

Quantitative Brain Volume Correlates of Neuropsychological and Neuropsychiatric Measures in Adults Living with HIV Receiving Antiretroviral Therapy: A 0.35-T MRI Study

Emmanuel Ayuba Buba^{1,2}, Anthony Chukwuka Ugwu¹, Mohammed Ali Wulgo³, Sulaiman Tanimu Sa'ad³, Victor Kelechi Nwodo¹, Uche Andrew George^{1,4}, Ugochukwu Celestine Opara^{1,5}, Bestman Izuchukwu Oriaku^{1,6}, Emeka Chukwumuanya Umeh^{1,7}, Stanley Olisa Nwefuru^{1,8}

¹Department of Radiography and Radiological Science, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

²MRI Department, Nottingham University Hospital NHS Trust, Nottingham, United Kingdom.

³Federal Teaching Hospital Gombe, Gombe State, Nigeria.

⁴Department of Ultrasound, Northern Lincolnshire and Goole NHS Foundation Trust, Grimsby, United Kingdom.

⁵CT/MRI Department, Barnsley Hospital NHS Foundation Trust, United Kingdom.

⁶Department of Interventional Radiology, University of Liverpool NHS Foundation Trust, United Kingdom.

⁷CT Department, Humber Health Partnership, Hull University Teaching NHS Trust, Hull, United Kingdom.

⁸MRI Department North East Lincolnshire and Goole NHS Foundation Trust, Grimsby, United Kingdom.

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ABSTRACT

Background: Cognitive, functional, psychological and sleep-related difficulties remain clinically relevant in people living with HIV (PLWH) receiving antiretroviral therapy (ART), but their relationship with macroscopic brain volume is incompletely characterised in African cohorts. **Objective:** To determine relationships between quantitative global and regional MRI brain volumes and neuropsychological and neuropsychiatric measures among adults living with HIV receiving ART. **Methods:** This cross-sectional analysis included 65 PLWH, of whom 60 had usable volumetric MRI data. Structural MRI was acquired using a 0.35-T GE SIGNA Ovation scanner and processed with an FSL-based pipeline incorporating SUSAN, BET, FAST and FIRST. Twenty-two MRI measures were correlated with five continuous outcomes (PAOFI, CTADL, CES-D, STAI-Trait and PSQI), yielding 110 Spearman correlations; pairwise sample sizes ranged from 56 to 60. Benjamini–Hochberg false-discovery-rate correction was applied across all tests. **Results:** Six correlations reached nominal $p < .05$, but none survived correction: adjusted white matter–CTADL ($\rho = -.30$, $p = .018$, $q = .672$), left thalamus–CTADL ($\rho = .27$, $p = .039$, $q = .811$), right globus pallidus–CTADL ($\rho = .35$, $p = .006$, $q = .425$), left hippocampus–CTADL ($\rho = .26$, $p = .043$, $q = .811$), brainstem–CTADL ($\rho = .34$, $p = .008$, $q = .425$), and left nucleus accumbens–STAI-Trait ($\rho = .27$, $p = .044$, $q = .811$). No PAOFI, CES-D or PSQI correlation reached nominal significance. **Conclusion:** Quantitative brain volumes showed several modest nominal relationships, mainly with everyday functioning, but no association remained statistically significant after multiple-comparison correction. The findings are exploratory and require replication in larger, longitudinal cohorts with formal low-field validation and higher-field comparison.

Keywords: HIV; brain volumetry; neuropsychological measures; everyday functioning; sleep quality; anxiety; subcortical volume; low-field MRI; 0.35 T; Nigeria

INTRODUCTION

Human immunodeficiency virus (HIV) continues to affect the central nervous system in the antiretroviral therapy (ART) era, even when severe HIV-associated dementia is uncommon. The Frascati framework and subsequent large cohort studies established the persistence and changing phenotype of HIV-associated neurocognitive disorders across the transition to effective combination ART (Antinori et al., 2007; Heaton et al., 2010, 2011). Contemporary neuroHIV research increasingly recognises a heterogeneous phenotype in which cognitive inefficiency, everyday functional difficulty, affective symptoms and other patient-centred outcomes may coexist with relatively subtle or regionally selective neurobiological abnormalities rather than a single stereotyped syndrome (Nightingale et al., 2021, 2023; O'Connor et al., 2023; McMahan et al., 2023). Recent longitudinal work further indicates that the relationship among HIV, ageing, brain structure and cognition is strongly modified by virological control, reinforcing the need to interpret neuropsychological findings within their biological and treatment context rather than assuming a uniform HIV-related trajectory (Kennedy et al., 2026).

Neuropsychological and neuropsychiatric measures capture related but non-equivalent dimensions of this burden. The Patient Assessment of Own Functioning Inventory (PAOFI) reflects subjective cognitive complaints; the CHARTER-derived Instrumental Activities of Daily Living measure (CTADL) assesses everyday functional independence; the Center for Epidemiologic Studies Depression Scale (CES-D) evaluates depressive symptoms; the State-Trait Anxiety Inventory-Trait scale (STAI-Trait) assesses trait anxiety; and the Pittsburgh Sleep Quality Index (PSQI) measures sleep quality (Chelune et al., 1986; Heaton et al., 2004; Radloff, 1977; Spielberger et al., 1983; Buysse et al., 1989). These measures are not treated as interchangeable proxies for objective cognitive impairment. The distinction is especially important in African and other low- and middle-income settings, where culturally and demographically appropriate neuropsychological interpretation remains challenging and where the method used to define cognitive impairment can materially alter both prevalence estimates and correspondence with neuroimaging biomarkers (Dreyer et al., 2021; Gouse et al., 2025).

Structural MRI provides an objective window on cerebral morphology, but the relationship between macroscopic volume and neurobehavioural function in treated HIV is complex. Earlier volumetric work demonstrated independent effects of HIV, ageing and treatment exposure on brain volumes, while later studies linked grey-matter, white-matter and regional subcortical abnormalities with cognitive performance; other cohorts, however, have shown weak or inconsistent correspondence between structural measures and clinical classification (Ances et al., 2012; Nichols et al., 2019; Dreyer et al., 2021; O'Connor et al., 2023). More recent work has strengthened evidence for ongoing brain injury despite treatment: reduced subcortical grey-matter proportion and neurocognitive dysfunction have been reported after long-duration ART, longitudinal grey-matter and global atrophy have been associated with neuropsychological decline, and advanced diffusion MRI has identified microstructural abnormalities in cognitively impaired PLWH (McMahan et al., 2023; Chien et al., 2024; Uddin et al., 2024). Cortical-thickness and connectomic studies similarly suggest that cognitive phenotype may relate to spatially distributed cortical and network abnormalities that are not captured fully by conventional global volumetry (Li et al., 2025; Zhou et al., 2025).

A South African study demonstrated HIV-associated reductions in white matter, thalamic and grey-matter volumes, yet subsequent studies also showed that neuropsychological definitions of impairment do not necessarily map cleanly onto structural or diffusion MRI biomarkers (Heaps et al., 2012; Dreyer et al., 2021). At the same time, quantitative neuroimaging capacity remains uneven across the continent, with access to high-field systems, specialised processing infrastructure and locally appropriate reference data still constrained in many settings (Hasford et al., 2022; Anazodo et al., 2023). The feasibility of lower-field quantitative neuroimaging is therefore increasingly relevant. Recent work has shown that low-field MRI can support brain morphometry, and a 2026 study specifically demonstrated portable low-field MRI segmentation and regional volumetric assessment in virally suppressed PWH (Murata et al., 2022; Samardzija et al., 2024; Sorby-Adams et al., 2026).

This study asks whether inter-individual variation in quantitative global and regional MRI brain volumes is related to continuous measures of subjective cognition, everyday functioning, depressive symptoms, trait anxiety, and sleep quality in PLWH.

MATERIALS AND METHODS

Study design and setting

This was a cross-sectional within-group analysis of PLWH recruited as part of a larger comparative study conducted at Federal Teaching Hospital, Gombe, Nigeria, between November 2025 and March 2026. The present manuscript includes only PLWH receiving ART because its analytical focus is the relationship between quantitative MRI brain volume and neuropsychological or neuropsychiatric measures within the HIV group.

Participants

Sixty-five PLWH receiving ART were recruited. Quantitative MRI volumetry was successfully completed for 60 participants; five MRI datasets were unavailable for segmented analysis because the transferred source (DVDs) was corrupted or empty. Questionnaire data were analysed without imputation using pairwise-complete observations. Among the 60 participants with usable MRI, valid sample sizes were 60 for PAOFI, 60 for CTADL, 57 for CES-D, 58 for STAI-Trait and 56 for PSQI, corresponding to questionnaire-specific missingness of 0, 0, 3, 2 and 4 cases, respectively. The median age of the PLWH cohort was 43 years (IQR 36–49), and 59 participants (90.8%) were women.

MRI Acquisition

MRI examinations were performed using a GE SIGNA Ovation 0.35-T scanner (GE Healthcare, Milwaukee, WI, USA) with an NV Array Head Coil. A standardised sagittal three-dimensional inversion-recovery spoiled gradient-recalled echo (3D IR-SPGR) acquisition was used. The protocol included a 24-cm field of view, frequency encoding 256, phase encoding 192, TR 8.2 ms, inversion time 300 ms, flip angle 15 degrees, NEX 3 and slice thickness 2 mm.

MRI Preprocessing, Segmentation And Normalisation

Images were converted from DICOM to NIfTI format and processed using the FMRIB Software Library (FSL), version 6.0.7.16. Preprocessing included denoising with SUSAN and brain extraction with BET. FAST was used for tissue segmentation, and FIRST was used for automated segmentation of the thalamus, caudate, putamen, globus pallidus, hippocampus, amygdala and nucleus accumbens bilaterally, with the brainstem segmented as a single structure. These FSL tools are established for structural brain processing and subcortical segmentation (Smith et al., 2004; Patenaude et al., 2011).

MRI Quality Control, Segmentation Reliability And Outlier Handling

Quality control was applied before and throughout quantitative processing. Acquisitions were reviewed for complete brain coverage, motion and susceptibility artefacts, ghosting, excessive noise, signal inhomogeneity, grey–white matter contrast and overall suitability for volumetry. After DICOM-to-NIfTI conversion, orientation, coverage and conversion integrity were checked. BET brain-extraction masks, FAST grey-matter, white-matter and CSF segmentations, and FIRST subcortical overlays were visually inspected in axial, coronal and sagittal planes. Outputs were accepted when the complete brain was included, non-brain tissue was satisfactorily removed, tissue and subcortical boundaries were anatomically plausible and no major artefact compromised segmentation. Unsatisfactory extractions or segmentations were reprocessed; datasets that could not meet the predefined quality criteria were excluded. All 60 MRI datasets retained for the present PLWH analysis passed final segmentation quality control. Potentially extreme volumetric values were not discarded solely on statistical grounds: numerical outputs were checked against the source images and segmentation overlays and retained

when anatomically plausible. No automatic trimming or winsorisation was applied. No formal inter-rater, test-retest, manual-tracing or within-participant cross-field-strength reliability study was performed.

Global measurements included total intracranial volume (TIV), total brain volume, grey matter, white matter, cerebrospinal fluid (CSF), brain parenchymal fraction and the grey matter-to-white matter ratio. Grey matter, white matter and CSF were expressed as percentages of TIV. Regional volumes were likewise normalised to TIV using: normalised volume (%) = (absolute regional volume/TIV) × 100. Brain parenchymal fraction was calculated as (grey matter + white matter)/TIV. TIV normalisation was used to reduce nuisance variation arising from inter-individual differences in cranial size (Voevodskaya et al., 2014; Malone et al., 2015).

Neuropsychological And Neuropsychiatric Measures

The continuous measures used in the MRI correlation analysis were PAOFI total score, CTADL total score, CES-D total score, STAI-Trait total score and PSQI global score. Higher PAOFI scores indicate greater perceived cognitive difficulty; higher CTADL scores indicate greater functional independence; higher CES-D and STAI-Trait scores indicate greater depressive and anxiety symptom burden, respectively; and higher PSQI scores indicate poorer sleep quality. The MINI was administered in the parent study for structured psychiatric assessment but was not treated as a continuous correlation outcome in the present MRI analysis.

Statistical Analysis

Statistical analyses were performed using R version 4.6.0. Continuous variables were summarised using medians and interquartile ranges where appropriate. Spearman rank correlation was used to examine relationships between quantitative MRI brain volumes and continuous PAOFI, CTADL, CES-D, STAI-Trait and PSQI scores among PLWH. The analysis comprised 22 MRI measures (seven global and 15 regional measures) tested against five questionnaire outcomes, yielding 110 correlations in total. Pairwise-complete observations were used and missing questionnaire values were not imputed. A two-sided raw $p < .05$ was designated nominal significance. Because all 110 correlations addressed the same exploratory family of MRI-questionnaire associations, the Benjamini-Hochberg procedure was applied across the complete set of 110 tests to control the false discovery rate. BH-adjusted p values (q values) $< .05$ were considered statistically significant after multiplicity correction (Benjamini & Hochberg, 1995). Raw and adjusted p values are reported separately, and the complete correlation matrix, including valid n for every test, is provided in Supplementary Table S1.

RESULTS

Participant Characteristics and MRI Availability

The analysis included 65 PLWH receiving ART, of whom 60 had usable quantitative MRI segmentation data. Table 1 summarises basic characteristics of the HIV cohort. The median age was 43 years (IQR 36–49), 59/65 (90.8%) participants were women, and the median duration since documented HIV diagnosis was 14 years (IQR 10–18). In this cohort, ART commenced at the documented time of diagnosis, so this interval was numerically equivalent to duration on ART. For MRI-questionnaire correlations, pairwise valid n was 60 for PAOFI and CTADL, 57 for CES-D, 58 for STAI-Trait and 56 for PSQI.

Table 1. Selected characteristics of the PLWH cohort

Characteristic	PLWH (n = 65)
Age, years, median (IQR)	43 (36-49)
Sex, female, n (%)	59 (90.8)
No formal education, n (%)	11 (16.9)
Primary education, n (%)	9 (13.8)
Secondary education, n (%)	29 (44.6)
Tertiary/higher education, n (%)	16 (24.6)
Years since commencement of HIV treatment, median (IQR)	14 (10-18)

First-line ART, n (%)	62 (95.4)
TDF/3TC/DTG regimen, n (%)	62 (95.4)
Usable segmented MRI datasets, n	60

Note. ART = antiretroviral therapy; IQR = interquartile range; PLWH = people living with HIV; TDF = tenofovir disoproxil fumarate; 3TC = lamivudine; DTG = dolutegravir.

Global Brain Volume Association

Across the seven global MRI measures and five questionnaire outcomes, only one correlation reached nominal significance. Adjusted white matter volume was inversely correlated with CTADL score ($n = 60$, $\rho = -.30$, raw $p = .018$, BH-adjusted $p = .672$). This association did not survive false-discovery-rate correction. No other global MRI-questionnaire correlation had raw $p < .05$.

Regional Brain Volume Associations

Five regional correlations reached nominal significance. CTADL score was positively correlated with left thalamic volume ($n = 60$, $\rho = .27$, raw $p = .039$, $q = .811$), right globus pallidus volume ($n = 60$, $\rho = .35$, raw $p = .006$, $q = .425$), left hippocampal volume ($n = 60$, $\rho = .26$, raw $p = .043$, $q = .811$), and brainstem volume ($n = 60$, $\rho = .34$, raw $p = .008$, $q = .425$). Left nucleus accumbens volume was positively correlated with STAI-Trait score ($n = 58$, $\rho = .27$, raw $p = .044$, $q = .811$). None survived Benjamini-Hochberg correction.

Overall, 6 of 110 correlations (5.5%) had raw $p < .05$, but none remained statistically significant after Benjamini-Hochberg correction. No PAOFI, CES-D or PSQI correlation reached nominal significance. The MINI was not analysed as a continuous MRI-correlation outcome. Table 2 presents the six nominal findings with their pairwise n , raw p and BH-adjusted p values; the complete 110-test matrix is provided in Supplementary Table S1.

Table 2. Nominal MRI–volume correlations (raw $p < .05$) with pairwise sample sizes and Benjamini–Hochberg-adjusted p values.

Domain/measure	MRI volumetric measure	Valid n	Spearman ρ	Raw p	BH-adjusted p
Everyday functioning (CTADL)	Right globus pallidus	60	.35	.006	.425
Everyday functioning (CTADL)	Brainstem	60	.34	.008	.425
Everyday functioning (CTADL)	Adjusted white matter volume	60	-.30	.018	.672
Everyday functioning (CTADL)	Left thalamus	60	.27	.039	.811
Everyday functioning (CTADL)	Left hippocampus	60	.26	.043	.811
Trait anxiety (STAI-Trait)	Left nucleus accumbens	58	.27	.044	.811

Note. CTADL = CHARTER-derived Instrumental Activities of Daily Living; STAI-Trait = State-Trait Anxiety Inventory, Trait subscale; PLWH = people living with HIV. Raw $p < .05$ indicates nominal significance only. The complete correlation matrix is provided in Supplementary Table S1.

DISCUSSION

Principal Findings

Among PLWH, no MRI–questionnaire association remained statistically significant after control of the false discovery rate. Of 110 correlations, six reached the conventional raw $p < .05$ threshold, predominantly involving everyday functioning measured by CTADL, but all were attenuated after Benjamini–Hochberg correction. The largest nominal coefficients were right globus pallidus–CTADL ($\rho = .35$) and brainstem–CTADL ($\rho = .34$); a smaller nominal association involved left nucleus accumbens volume and trait anxiety ($\rho = .27$). No PAOFI, CES-D or PSQI correlation reached nominal significance. The central result is therefore not evidence of statistically robust regional biomarkers, but a small set of exploratory covariance signals that may require independent replication.

The modest magnitude, mixed direction and loss of statistical significance after multiplicity correction are central to interpretation. Greater regional or tissue volume cannot automatically be equated with better neurobehavioural health, particularly in a cross-sectional design where developmental anatomy, intracranial scaling, ageing, vascular and metabolic factors, ART exposure, neuroinflammation and unmeasured comorbidity may influence structural measurements. Contemporary neuroHIV studies similarly show that brain-behaviour relationships vary by imaging modality, clinical phenotype and virological context (Dreyer et al., 2021; O'Connor et al., 2023; Chien et al., 2024; Kennedy et al., 2026). These nominal correlations are therefore hypothesis-generating rather than diagnostic, causal, or confirmatory.

Global Tissue Measurements

Adjusted white matter volume showed a nominal inverse correlation with CTADL score ($\rho = -.30$, raw $p = .018$), but this association did not survive Benjamini-Hochberg correction ($q = .672$). No other global measure, including total brain volume, TIV, brain parenchymal fraction, adjusted grey matter, adjusted CSF or GM:WM ratio, showed a nominal relationship with the questionnaire outcomes. Global tissue measures average anatomically heterogeneous regions and can therefore obscure focal differences in circuits supporting cognition, arousal, motivation and behaviour. Contemporary HIV imaging studies likewise suggest that regional, cortical or microstructural measures may be more informative than global volumetry in some cohorts (McMahan et al., 2023; Chien et al., 2024; Uddin et al., 2024). The unexpected inverse white-matter-CTADL direction should not be interpreted as evidence that greater white-matter proportion is detrimental; given $q = .672$, chance and residual confounding remain plausible explanations.

Everyday Function And Regional Brain Volume

CTADL produced the broadest nominal regional pattern, involving the left thalamus, right globus pallidus, left hippocampus and brainstem. Everyday functioning depends on distributed cognitive, motor, motivational and arousal systems rather than a single anatomical substrate. HIV-specific imaging literature provides biological context for the functional relevance of these regions: thalamic and subcortical abnormalities have been linked to attention, working memory, motor performance and neurocognitive impairment in prior cohorts (Heaps et al., 2015; Pfefferbaum et al., 2024). However, none of the present CTADL correlations survived false-discovery-rate correction, so biological plausibility should not be mistaken for statistical confirmation.

CTADL is also a multidetermined outcome. Everyday independence is influenced by cognition, mood, physical health, education, social environment, compensatory strategies and opportunity to perform complex activities. This helps explain why structural MRI may account for only a limited proportion of functional variation. Recent consensus recommendations similarly argue against equating an imaging or neuropsychological abnormality with clinically meaningful impairment without considering symptoms, premorbid functioning, comorbidities and everyday function together (Nightingale et al., 2023).

Sleep Quality and Absence of a Volumetric Signal

No correlation between PSQI global score and any of the 22 MRI measures reached the nominal $p < .05$ threshold in the present analysis. This includes global tissue measures and bilateral caudate volumes. Sleep disturbance remains common and clinically important in PLWH, but it is multifactorial and influenced by psychiatric symptoms, medication, pain, social conditions and other health factors (Lee et al., 2024; Melese et al., 2024). The present data therefore do not support a specific macroscopic volumetric correlate of self-reported sleep quality in this cohort.

Nucleus Accumbens and Trait Anxiety

Left nucleus accumbens volume showed a nominal positive correlation with STAI-Trait score ($n = 58$, $\rho = .27$, raw $p = .044$), but the BH-adjusted p value was .811. Anxiety in PWH is unlikely to reflect a single structural pathway. A recent multimodal MRI study of HIV-associated anxiety disorders identified functional-connectivity and regional functional abnormalities together with inflammatory differences, but did not establish a clear group-level structural abnormality (Shan et al., 2024). The present accumbens finding should therefore be treated as exploratory rather than evidence of a structural anxiety biomarker.

Absence of a Uniform Structure-Function Relationship

The absence of nominally significant MRI associations involving PAOFI, CES-D or PSQI further argues against a uniform macroscopic structure-function relationship. Subjective cognitive complaints are shaped by mood, fatigue, health perception and psychosocial context and do not map one-to-one onto objective cognitive impairment. Structural correlates of depressive symptoms and sleep disturbance in HIV are also heterogeneous across cohorts and imaging approaches (McMahan et al., 2023; Peric et al., 2025; Mudra Rakshasa-Loots et al., 2025). These null findings do not imply absence of neurobiological relevance; rather, the measured low-field macroscopic volumes did not provide statistically robust correlates of these symptom domains in this sample.

Multiple Comparisons

The analysis comprised 110 correlations, six of which (5.5%) produced raw $p < .05$; none remained significant after Benjamini–Hochberg correction, and the smallest adjusted p value was .425. The observed 5.5% proportion is numerically close to the conventional 5% nominal threshold, although the tests are correlated and this comparison is not a formal test of the global null hypothesis. It nevertheless reinforces the need to avoid treating the raw p values as confirmatory evidence. Reporting both raw and adjusted p values therefore serves different purposes: the raw results identify candidate signals for future study, whereas the corrected analysis indicates that the present dataset provides no statistically robust evidence for a specific MRI–questionnaire association. The study used a single 0.35-T scanner with 2-mm structural acquisition and automated FSL segmentation; lower signal-to-noise ratio, tissue contrast, voxel size, partial-volume effects and algorithmic assumptions can influence estimates, particularly for small subcortical structures (Marques et al., 2019; Murata et al., 2022; Samardzija et al., 2024). Recent portable low-field work confirms that regional volumetry is feasible, but scanner- and pipeline-specific validation remains necessary (Sorby-Adams et al., 2026).

Strengths And Limitations

All participants underwent a standardised acquisition and processing workflow, with TIV adjustment used to reduce cranial-size confounding. Secondly, the clinical phenotyping spans subjective cognition, everyday functioning, mood, anxiety and sleep rather than relying on a single symptom domain. Finally, the study contributes quantitative neuroHIV data from northeastern Nigeria, a region underrepresented in the structural imaging literature and in global neuroimaging datasets (Hasford et al., 2022; Anazodo et al., 2023).

Several limitations require emphasis. First, the maximum imaging sample was 60 and questionnaire-specific missingness reduced pairwise n to 56–60, limiting precision and statistical power, particularly for small effects. Second, recruitment was from a single tertiary centre and the cohort was predominantly female (59/65; 90.8%),

restricting generalisability and precluding reliable sex-stratified inference. Third, the 0.35-T field strength and 2-mm slice thickness provide lower signal-to-noise ratio and tissue contrast than conventional 1.5-T or 3-T structural imaging and may increase partial-volume and segmentation uncertainty, particularly for small structures such as the amygdala and nucleus accumbens. Although brain extraction, tissue segmentation and FIRST masks were visually quality controlled and potentially extreme numerical values were checked against the images, formal inter-rater, test–retest, manual-tracing or higher-field validation was not performed. Fourth, the cross-sectional design precludes temporal or causal inference, and the clinical battery emphasised self-report and functional measures rather than a fully locally normed multidomain performance battery. Finally, 110 correlations were examined and none survived false-discovery-rate correction. The nominal findings should therefore be regarded as exploratory and potentially susceptible to false-positive error.

Clinical And Research Implications

The findings support a research role for quantitative volumetry as one component of multidimensional neuroHIV phenotyping rather than as a standalone clinical test. Future studies should prespecify a smaller set of anatomically and clinically justified hypotheses, recruit larger multicentre and more sex-balanced cohorts, incorporate locally normed objective cognitive batteries, and obtain longitudinal imaging alongside repeated functional, sleep and affective assessments. Replication at 1.5 T and 3 T, formal repeatability testing at 0.35 T, and manual or cross-platform validation of selected subcortical structures would help distinguish biological signals from scanner- or segmentation-dependent variation. Multimodal approaches combining structural MRI with diffusion, functional or metabolic imaging may also capture clinically relevant processes that macroscopic volumetry alone cannot resolve.

CONCLUSION

Among adults living with HIV receiving ART, six of 110 MRI–questionnaire correlations reached nominal significance, mainly involving everyday functioning, but none remained statistically significant after Benjamini–Hochberg correction. The corrected analysis therefore provides no statistically robust evidence for a specific macroscopic volumetric correlate of subjective cognition, everyday functioning, depressive symptoms, trait anxiety or sleep quality in this cohort. Larger longitudinal, multicentre studies with more balanced samples, locally appropriate neuropsychological assessment, formal low-field segmentation validation and replication across MRI field strengths are required.

Ethics Approval

Ethical approval for the parent study was obtained from the Research and Ethics Committee of Federal Teaching Hospital, Gombe (FTHG/HREC/S.13/398). Written informed consent was obtained from all participants, and study data were handled using coded identifiers.

Funding

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Conflict of Interest

No conflict of interest

Data Availability

The underlying clinical and imaging dataset was generated as part of the doctoral research and is not reproduced in full in this manuscript. The complete de-identified correlation summary used for the present analysis, including all 110 MRI–questionnaire tests, valid pairwise sample sizes, raw p values and Benjamini–Hochberg-adjusted p values, is provided as Supplementary Table S1.

Authors Contribution

Emmanuel Ayuba Buba designed the study, performed the statistical analysis, wrote the protocol and prepared the first draft of the manuscript. Anthony Chukwuka Ugwu and Mohammed Ali Wulgo helped with the study framework and statistical analysis and supervised the study. All authors reviewed and approved the manuscript and contributed to the work.

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