials 1-3 as detailed above, with a cognitive component of counting backward from 100 by 3. Therefore, two more gait trials were performed with the added cognitive component.

Data analysis

We conducted a secondary analysis of existing data to compare gait parameters during single and dual tasks, to better understand how gait is affected in PLHIV. The compiled temporo-spatial parameters were organized in Excel worksheets, and then analyzed using IBM SPSS v. 28 Statistics for MANOVA analysis and pair-wise comparison. Pair-wise comparisons in MANOVA were gathered for gait speed, stride length, single/double limb support time, cadence, stance/swing percentage, sway and turns phase to identify the differences among the tasks and the computation of *p*-value for each pair of variables among the single and dual tasks. A *p*-value of 0.05 or less was considered significant (*p* < 0.05).

Results

Table 1 illustrates the population sample characteristics. The sample consisted of 29 participants, with a mean age of 60.3 ± 7.8 (11 females and 18 males). Of these participants, the average CD4 count was 899.9 ± 155.6 cells/μl. Additionally, the average weight of participants was 177.0 ± 50.2 pounds, with an average height of 65.6 ± 3.3 inches. The participants'

average BMI was 29.0 ± 8.0 kg/m². Other demographic averages included HR: 79.0 ± 15.1 beats per minute (bpm), and SaO₂: 97.5 ± 1.0%. Of the included individuals, 24 were right leg dominant, and 5 were left leg dominant.

Table 2 shows the gait parameter in both activities, gait during single and dual tasks. The participants exhibited significant reductions in cadence (single tasks: 108.6 ± 16.7, dual tasks: 92.3 ± 25.9; *p* ≤ 0.001) and gait speed (single tasks: 0.98 ± 0.3, dual tasks: 0.78 ± 0.3; *p* ≤ 0.001) during dual cognitive tasks compared with single tasks. Additionally, data showed a significant decrease in time during swing phase percentage (single tasks: 38.7 ± 3.9, dual tasks: 35.3 ± 7.9; *p* ≤ 0.05) and single-limb support time (single tasks: 38.2 ± 3.9, dual tasks: 35.4 ± 7.9; *p* ≤ 0.05) while dual-tasking. Finally, a significant stride length reduction was observed (single tasks: 1.1 ± 0.2, dual tasks: 0.95 ± 0.3; *p* ≤ 0.05) during dual tasks activities compared with single tasks.

Discussion

The aim of the present study was to describe the influence of dual cognitive tasks on gait parameters in PLHIV.

Table 1. Demographic characteristics and measurements data of all participants

Age (years)	M: 60.3 ± 7.82
Gender	
Male	18
Female	11
Time from diagnosis (year)	M: 25.0 ± 23.6
CD4 (cells/μl)	M: 899.9 ± 155.6

Values are expressed as mean (M) ± standard deviation.

Table 2. Comparison of walking parameters between single and dual tasks. Results of MANOVA performed comparing tasks. Significance level set at *p* ≤ 0.05

Motor component variables	Single tasks	Dual tasks	<i>p</i> -value
Cadence (steps/min)	108.6 ± 16.7	92.3 ± 25.9	0.001
Gait speed (m/secs)	0.98 ± 0.3	0.8 ± 0.3	0.001
Stride length (m)	1.1 ± 0.2	0.95 ± 0.3	0.05
Single limb (secs)	38.2 ± 3.9	35.4 ± 7.9	0.05
Double limb (secs)	23.6 ± 7.8	25.5 ± 8.6	0.23
Stance (% gait cycle)	61.7 ± 3.9	60.1 ± 12.7	0.63
Swing (% gait cycle)	38.7 ± 3.9	35.3 ± 7.9	0.05
A-P sway velocity (m/s)	0.5 ± 0.3	0.6 ± 0.5	0.40
M-L sway velocity (m/s)	0.3 ± 0.1	0.3 ± 0.1	0.29
Turns-angle (degrees)	176.6 ± 22.9	175.2 ± 24.8	0.76
Turns-duration (secs)	2.2 ± 0.5	2.2 ± 0.4	0.81
Turn-velocity (degrees/secs)	183.7 ± 37.6	181.2 ± 38.7	0.73
Turns – No. of steps	3.9 ± 1.0	3.6 ± 1.1	0.23

Min – minutes, m – meters, secs – seconds, A-P – antero-posterior, M-L – medio-lateral

The first main finding showed that gait parameters, such as cadence, stride length, and gait speed, decrease during dual cognitive tasks compared with single tasks. This study suggests cognitive function is altered, and individuals reduce the above-mentioned gait parameters as a compensation mechanism. Previous studies reported that PLHIV with a faster gait speed also showed competently cognitive function than those with a slower gait speed [21]. Comparable to the current study, Seo *et al.* [22] identified an association between slower gait speed and cognitive decline. A possible explanation of the reduction in cognitive function could be related to the various areas of the brain, such as the frontal lobe, which are affected in people with HIV [18]. These changes impact the central nervous system and cause cognitive decline, among other complications [2]. Cognitive changes include dementia, anxiety, and depression [23]. Those above-mentioned HIV complications have been shown to significantly reduce quality of life, increase fall risk, increase fear of falling, decrease physical activity, and cognitive decline [24, 25].

Rosario *et al.* [4] recruited a Hispanic group of people living with HIV, a group similar to that in the current study, and reported depression as one of the leading neuro-cognitive diseases diagnosed in these individuals. However, Hyder and Rosario [26] compared motor components, such as gait speed in PLHIV with and without depression, and found similarity regardless of the depression diagnosis. The above study suggests that other factors are related to the cognitive profile in this group, since the current study found gait alterations during cognitive tasks.

The second main finding of this study showed that gait components were reduced during dual cognitive tasks compared with single tasks during gait, such as swing phase and single-limb support. These findings suggest that PLHIV exhibited dynamic balance alterations as a compensatory mechanism to preserve postural control during cognitive tasks. Previous studies have shown that people living with HIV withstand balance changes [3]. HIV influences gait and balance, leading to an increased risk of falls and injuries, regardless of antiretroviral therapy (ART) [27-29]. Those living with HIV over the age of 50 report significantly more falls and balance problems than aged match non-HIV diagnosed individuals [23]. Various reasons for gait and balance alterations evolve around neuro-muscular alterations [3], ankle complex muscular poor coordination [21], and a combination of proprioceptive and vestibular systems alterations [8]. The current study points out, based on the results, that cognitive interplay between two tasks is also altered, making walking and diverting attention to other tasks difficult in this group. Furthermore, these adjustments suggest that gait deviation is potentially associated with injury in higher control centers, such as the frontal cortex.

Conclusions

The current study focused on gait parameters, combined with dual tasks in PLHIV. This research helps identify dy-

namic balance changes as a compensatory strategy for dual cognitive tasks in PLHIV. This particular group presented gait alterations when required to walk during cognitive tasks. One of the limitations of this study is that we recruited only ambulatory participants with relatively good health, making identifying the progression of gait deviations difficult. Also, the current research erred to assess neuro-muscular activation in this group. However, lower limb patterns during dual cognitive tasks can provide a promising portrait of compensatory mechanism in PLHIV. Based on our results, this study proposes cognitive testing in all HIV-diagnosed people. Forthcoming studies should look into muscle activation and dual cognitive walking tasks. Additionally, assessing dual-motor tasks during walking to adequately understand the impact of HIV on other areas of the brain, such as the motor cortex, are recommended. We propose future studies to investigate the benefits of gait exercise combined with cognitive tasks at different stages of the disease. We also recommend treadmill training and other challenging surfaces combined with dual cognitive tasks. Finally, we encourage clinicians to examine the cognitive components of all people suffering from HIV complications, regardless of the status of the condition.

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Ethics approval

IRB approval TWU protocol approval No.: FY2020-32.

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Conflict of interest

The author declares no conflict of interest.

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