MPPKI MEDIA PUBLIKASI PROMOSI KESEHATAN INDONESIA

Media Publikasi
Promosi Kesehatan Indonesia

e-ISSN 2597-6052
PUBLISHED BY
Fakultas Kesehatan Masyarakat
Universitas Muhammadiyah Palu
Indonesia

RESEARCH ARTICLE

The Role of Nutritional Status in the Quality of Life (QoL) of PLHIV

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ARTICLE HISTORY
Received: 31 March 2026
Revised: 11 August 2026
Accepted: 04 September 2026
Published: 13 September 2026

ARTICLE IDENTIFIERS
Volume 9 - **Issue** 9 - 2026
Pages: 1682-1699
DOI: 10.56338/mppki.v9i9.10729

ABSTRACT

Introduction: Despite significant advances in antiretroviral therapy (ART), multiple factors continue to be associated with the Quality of Life (QoL) among people living with HIV (PLHIV). Although nutritional status may play an important biological role in the observed relationships, limited evidence exists regarding its statistical mediating role between behavioural, environmental, personal, and metacognitive factors and QoL among PLHIV receiving long-term treatment.

Methods: This study employed an analytical cross-sectional design using Structural Equation Modelling–Partial Least Squares (SEM-PLS). Participants were selected using purposive sampling based on predefined inclusion criteria. Sample size adequacy was determined using the 10-fold rule with 10-times rule and G*Power analysis with a medium effect size ($f^2 = 0.15$), significance level of 0.05, and statistical power of 0.80. A total of 127 PLHIV receiving ART participated in the study.

Results: Among 126 PLHIV analysed (purposive, service-based sample), the measurement model showed strong convergent validity (AVE > 0.80) and reliability (Cronbach's alpha > 0.89). Personal, behavioural, environmental, and metacognitive factors were each significantly associated with nutritional status, with personal factors showing the strongest effect ($\beta = 0.468$; $p < 0.001$). Nutritional status, in turn, was significantly associated with Quality of Life ($\beta = 0.746$; $p < 0.001$), while none of the four determinants showed a significant direct association with QoL once nutritional status entered the model. Bootstrapped indirect effects were significant for all four determinants ($\beta = 0.249$ to 0.349; 95% CI excluding zero), a pattern consistent with a statistical mediation model rather than evidence of a causal mechanism. The structural model accounted for 66.2% of the variance in QoL ($R^2 = 0.662$).

Conclusion: In this cross-sectional sample of PLHIV aged 30 years and above, nutritional status showed a statistical pattern consistent with mediating the associations between personal, behavioural, environmental, and metacognitive factors and Quality of Life, explaining 66.2% of its variance ($R^2 = 0.662$). These findings should be read as hypothesis-generating rather than proof of a causal pathway, given the cross-sectional design.

Keywords: People Living With HIV; Nutritional Status; Quality of Life; Metacognitive; Health Determinants

INTRODUCTION

Data from 2023 recorded 39.9 million people living with HIV/AIDS worldwide and 1.3 million new HIV infections that year despite significant progress in antiretroviral therapy (ART) for people living with HIV (PLHIV) (1). Although ART significantly reduces mortality and increases life expectancy for PLHIV, especially in low- and middle-income countries, HIV/AIDS is now recognised as a chronic condition that requires ongoing self-management and support from the health system (2). The HIV pandemic in Indonesia continues to be a major public health issue. South Sulawesi has continued to record HIV cases in recent years, according to provincial health data (3).

Sidenreng Rappang Regency recorded a year-on-year increase in newly reported HIV cases from 2021 to 2024 (31, 36, 46, and 54 cases, respectively), and 175 people living with HIV were receiving antiretroviral therapy (ART) across local health facilities as of 2024 (4). These patterns underscore the need to shift from survival-oriented outcomes to enhancing Quality of Life (QoL) among PLHIV. QoL among PLHIV was assessed across six domains: physical health, psychological health, independence, social relationships, environment, and spirituality (2). Previous research shows that QoL among PLHIV is associated with personal, behavioural, and environmental factors in addition to clinical symptoms (5,6). Long-term antiretroviral treatment has shifted HIV/AIDS care beyond clinical management and may be associated with QoL among PLHIV (7).

Existing evidence on QoL among PLHIV falls into three overlapping strands. Studies in Nepal and Uganda link nutritional indicators such as BMI and dietary intake (8,9) directly to QoL domains. A separate body of work connects psychosocial determinants, including social support and stigma, to QoL or related mental-health outcomes through direct-effect regression models, without a biological mediator in the model (10,11). A smaller, more limited set of studies has tested a single psychosocial determinant's association with a mental-health or QoL-related outcome through a mediation model, rather than testing multiple determinant domains together (12); this strand is thin enough that we frame it as limited rather than absent evidence. None of these three strands, taken alone, explains how personal, behavioural, environmental, and metacognitive factors act together on QoL through a shared biological pathway. This study addresses that gap by testing nutritional status as a statistical mediator of all four determinant domains simultaneously within one structural model.

Nutritional status provides a biological perspective for understanding how multiple factors may relate to health among PLHIV. Good nutritional status supports immune function, healing, energy levels, and physical strength, all of which may influence Quality of Life (13). Although antiretroviral therapy (ART) is effective, malnutrition and weight loss still occur among PLHIV. These conditions can adversely affect health and the ability to perform daily activities (14). Several previous studies have shown that low QoL scores among PLHIV are associated with poor nutritional status, such as low body mass index (BMI) and decreased food intake quality (8,9,15). However, research examining the mediating role of nutritional status between broader determinants and QoL remains limited, particularly within an integrative structural modelling approach.

Bandura's Social Cognitive Theory (SCT) (16) describes health behaviour as the product of reciprocal interaction between personal, behavioural, and environmental factors. The present model draws on this triadic structure to select which determinant domains to include, but tests them as parallel predictors of nutritional status rather than modelling the feedback loops SCT allows, because the cross-sectional design cannot support reciprocal or lagged paths. Metacognitive ability is treated here as distinct from self-efficacy and self-regulation: it captures the planning, monitoring, and evaluation of one's own health-related cognition and behaviour, whereas self-efficacy reflects confidence in performing a specific behaviour (17,18) and self-regulation refers to the ongoing behavioural adjustment itself. Personal, behavioural, and environmental factors were modelled as direct predictors of nutritional status rather than as sequential antecedents of behaviour, because the instruments used here measure standing levels of each construct rather than the behavioural processes needed to test a mediated-through-behaviour pathway; this is a data-driven analytic choice, not a claim that such pathways do not exist theoretically.

Based on this framework, the study tested five hypotheses: personal factors are associated with nutritional status (H1); behavioural factors are associated with nutritional status (H2); environmental factors are associated with nutritional status (H3); metacognitive ability is associated with nutritional status (H4); and nutritional status is associated with Quality of Life, statistically mediating the relationship between the four determinant domains and QoL (H5).

METHODS

Study Design

This study used an analytical cross-sectional design with a Structural Equation Modelling–Partial Least Squares (SEM-PLS) approach to analyse the relationships between determinants and Quality of Life among PLHIV. This design was chosen to examine nutritional status as a mediator of the associations between personal, behavioural, environmental, and metacognitive factors and Quality of Life in PLHIV. The study was conducted from December 2025 to April 2026.

Population and Sample

The sampling frame was the full registry of 203 PLHIV registered in the district ART programme in Sidenreng Rappang Regency as of the 2025 data extract (*Dinas Kesehatan Kabupaten Sidenreng Rappang*), which includes individuals who had become lost to follow-up since their last recorded contact; registry membership therefore reflects programme enrolment history rather than confirmed current ART receipt. All 203 individuals on this list were screened for eligibility over a two-month period (November–December 2025); November was used for administrative preparation and coordination with the three participating hospitals and eleven community health centres, and direct participant contact began on December 5, 2025.

Eligibility was assessed sequentially against the criteria below, and each excluded individual was counted once under the first criterion that applied: 13 were under 30 years of age, 17 were experiencing an acute illness at screening, 8 were pregnant, 18 were classified as lost to follow-up (LTFU) and could not be reached, and 20 were reachable and eligible but declined to participate. None of the 17 illness-related exclusions were for a chronic disease other than HIV; no chronic non-HIV comorbidities were identified during screening in this sample, so the chronic-comorbidity exclusion criterion below was not triggered in practice. This left 127 individuals who met all inclusion criteria and consented to participate, for an overall enrolment rate of 127/203 (62.6%) among the full registry and a participation rate of 127/147 (86.4%) among the 147 individuals who were both reachable and eligible (the 203 registry members minus the 13 under 30, 17 acutely ill, 8 pregnant, and 18 LTFU). Participants were selected using purposive sampling. The inclusion criteria were: (1) aged ≥30 years; (2) receiving ART for ≥6 months; (3) able to communicate and willing to provide informed consent. The age threshold of ≥30 years was a pragmatic sampling decision rather than an evidence-based clinical cutoff: it was intended to focus the sample on PLHIV with an established history of ART engagement, on the assumption that nutritional and self-management patterns are more likely to have stabilised after the initial adjustment period following diagnosis and treatment initiation, but ART duration was already captured separately as an inclusion criterion (≥6 months), so the age threshold adds a further restriction on top of that without its own clinical evidence base; this restriction is carried forward explicitly as a limitation below. The exclusion criteria were: (1) aged under 30 years; (2) an acute illness or a chronic disease other than HIV, to isolate the determinants and outcomes of interest from confounding effects of unrelated comorbidity; (3) pregnancy, given its independent effects on anthropometric status; and (4) lost to follow-up. This clinic-based recruitment approach aligns with common strategies used to capture PLHIV experiences within healthcare settings.
Sample size adequacy for SEM-PLS was determined using two approaches. First, the 10-times rule was applied, which requires a minimum sample size of 10 times the largest number of predictors directed at a single latent construct; in this model, the largest number was 5 (the paths directed at QoL), giving a minimum required sample of 50. Second, an a priori power analysis was performed in G*Power 3.1 (19,20) using the F-test family for linear multiple regression (fixed model, R^2 deviation from zero), with 5 predictors, a medium effect size ($f^2 = 0.15$), $\alpha = 0.05$, and target power of 0.80, giving a minimum required sample of 92. The analysed sample of 126 exceeded both thresholds. A post hoc sensitivity analysis, computed directly from this sample ($n = 126$, 5 predictors, $\alpha = 0.05$), showed an achieved power of 0.928 at $f^2 = 0.15$, and the smallest effect size detectable at 80% power was $f^2 = 0.107$. This confirms that the study was adequately powered for the regression-equivalent endogenous equation predicting Quality of Life from its five predictors (the four determinants plus nutritional status); it does not establish power for the four bootstrapped indirect effects reported in Table 7, since indirect-effect power depends on the joint distribution of the a-path and b-path coefficients rather than on the R^2 of a single regression equation, and this was not directly assessed here.

Research Location

The study was conducted in a regency area in South Sulawesi, Indonesia, involving three hospitals and eleven community health centres.

Variables and Measurement

Instrument Adaptation Procedure

Instruments adapted from previously validated scales (Objective Self-Awareness Scale, General Self-Efficacy Scale, AACTG Adherence Questionnaire, Health-Promoting Lifestyle Profile II, Social Support Questionnaire, Medical Outcomes Study Social Support Survey, Berger HIV Stigma Scale, Metacognitive Awareness Inventory, WHOQOL-HIV BREF) draw on published validation evidence from their original development or from prior use in Indonesian or Southeast Asian samples, as cited in each subsection below. That evidence applies to the source instruments and not automatically to the exact adapted version used here. For this study, the first author translated each instrument into Bahasa Indonesia; a formal forward-backward translation procedure was not conducted. Three field experts, a clinical nutritionist, a public health practitioner, and a district health-office programme head, reviewed the item pool for content relevance and clarity before data collection; this review informed item wording but did not include a formal content validity index such as Aiken's V or I-CVI. Three instruments, the Nutrition Knowledge Questionnaire for PLHIV, the Food Frequency Questionnaire for PLHIV, and the Health Culture instrument, were developed de novo for this study following the procedures described in their respective subsections below. Several instruments, including HIV-Related Stigma, Family Support, and Healthcare Provider Support, combined positively- and negatively-worded items to reduce acquiescence bias; negatively-worded items were reverse-scored (transformed score = maximum item value + 1 − raw response) before item scores were summed within each instrument, so that a higher summed score consistently reflects more of the construct being measured in every instrument. For each instrument, the summed raw score was then categorised into the three ordinal levels described above (low <56%, moderate 56–75%, high >75% of the maximum attainable score); this three-level categorical score, not the raw continuous sum, was the indicator entered into the SEM-PLS model. Treating these categorised, summated Likert-derived scores as metric indicators in PLS-SEM follows common practice for multi-item scales with three or more ordered categories (21); this treatment was not separately verified here through a robustness comparison against the underlying continuous scores, because those scores were not part of the verified analysis dataset used for the reported results, and this is noted as a limitation below. No separate pilot administration was conducted; all instruments were applied directly with the 127 enrolled participants, and study-specific psychometric properties (outer loadings, AVE, Cronbach's α, Composite Reliability) were evaluated using SEM-PLS within the analysed sample and are reported for each construct below. One participant had incomplete responses on several instruments and was excluded listwise, leaving an analysed sample of 126.

Independent Variables

The SEM-PLS model included personal, behavioural, environmental, and metacognitive determinants, each specified as a first-order reflective (Mode A) construct measured by its component indicators. Personal determinants were defined as an individual's own cognitive and psychological capacity for health self-management, distinct from the behaviours that capacity produces (captured separately under behavioural determinants) and from the external conditions surrounding the individual (captured under environmental determinants). Nutrition knowledge, self-awareness, and self-efficacy were grouped under this construct because each reflects a facet of that same underlying personal capacity rather than a standalone behaviour or outcome; the high inter-item loadings and AVE reported below are consistent with this reflective specification. High loadings and convergent validity are consequences of a reflective specification, not evidence for choosing one: the specification itself rests on the theoretical claim that a change in personal capacity is expected to produce a corresponding change in all three indicators together, that the indicators are therefore expected to correlate with one another, and that no single indicator is definitionally necessary to the construct, since dropping any one would not change what "personal capacity for health self-management" means; a formative specification, by contrast, would treat the indicators as separately necessary components that jointly define the construct, which is not how they are conceptualised here (21). For questionnaire-derived indicators, raw item responses were first summed within each instrument and then categorised into three ordinal levels based on the percentage of the maximum attainable score: low (<56%), moderate (56–75%), and high (>75%), following a cutoff convention common in Indonesian health-research practice. These three-level categorical scores, not the raw continuous totals, were the indicators entered into the SEM-PLS model. (1) Personal determinants comprised three indicators: (a) Nutrition Knowledge was measured using the 20-item Nutrition Knowledge Questionnaire for PLHIV (NKQ-PLHIV), developed de novo for this study based on established nutrition knowledge assessment frameworks (22). Items were scored dichotomously (0–1; raw total range: 0–20) before categorisation, with a higher category reflecting superior nutrition knowledge; the item pool underwent the expert content review described above. (b) Self-Awareness was assessed using a 10-item instrument adapted from the Objective Self-Awareness Scale (OSA) (23), rated on a five-point Likert scale (raw total range: 10–50), with a higher category indicating greater capacity for health-related self-awareness. (c) Self-Efficacy was measured using a 10-item instrument adapted from the General Self-Efficacy Scale; the Indonesian version has demonstrated sound construct validity and psychometric equivalence in prior Indonesian and broader Asian samples (24,25). Items were rated on a five-point Likert scale (raw total range: 10–50), with a higher category indicating stronger self-efficacy for health-related behaviour. Personal determinants collectively demonstrated strong convergent validity in this sample (AVE = 0.919; α = 0.956; CR = 0.971).

(2) Behavioural determinants comprised three indicators: (a) Diet Quality was assessed using the 12-item Food Frequency Questionnaire for PLHIV (FFQ-PLHIV), developed de novo for this study, adapted from the standard FFQ framework (26) and contextualised for dietary assessment among ART-treated PLHIV; the item pool underwent the expert content review described above. Items were rated on a five-point Likert scale (raw total range: 12–60), with a higher category indicating higher dietary quality. (b) ART Adherence was assessed using a 12-item instrument developed for this study around the core adherence domains of the Adult AIDS Clinical Trials Group (AACTG) Adherence Questionnaire (27): ARV dosing schedule and dose accuracy (3 items), consistency of healthcare-facility control visits (3 items), adherence to healthcare-provider guidance (3 items), and self-management behaviours supporting adherence, such as reminders (3 items). Unlike the original AACTG instrument's dose-recall format, items here were rated on a five-point frequency scale (Never, Rarely, Sometimes, Often, Always; raw total range: 12–60), consistent with prior Indonesian PLHIV research applying an AACTG-based adherence measure (28). All 12 items were worded in the same direction (higher frequency indicating better adherence), so no reverse-scoring was applied to this instrument. (c) Health-Promoting Behaviour was measured using 15 items adapted from the Health-Promoting Lifestyle Profile II (HPLP-II) (29), previously validated across Southeast Asian populations including Indonesian patients (30). Items were rated on a five-point Likert scale (raw total range: 15–75), with a higher category indicating healthier lifestyle behaviours. Diet quality, ART adherence, and health-promoting behaviour are specified as reflective, not formative, indicators of behavioural determinants because each is conceptualised as an observable expression of the same underlying disposition toward health-protective action, rather than as a separately necessary component that defines that disposition; a stronger disposition toward health-protective action is expected to raise scores on all three indicators together, which is the covariation pattern a reflective direction implies and a formative direction does not require (21). Behavioural determinants collectively demonstrated strong convergent validity (AVE = 0.850; α = 0.917; CR = 0.945).

(3) Environmental determinants comprised five indicators: (a) Family Support was assessed using a 12-item instrument adapted from the Social Support Questionnaire (31), contextualised for the PLHIV care setting. Items were rated on a five-point Likert scale (raw total range: 12–60), with a higher category reflecting stronger perceived family support. (b) Healthcare Provider Support was assessed using a 12-item instrument adapted from the Medical Outcomes Study Social Support Survey (32). Items were rated on a five-point Likert scale (raw total range: 12–60), with a higher category reflecting greater perceived provider support. (c) HIV-Related Stigma was measured using a 12-item abbreviated version of the Berger HIV Stigma Scale (33), previously used among PLHIV populations in Indonesia (34,35). Items were rated on a five-point Likert scale (raw total range: 12–60); scores were reverse-coded such that a higher category indicates lower perceived stigma. (d) Health Culture was assessed using an 8-item instrument developed de novo for this study, grounded in Leininger's Transcultural Nursing Model (36) and the Health Belief Model (37); the item pool underwent the expert content review described above. Items were rated on a five-point Likert scale (raw total range: 8–40). (e) Socioeconomic Status was assessed using a 5-item index

adapted from established multidimensional socioeconomic measures (38), rated on a five-point Likert scale (raw total range: 5–25), with a higher category indicating more favourable socioeconomic conditions. Family support, healthcare provider support, HIV-related stigma, health culture, and socioeconomic status are specified as reflective indicators of environmental determinants on the theoretical premise that each is a manifestation of the same underlying supportive-environment construct rather than a separately necessary component defining it, so that a more supportive environment is expected to raise scores on all five together (21). This is a stronger assumption here than for the other two domains, given the more heterogeneous content spanning interpersonal support, stigma, culture, and socioeconomic status; the reflective model's fit and discriminant-validity statistics in this sample support treating them as reflective, but we cannot rule out that some of these indicators define, not merely reflect, environmental determinants, and a formative re-specification, evaluated through outer weights and redundancy analysis rather than loadings and AVE, remains a reasonable alternative for future work. Environmental determinants collectively demonstrated strong convergent validity (AVE = 0.852; α = 0.956; CR = 0.966).

(4) Metacognitive ability was assessed using 20 items adapted from the Metacognitive Awareness Inventory (MAI) (39), encompassing planning, monitoring, evaluation, and self-adjustment domains. This construct is conceptually distinct from the self-efficacy and self-regulation indicators captured under Personal and Behavioural determinants: it captures awareness and control of one's own thinking about health-related tasks, rather than confidence in performing a behaviour or the behaviour itself. The Bahasa Indonesia version of the MAI (40) has demonstrated sound construct validity and internal consistency (Cronbach's α = 0.904) in prior Indonesian samples, though that evidence concerns the instrument's original learning-context application and not its adaptation to HIV self-management measured here. Items were rated on a five-point Likert scale (raw total range: 20–100), with a higher category indicating greater metacognitive capacity. In the present study, the instrument demonstrated strong internal consistency (Cronbach's α = 0.943) and construct validity (AVE = 0.853; CR = 0.959).

Mediating Variable

Nutritional status was assessed using two objective anthropometric indicators: Body Mass Index (BMI; kg/m²) and Mid-Upper Arm Circumference (MUAC; cm), both measured by trained research assistants following standardised anthropometric protocols. Both indicators were modelled reflectively (Mode A) in SmartPLS (21), consistent with the outer loadings, AVE, Cronbach's α, and Composite Reliability reported for this construct, which are reflective-model statistics; a formative (Mode B) specification would instead be evaluated through outer weights, indicator VIF, and redundancy analysis, none of which were computed here. Conceptually, BMI and MUAC are treated here as two partially redundant, imperfect proxies for the same underlying construct, whole-body nutritional status, rather than as separately necessary components that jointly define it: both are expected to move in the same direction as a person's nutritional status changes, and dropping either indicator would not change what the construct "nutritional status" refers to, even though the two measures are not perfectly interchangeable at the individual level, for example, MUAC can remain comparatively stable during short-term fluid-status changes that shift BMI, or the reverse (41). This theoretical premise, not the loadings reported below, is the basis for the reflective specification; the loadings, AVE, and reliability statistics are consistent with, but do not by themselves establish, that specification. We did not re-estimate the model treating nutritional status as formative (Mode B); this would require evaluating outer weights, indicator VIF, and redundancy analysis, none of which were computed here, and remains a direction for future work. As a sensitivity check, we did re-estimate the model with BMI and MUAC specified as two separate single-indicator mediators rather than as two indicators of one reflective construct; this analysis is reported in the Results section. BMI was classified according to WHO cutoffs (42) into three categories actually observed in this sample: underweight (<18.5 kg/m²; category 1), normal (18.5–24.9 kg/m²; category 2), and overweight (25.0–29.9 kg/m²; category 3); no participant met the obese threshold (≥30.0 kg/m²). MUAC was classified into three categories following NACS (Nutrition Assessment, Counseling, and Support) guidelines (41): severe acute malnutrition (category 1, <18.5 cm), moderate acute malnutrition (category 2, 18.5–22.0 cm), and normal nutritional status (category 3, ≥22.0 cm), following NACS terminology for adolescents aged 15–17 years and adults. In the analysed sample (n = 126), BMI categories were distributed as 47 underweight (37.3%), 39 normal (31.0%), and 40 overweight (31.7%); MUAC categories were distributed as 45 with severe acute malnutrition (35.7%), 40 with moderate acute malnutrition (31.7%), and 41 with normal nutritional status (32.5%). For BMI, the normal category sits between the two extremes, so an increase in the coded category does not necessarily represent movement toward better clinical status in the general sense. For MUAC, by contrast, the NACS categories are ordered by malnutrition severity, so a higher coded category directly corresponds to improved nutritional status; we nonetheless conducted a sensitivity analysis to test whether this ordinal coding tracks QoL as expected in this specific sample, reported in the Results and interpreted in the Discussion. The construct demonstrated strong convergent validity in this sample (AVE = 0.904; α = 0.894; CR = 0.950).

Dependent Variable

Quality of Life was measured using the WHOQOL-HIV BREF (31 items across six domains: physical health, psychological, level of independence, social relationships, environment, and spirituality; five-point Likert scale). The Indonesian version has demonstrated acceptable validity and reliability among PLHIV in Indonesia (43). The six domain scores were treated as reflective indicators of a single global QoL construct, consistent with the instrument developer's original global-score approach and supported empirically in this sample by outer loadings from 0.879 to 0.920 and AVE of 0.805, indicating the domains share substantial common variance. Domain content can overlap conceptually with the environmental determinant construct and, to a lesser extent, with nutritional status; the Fornell–Larcker and HTMT results reported in the Results section were examined specifically for this reason. QoL is empirically distinguishable from personal, behavioural, environmental, and metacognitive determinants, but its HTMT with nutritional status (0.874, 95% CI [0.788, 0.945]) has a confidence interval extending above the conservative 0.90 threshold, so discriminant validity between these two specific constructs cannot be fully confirmed and is discussed as a limitation below. Domain scores were categorised following the same three-level procedure described above, with a higher category indicating better QoL. In the present study, the instrument demonstrated strong internal consistency (Cronbach's α = 0.952) and construct validity (AVE = 0.805; CR = 0.961).

Data Collection Procedures

Data collection was conducted through face-to-face interviews performed by trained research assistants under strict privacy procedures, with anthropometric measurements taken according to standard protocols to ensure accurate and consistent results. Because most predictor and outcome variables were collected from the same respondents, at the same time, and through the same interview method, the design carries some risk of common-method variance and social-desirability bias, particularly for self-reported adherence, health behaviour, stigma, and QoL items. To limit this risk, interviewers received standardised training before data collection and administered items in a private setting with assurances of confidentiality. As a statistical check, Harman's single-factor test was conducted post hoc on all 23 indicators: an unrotated principal component analysis showed the first factor accounted for 34.8% of total variance, well below the 50% threshold commonly used to flag common-method bias as a serious concern. This test has recognised limitations as a sole safeguard, and residual method-related variance cannot be fully ruled out. After data collection, all responses were checked and verified, and one participant's incomplete data were excluded prior to analysis in SmartPLS version 3.

Data Analysis

Preliminary Analysis

Of the 127 enrolled participants, one had incomplete responses across several instruments and was excluded listwise, leaving 126 cases for analysis; no other missing data were present in the analysed dataset. Prior to structural equation modelling, preliminary analysis examined data distribution and multivariate outliers. Univariate normality was assessed using skewness and kurtosis for all 23 indicators: skewness ranged from -0.084 to 0.117 and kurtosis from -1.599 to -1.374, both well within the ±2 range conventionally used to indicate acceptable univariate normality. Multivariate outliers were assessed using Mahalanobis distance (D^2) against a chi-square critical value at $\alpha = 0.001$ ($df = 23$, $\chi^2 = 49.73$); the highest observed D^2 was 47.53, below this threshold, so no cases were identified as multivariate outliers and none were excluded on these grounds. Because PLS-SEM does not require multivariate normality, all 126 cases were retained for the structural analysis.

Structural Equation Modelling — Partial Least Squares (SEM-PLS)

Structural Equation Modelling using Partial Least Squares (SEM-PLS) was performed using SmartPLS version 3, applying the path weighting scheme (21). PLS-SEM was selected over covariance-based SEM for two main reasons: (1) the primary analytical objective is predictive and explanatory rather than confirmatory, which favours PLS-SEM's variance-based approach; and (2) the analysed sample (n = 126) meets PLS-SEM requirements but may be insufficient for the more parameter-hungry estimation demands of CB-SEM. All six constructs, including nutritional status, were specified reflectively (Mode A); no construct in this model was estimated as formative. Analysis followed the two-stage sequence recommended for PLS-SEM (44): evaluation of the measurement model (outer model) before assessment of the structural model (inner model).

Stage 1: Measurement Model Evaluation (Outer Model)

The measurement model was evaluated to establish construct validity and reliability across all six reflective constructs, using the following criteria: (a) Convergent Validity was assessed through two indicators. First, outer loadings (standardised factor loadings) for each indicator were required to exceed 0.70, reflecting that the indicator explains at least 49% of the variance in its respective construct. Second, Average Variance Extracted (AVE) was required to exceed 0.50, indicating that a construct explains more than half of the variance in its indicators; AVE above 0.70 is considered excellent. (b) Internal Consistency Reliability was assessed using two complementary indices. Cronbach's Alpha (α) was required to exceed 0.70, with values ≥ 0.90 considered excellent. Composite Reliability (CR), which weights indicators by their actual loadings rather than assuming equal weighting, was also required to exceed 0.70, with values ≥ 0.90 considered excellent; CR is generally preferred over α for this reason. (c) Discriminant Validity was assessed using both the Fornell–Larcker criterion (45), which requires the square root of each construct's AVE to exceed its highest inter-construct correlation, and the Heterotrait-Monotrait ratio (HTMT), a more sensitive test recommended as a supplement to Fornell–Larcker, with values below 0.90 (conservative threshold) or 0.85 (stricter threshold) indicating adequate discriminant validity (46).

Stage 2: Structural Model Evaluation (Inner Model)

Following confirmation of satisfactory measurement model properties, the structural model was evaluated through the following procedures: (a) Multicollinearity Assessment was conducted prior to path coefficient estimation using the Variance Inflation Factor (VIF). Inner VIF values below 3.3 indicate acceptable levels of multicollinearity among predictor constructs (21). VIF values exceeding 5.0 would signal problematic multicollinearity requiring remediation. (b) Path Coefficient Significance Testing was conducted using nonparametric bootstrapping with 5,000 resamples, consistent with the recommendation (21,47). Bootstrapping generates an empirical sampling distribution without relying on distributional assumptions, yielding t-statistics and 95% percentile bootstrap confidence intervals for each path coefficient (β). A path coefficient was considered statistically significant when the two-tailed p-value was less than 0.05 (t > 1.96). (c) Coefficient of

Determination (R^2) was computed for each endogenous (dependent) latent variable to quantify the proportion of variance explained by its predictor constructs. Interpretive thresholds vary across sources. Cohen (48) proposed R^2 values of 0.26, 0.13, and 0.02 as large, medium, and small effect sizes, respectively, while Hair et al. (21) proposed ≥0.67, 0.33, and 0.19 as substantial, moderate, and weak, respectively, for behavioural PLS-SEM. For consistency, however, all endogenous R^2 values reported in this manuscript were classified using Hair, Ringle, and Sarstedt (2011) (49). (d) Predictive Relevance (Q^2) was assessed using the blindfolding procedure (omission distance D = 7) to evaluate the model's predictive relevance within the PLS-SEM estimation framework for each endogenous construct (50,51); this is distinct from out-of-sample predictive accuracy, which would require a holdout procedure such as PLSpredict and was not performed here. Q^2 values greater than 0 confirm that the model has predictive relevance for the respective construct; values of 0.02, 0.15, and 0.35 indicate small, medium, and large predictive relevance, respectively (21). (e) Model Fit was assessed using the Goodness-of-Fit (GoF) index (52), calculated as the geometric mean of the average AVE and average R^2: $GoF = \sqrt{(\text{Average AVE} \times \text{Average } R^2)}$ Threshold values of 0.10, 0.25, and 0.36 represent small, medium, and large GoF, respectively (53).

Mediation Analysis

Mediation analysis was performed to examine whether nutritional status statistically mediates the relationship between independent constructs (personal, behavioural, environmental, and metacognitive factors) and Quality of Life. Bootstrapping with 5,000 resamples was used to test indirect effects via 95% percentile bootstrap confidence intervals (54), which provide more accurate inference than the Sobel test under non-normality. Because the cross-sectional design cannot establish temporal precedence, results are reported as indirect associations rather than causal mediation. For each determinant, we report the direct effect, the indirect effect through nutritional status, and the total effect, each with its point estimate and 95% bootstrap confidence interval; a confidence interval for the indirect effect excluding zero is described as a significant indirect association, without a full-versus-partial mediation classification, because a non-significant direct path does not itself demonstrate the absence of a direct association and the cross-sectional design cannot establish temporal mediation. This pattern describes the statistical structure of the associations observed in this sample and does not by itself establish that nutritional status is the causal mechanism linking these determinants to QoL.

Ethical Approval

This study was approved by the appropriate institutional ethics committee with approval number 1223416/EC/KEPK/I/11/2025 of Universitas Strada Indonesia, issued on November 28, 2025. All participants provided written informed consent prior to data collection and were informed of the study's purpose and their right to withdraw at any time without consequence. Given the sensitive nature of PLHIV status, strict confidentiality measures were applied throughout the study. All personal identifiers were removed and replaced with unique participant codes during data entry and analysis. Data collection was conducted in a private setting to prevent unauthorised disclosure of HIV status, and all data were stored securely with access restricted to the research team only. No identifying information was included in any report or publication. All procedures were conducted in accordance with the Declaration of Helsinki.

RESULTS

Characteristics of Respondents

Table 1. Summary Characteristics of Respondents

Parameter	Category	Frequency	(%)
Age (year)	30–39	37	29.1
	40–49	68	53.5
	50–59	13	10.2
	≥ 60	9	7.1
Gender	Male	73	57.5
	Female	54	42.5
Occupation	Farmer	32	25.2
	Labourer	24	18.9
	Housewife (Homemaker)	22	17.3
	Private sector employee	21	16.5
	Self-employed	15	11.8
	Government employee	7	5.5
	Unemployed	6	4.7
Health Insurance ownership	Yes (BPJS/insurance)	127	100.0
	No	0	0.0

Data are expressed as frequency and percentage, n (%), for all 127 enrolled participants. Percentages may not total 100 because of rounding.

A total of 127 PLHIV were enrolled in this study; one participant had incomplete data on several instruments and was excluded from the SEM-PLS analysis, leaving an analysed sample of 126 (Table 1 reports demographic characteristics for all 127 enrolled participants). Most participants were aged 40–49 years (53.5%) and were male (57.5%). The predominant occupations were farmer (25.2%), labourer (18.9%), and homemaker (17.3%). All participants were covered by national health insurance. Among the 126 analysed cases, BMI categories were distributed as 37.3% underweight, 31.0% normal, and 31.7%

overweight (no participant met the obese threshold), and MUAC categories were distributed as 35.7% with severe acute malnutrition, 31.7% with moderate acute malnutrition, and 32.5% with normal nutritional status.
Descriptive statistics for all 23 study indicators are reported in Table 2. Because every indicator entered SmartPLS as a three-level ordinal score rather than as a continuous score, the indicators are reported as category frequencies and percentages rather than as means, standard deviations, or medians, consistent with the measurement approach described in the Methods. No indicator showed a pronounced ceiling or floor effect: category frequencies for all 23 indicators fell within a roughly balanced 28.6–38.1% range across the three levels.

Table 2. Category-Level Distribution of Study Indicators (n = 126)

Indicator	Category 1 (%)	Category 2 (%)	Category 3 (%)
Personal - Nutrition Knowledge	36.5	28.6	34.9
Personal - Self-Awareness	34.1	31.7	34.1
Personal - Self-Efficacy	35.7	30.2	34.1
Behavioural - Diet Quality	31.7	36.5	31.7
Behavioural - ART Adherence	28.6	38.1	33.3
Behavioural - Health-Promoting Behaviour	31.0	37.3	31.7
Environmental - Family Support	34.9	34.1	31.0
Environmental - Healthcare Provider Support	34.9	34.9	30.2
Environmental - HIV Stigma (reverse-coded)	34.9	34.1	31.0
Environmental - Health Culture	35.7	33.3	31.0
Environmental - Socioeconomic Status	35.7	34.9	29.4
Metacognitive - Planning	32.5	34.1	33.3
Metacognitive - Monitoring	32.5	33.3	34.1
Metacognitive - Evaluation	32.5	33.3	34.1
Metacognitive - Self-adjustment	33.3	31.0	35.7
Nutritional Status - BMI	37.3	31.0	31.7
Nutritional Status - MUAC	35.7	31.7	32.5
QoL - Physical	35.7	31.0	33.3
QoL - Psychological	36.5	29.4	34.1
QoL - Independence	36.5	33.3	30.2
QoL - Social	36.5	33.3	30.2
QoL - Environment	35.7	31.0	33.3
QoL - Spirituality	35.7	32.5	31.7

Values are percentages among the 126 analysed cases. For questionnaire-derived indicators, categories were low (<56%), moderate (56–75%), and high (>75%) of the maximum attainable score. For BMI, Categories 1–3 correspond to underweight, normal, and overweight, respectively; for MUAC, they correspond to severe acute malnutrition, moderate acute malnutrition, and normal nutritional status, respectively. Percentages may not total 100 because of rounding.

Coefficient of Determination (R^2)

Table 3. Summary Coefficient of Determination (R^2)

Variable	R^2	Adjusted R^2	Result
Nutritional status	0.579	0.565	Moderate
Quality of Life (QoL)	0.662	0.648	Moderate

R^2 and adjusted R^2 for the two endogenous constructs, estimated with the PLS algorithm in SmartPLS version 3 (n = 126).
Note: Result classification follows the PLS-SEM benchmarks applied throughout this manuscript: $R^2 \geq 0.75$ substantial, ≥ 0.50 moderate, ≥ 0.25 weak.
The model explained 57.9% of the variance in nutritional status ($R^2 = 0.579$; R^2 adjusted = 0.565) and 66.2% of the variance in Quality of Life ($R^2 = 0.662$; R^2 adjusted = 0.648), indicating moderate explanatory power for both endogenous variables under the benchmark applied throughout this manuscript (Table 3).

Measurement Model Evaluation

Table 4. Summary of Measurement Model Evaluation Results

Construct	No. of Indicators	Outer Loading Range	AVE	Composite Reliability (CR)	Cronbach's Alpha	Convergent Validity
Personal Determinants	3	0.957 – 0.963	0.919	0.971	0.956	Established
Behavioural Determinants	3	0.887 – 0.946	0.850	0.945	0.917	Established
Environmental Determinants	5	0.902 – 0.941	0.852	0.966	0.956	Established
Metacognitive Ability	4	0.917 – 0.935	0.853	0.959	0.943	Established
Nutritional Status	2	0.948 – 0.954	0.904	0.950	0.894	Established
Quality of Life	6	0.879 – 0.920	0.805	0.961	0.952	Established

Values are outer loading ranges, Average Variance Extracted (AVE), Composite Reliability (CR), and Cronbach's alpha for each reflective construct (n = 126). Convergent validity was established when all outer loadings exceeded 0.70 and AVE exceeded 0.50.
All constructs demonstrated convergent validity, with outer loadings exceeding 0.70 and AVE above 0.50 for every construct. Internal consistency reliability was confirmed through Composite Reliability (CR > 0.94) and Cronbach's alpha ($\alpha > 0.89$) across all constructs.

Sensitivity Analysis: Robustness to Ordinal-to-Metric Treatment
Because all 23 indicators were entered into the SEM-PLS model as three-level categorical scores treated as metric (interval) data, a supplementary robustness check compared this standard treatment against a purely ordinal, rank-based treatment of the same indicators. Each indicator was rank-transformed before model estimation, so that every correlation used in the outer and inner model estimation was equivalent to a Spearman rank correlation rather than a Pearson correlation, with no other change to the estimation procedure. Both specifications were re-estimated with 2,000-resample bootstrapping on the verified analysis dataset. The rank-based treatment produced path coefficients and bootstrap 95% confidence intervals that were, in every path, within 0.002 of the standard interval-treatment estimates (nutritional status → QoL: $\beta = 0.746$, 95% CI [0.583, 0.901] under interval treatment versus $\beta = 0.746$, 95% CI [0.582, 0.900] under rank-based treatment; personal, behavioural, environmental, and metacognitive paths to nutritional status differed by at most 0.002 between treatments), and R^2 values were unchanged to three decimal places (nutritional status: 0.579; QoL: 0.662–0.663). This indicates that treating the three-level categorical indicators as metric did not materially distort the associations reported in this study.

Discriminant Validity Assessment Using Fornell–Larcker

Table 5a. Summary Discriminant Validity Assessment Using Fornell–Larcker

Construct	Personal	Behavioural	Environmental	Metacognitive	Nutritional Status	Quality of Life
Personal Determinants	**0.959**					
Behavioural Determinants	-0.176	**0.922**				
Environmental Determinants	-0.152	-0.027	**0.923**			
Metacognitive Ability	0.005	-0.008	0.027	**0.924**		
Nutritional Status	0.350	0.236	0.337	0.452	**0.951**	
Quality of Life	0.324	0.147	0.268	0.421	0.809	**0.897**

Bold diagonal values are the square root of each construct's Average Variance Extracted; off-diagonal values are inter-construct correlations (n = 126). Discriminant validity is supported when each diagonal value exceeds the correlations in its row and column.
The Fornell–Larcker criterion showed that all constructs met discriminant validity requirements: the square root of AVE for each construct (bold diagonal values in Table 5a) exceeded its correlations with every other construct. Because Fornell–Larcker is a comparatively insensitive test, HTMT values were also computed for all construct pairs (Table 5c).

Table 5b. Summary Inner Collinearity Statistics (VIF)

Construct	Target: Nutritional Status	Target: Quality of Life
Personal Determinants	1.059	1.580
Behavioural Determinants	1.035	1.300
Environmental Determinants	1.028	1.417
Metacognitive Ability	1.001	1.464
Nutritional Status	-	2.375

Values are inner Variance Inflation Factors for each predictor construct in relation to the two endogenous constructs (n = 126). Values below 3.3 indicate acceptable levels of collinearity.
Prior to structural model evaluation, inner collinearity among predictor constructs was assessed using the Variance Inflation Factor (VIF). As presented in Table 5b, all inner VIF values ranged from 1.001 to 2.375, well below the acceptable threshold of 3.3, confirming the absence of multicollinearity in the structural model. All predictor constructs are sufficiently distinct from one another and suitable for path analysis.
HTMT point estimates and bootstrap 95% confidence intervals (5,000 resamples) were computed for all 15 construct pairs (Table 5c). Point estimates for 14 of the 15 pairs were below the stricter 0.85 threshold, with confidence intervals also remaining below the conservative 0.90 threshold, supporting discriminant validity for those pairs. The exception was Nutritional Status–Quality of Life (HTMT = 0.874, 95% CI [0.788, 0.945]): the point estimate sits between the two thresholds, and the confidence interval extends above 0.90, so discriminant validity between these two constructs cannot be fully confirmed at the 95% confidence level. This elevated value plausibly reflects the strong direct path between the two constructs ($\beta = 0.746$) rather than a measurement-model confound, since they draw on entirely different indicator types (anthropometric measurements versus self-reported WHOQOL-HIV BREF domains), but it is also consistent with the possibility that the two constructs share more variance than the structural model assumes.
This finding reinforces the caution already raised elsewhere in this article about over-interpreting the nutritional status–QoL path as a fully distinct causal mechanism. The comparatively low correlations among personal, behavioural, and environmental determinants (Table 5a) were checked against the raw indicator coding and SmartPLS data input; no coding

or reverse-scoring errors were found, and the pattern is consistent with these three domains capturing conceptually distinct aspects of an individual's circumstances that need not covary strongly with one another even though each is separately associated with nutritional status.

Table 5c. Heterotrait-Monotrait Ratio (HTMT) Matrix, with Bootstrap 95% Confidence Intervals

Construct	Personal Determinants	Behavioural Determinants	Environmental Determinants	Metacognitive Ability	Nutritional Status	Quality of Life
Personal Determinants	-					
Behavioural Determinants	0.189 [0.060–0.370]	-				
Environmental Determinants	0.160 [0.049–0.338]	0.068 [0.059–0.231]	-			
Metacognitive Ability	0.029 [0.033–0.215]	0.051 [0.044–0.215]	0.059 [0.051–0.214]	-		
Nutritional Status	0.376 [0.195–0.541]	0.242 [0.081–0.435]	0.361 [0.183–0.524]	0.490 [0.332–0.639]	-	
Quality of Life	0.339 [0.164–0.505]	0.142 [0.066–0.329]	0.276 [0.118–0.442]	0.440 [0.292–0.573]	0.874 [0.788–0.945]	-

Values are Heterotrait-Monotrait ratios computed from the indicator correlation matrix, with 95% confidence intervals from a 5,000-resample percentile bootstrap on the analysed dataset (n = 126).

Sensitivity Analysis: Domain-Specific Quality of Life Outcomes

Because the elevated HTMT value between nutritional status and QoL raises the possibility that the reported association reflects shared measurement variance rather than a relationship distributed across independent QoL domains, nutritional status was examined separately against each of the six WHOQOL-HIV BREF domains, instead of the aggregate global QoL score used in the primary model. Both BMI and MUAC categories showed a positive, statistically significant association with every domain (Spearman's ρ ranging from 0.570 to 0.731 across the six domains for BMI, and from 0.686 to 0.772 for MUAC; Kruskal–Wallis test across the three categories, all $p < 0.001$ for every domain and both indicators). Mean domain scores increased monotonically across ordinal categories for all six domains and both indicators, without exception, from underweight to overweight for BMI and from severe acute malnutrition to normal nutritional status for MUAC. This indicates that the nutritional status–QoL association is not concentrated in, or driven by, any single QoL domain, and is not an artefact specific to the aggregate scoring approach used in the primary model. This check is bivariate and descriptive; it does not re-estimate the structural model with each domain as a separate endogenous variable, so it cannot directly confirm whether the four bootstrapped indirect effects would persist at the domain level, and it does not establish that nutritional status and QoL are measured independently of one another. The elevated HTMT value reported above should still be read as an unresolved discriminant-validity concern that this sensitivity check narrows but does not resolve.

Model Fit & Predictive Relevance (GoF + Q²)

Table 6. Summary Model Fit & Predictive Relevance

Criterion	Value	Threshold	Result
Average AVE	0.864	> 0.50	Acceptable
Average R^2	0.620	0.50–0.75	Moderate
GoF Index	0.732	> 0.36	Large
Q^2 – Nutritional Status	0.507	> 0	Good
Q^2 – Quality of Life	0.522	> 0	Good

The Goodness-of-Fit index is the geometric mean of the average AVE and the average R^2. Q^2 values were obtained by blindfolding with an omission distance of 7 (n = 126).

The Goodness-of-Fit (GoF) index, calculated as the geometric mean of average AVE (0.864) and average R^2 (0.620), was 0.732, above the conventional large-effect threshold of 0.36. This index has been criticised in the PLS-SEM literature for lacking a formal statistical basis and should be read as a descriptive heuristic rather than confirmation of model fit in the covariance-based sense. Blindfolding-based Q^2 values for nutritional status (0.507) and Quality of Life (0.522) were both greater than zero, indicating the model has predictive relevance within the sample used to estimate it; this is distinct from out-of-sample predictive accuracy, which would require a holdout procedure such as PLSpredict that was not performed here.

Direct and Indirect Effects with Bootstrapping Results (5,000 resamples)

Table 7. Summary Direct and Indirect Effects with Bootstrapping Results (5,000 resamples)

Path	Effect Type	β	t	p	Decision
Personal → Nutritional Status	Direct	0.468 (95% CI 0.355–0.572)	8.889	<0.001	Significant
Behavioural → Nutritional Status	Direct	0.334 (95% CI 0.155–0.435)	4.964	<0.001	Significant
Environmental → Nutritional Status	Direct	0.405 (95% CI 0.292–0.506)	7.097	<0.001	Significant
Metacognitive → Nutritional Status	Direct	0.442 (95% CI 0.311–0.568)	6.988	<0.001	Significant
Nutritional Status → QoL	Direct	0.746 (95% CI 0.597–0.897)	9.491	<0.001	Significant

Path	Effect Type	β	t	p	Decision
Personal → QoL	Direct	0.063 (95% CI -0.066–0.205)	0.904	0.366	Not Significant
Behavioural → QoL	Direct	-0.016 (95% CI -0.136–0.079)	0.310	0.757	Not Significant
Environmental → QoL	Direct	0.024 (95% CI -0.104–0.137)	0.373	0.709	Not Significant
Metacognitive → QoL	Direct	0.082 (95% CI -0.055–0.216)	1.231	0.219	Not Significant
Personal → Nutritional Status → QoL	Indirect	0.349 (95% CI 0.256–0.473)	6.366	<0.001	Significant
Behavioural → Nutritional Status → QoL	Indirect	0.249 (95% CI 0.145–0.343)	4.504	<0.001	Significant
Environmental → Nutritional Status → QoL	Indirect	0.302 (95% CI 0.208–0.409)	5.669	<0.001	Significant
Metacognitive → Nutritional Status → QoL	Indirect	0.329 (95% CI 0.221–0.463)	5.260	<0.001	Significant

β denotes standardised path coefficients with 95% percentile bootstrap confidence intervals from 5,000 resamples (n = 126). Direct effects are the paths estimated in the structural model; indirect effects are the product of the corresponding a-path and b-path through nutritional status. A path was considered significant when the two-tailed p value was below 0.05.

All four direct paths from personal, behavioural, environmental, and metacognitive factors to nutritional status were statistically significant, with bootstrap 95% confidence intervals excluding zero (Table 7). Personal factors showed the strongest effect (β = 0.468, 95% CI [0.355, 0.572]), followed by metacognitive ability (β = 0.442, CI [0.311, 0.568]), environmental factors (β = 0.405, CI [0.292, 0.506]), and behavioural factors (β = 0.334, CI [0.155, 0.435]). Nutritional status showed a significant direct association with QoL (β = 0.746, CI [0.597, 0.897]). None of the four determinants showed a significant direct association with QoL once nutritional status was included in the model (all CIs span zero). All four indirect effects through nutritional status were significant, with confidence intervals excluding zero: personal factors (β = 0.349, CI [0.256, 0.473]), metacognitive ability (β = 0.329, CI [0.221, 0.463]), environmental factors (β = 0.302, CI [0.208, 0.409]), and behavioural factors (β = 0.249, CI [0.145, 0.343]). This pattern of significant indirect associations alongside non-significant direct associations is reported descriptively, without a full-versus-partial mediation classification, because the cross-sectional design cannot establish temporal mediation and a non-significant direct path does not itself demonstrate the absence of a direct association.

Total Effects with Bootstrapping Results (5,000 resamples)

Table 8. Summary Total Effect with Bootstrapping Results (5,000 resamples)

Path	β	t	p	Decision
Personal → Nutritional Status	0.468 (95% CI 0.355–0.572)	8.889	<0.001	Significant
Personal → QoL	0.413 (95% CI 0.298–0.543)	6.575	<0.001	Significant
Behavioural → Nutritional Status	0.334 (95% CI 0.155–0.435)	4.964	<0.001	Significant
Behavioural → QoL	0.232 (95% CI 0.035–0.348)	3.109	0.002	Significant
Environmental → Nutritional Status	0.405 (95% CI 0.292–0.506)	7.097	<0.001	Significant
Environmental → QoL	0.326 (95% CI 0.199–0.445)	5.111	<0.001	Significant
Metacognitive → Nutritional Status	0.442 (95% CI 0.311–0.568)	6.988	<0.001	Significant
Metacognitive → QoL	0.412 (95% CI 0.277–0.533)	6.458	<0.001	Significant
Nutritional Status → QoL	0.746 (95% CI 0.597–0.897)	9.491	<0.001	Significant

Total effects are the sum of the direct and indirect effects of each construct on Quality of Life, with 95% percentile bootstrap confidence intervals from 5,000 resamples (n = 126).

Combining direct and indirect effects, all four determinants showed significant total effects on QoL, with 95% confidence intervals excluding zero (Table 8). Personal factors showed the highest total effect (β = 0.413, CI [0.298, 0.543]), followed closely by metacognitive ability (β = 0.412, CI [0.277, 0.533]), then environmental factors (β = 0.326, CI [0.199, 0.445]) and behavioural factors (β = 0.232, CI [0.035, 0.348]). Nutritional status retained the strongest total effect on QoL (β = 0.746, CI [0.597, 0.897]).

Mediation Analysis

The pattern of results, significant indirect associations alongside non-significant direct associations for all four determinants, is consistent with nutritional status statistically mediating the relationship between these determinants and Quality of Life (Table 7). The indirect association was strongest for personal factors (β = 0.349, 95% CI [0.256, 0.473]), followed by metacognitive ability (β = 0.329, CI [0.221, 0.463]), environmental factors (β = 0.302, CI [0.208, 0.409]), and behavioural factors (β = 0.249, CI [0.145, 0.343]). Because the data are cross-sectional, this pattern should be read as a statistical description of the associations observed rather than confirmation that nutritional status is the causal mechanism linking these determinants to QoL. The complete structural model with standardised path coefficients is presented in Figure 1.

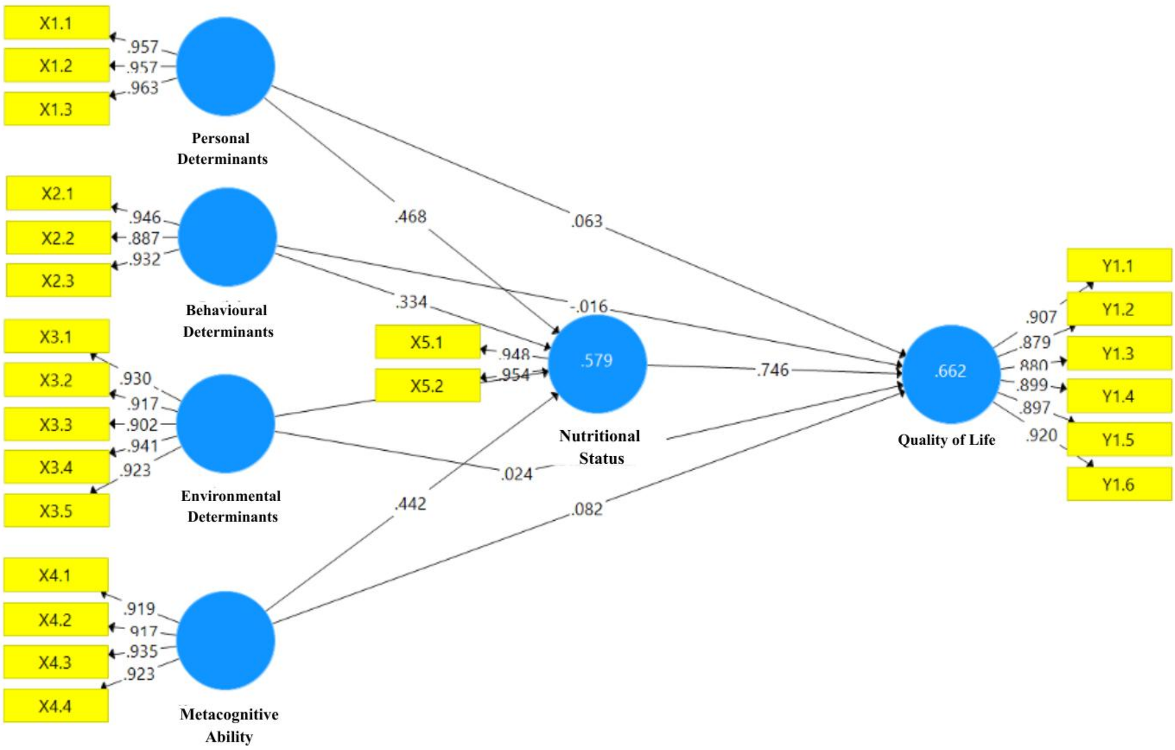

Figure 1. Structural Model with Standardised Path Coefficients (β). Values on each path are standardised path coefficients from the SmartPLS PLS Algorithm output, not bootstrap t-statistics. R^2 values are shown inside the two endogenous constructs (Nutritional Status and QoL).

Estimates were obtained with the PLS algorithm in SmartPLS version 3 (n = 126).

Sensitivity Analysis: Nutritional Status as Separate BMI and MUAC Indicators

As a further check on the reflective two-indicator specification of nutritional status, the structural model was re-estimated with BMI and MUAC specified as two separate single-indicator mediators rather than as two indicators of one reflective construct, so that each anthropometric measure had its own direct paths from the four determinant constructs and to QoL, without imposing an assumption about their joint measurement structure. Both single-indicator mediators were moderately explained by the four determinants, using the benchmark applied throughout this manuscript (49) ($R^2 = 0.504$ for BMI; $R^2 = 0.544$ for MUAC) and both showed significant direct associations with QoL, though of different magnitude (BMI: $\beta = 0.253$; MUAC: $\beta = 0.536$). Combining the indirect effects through both anthropometric measures produced a total similar in magnitude to the indirect association reported for the single combined construct in Table 7 (for example, personal factors: combined indirect $\beta = 0.355$, 95% CI [0.251, 0.471], compared with $\beta = 0.349$, 95% CI [0.256, 0.473] for the original combined-construct specification), and remained significant for all four determinants under bootstrapping. The reported mediation pattern therefore does not depend on combining BMI and MUAC into a single reflective construct. The stronger MUAC path does suggest the two anthropometric measures are not fully interchangeable in their association with QoL.

Sensitivity Analysis: Direction of the Nutritional Status Coding

Because an increase in the ordinal BMI and MUAC categories does not necessarily represent linear improvement in nutritional health, a sensitivity analysis tested whether this coding behaves as expected in the analysed sample. For BMI, categories were collapsed into a binary nutritional-adequacy indicator (adequate = normal category; not adequate = underweight or overweight, collapsing the two extremes into a single group), consistent with the conventional clinical assumption that both extremes represent departures from health. For MUAC, the same middle-versus-extremes collapsing procedure was applied for statistical parallelism with BMI (adequate = category 2, moderate acute malnutrition; not adequate = category 1 or category 3 combined); this grouping does not correspond to the NACS severity ordering, under which category 3 (normal nutritional status), not category 2, represents nutritional adequacy, and this mismatch is noted as a limitation of this check rather than a substantive finding. This adequacy indicator showed a weak, non-significant association with total QoL score (BMI-based adequacy: Spearman's $\rho = 0.07$, $p = 0.46$; MUAC-based adequacy: $\rho = 0.11$, $p = 0.21$), in contrast to the association obtained with the original three-level ordinal coding used in the primary model (BMI: $\rho = 0.73$; MUAC: $\rho = 0.79$; both $p < 0.001$, Kruskal–Wallis test across the three categories, both $p < 0.001$). Mean QoL scores (summed across the six WHOQOL-HIV BREF domains, range 6–18) increased across the three original categories rather than following a U-shaped pattern: for BMI, 8.0 (SD = 2.4) for the underweight group, 12.1 (SD = 3.6) for the normal group, and 15.9 (SD = 3.0) for the overweight group; for MUAC, 7.5 (SD = 2.0), 12.2 (SD = 3.3), and 16.0 (SD = 2.7) for the severe acute malnutrition, moderate acute malnutrition, and normal nutritional status groups, respectively. The overweight subgroup for BMI, and the normal-nutritional-status subgroup for MUAC, reported the highest QoL scores in this sample.

DISCUSSION

Interpretation of Key Findings

This study examined the statistical associations between personal, behavioural, environmental, and metacognitive factors and QoL among PLHIV, testing nutritional status as a mediator in a cross-sectional sample. Because the data were collected at a single time point, the direction of these relationships cannot be established from the model alone. QoL could plausibly influence eating patterns, physical activity, perceived support, or anthropometric status just as easily as nutritional status could influence QoL, and unmeasured clinical factors, such as disease stage, viral load, or comorbidity, could drive both sets of variables simultaneously. The results reported here are statistically compatible with the hypothesised pathway, in which nutritional status sits between the four determinants and QoL, but they do not by themselves distinguish this pathway from reverse or bidirectional alternatives. With this caveat in mind, personal factors showed the strongest association with nutritional status ($\beta = 0.468$, 95% CI [0.355, 0.572]), followed by metacognitive ability ($\beta = 0.442$, CI [0.311, 0.568]), environmental factors ($\beta = 0.405$, CI [0.292, 0.506]), and behavioural factors ($\beta = 0.334$, CI [0.155, 0.435]); together these four factors accounted for 57.9% of the variance in nutritional status.

These findings suggest that nutritional status among PLHIV is statistically associated with multidimensional determinants, including individual capacity, behavioural patterns, environmental support, and self-regulation ability, while none of these determinants showed a significant direct association with QoL. All four indirect associations through nutritional status were significant, while the corresponding direct associations were not; consistent with the cross-sectional design, this pattern is reported as indirect association rather than classified as full or partial mediation. Higher metacognitive ability, healthier behaviour patterns, stronger environmental support, and greater personal capacity were associated with QoL indirectly, through their statistical association with nutritional status.

A central finding of this study was that nutritional status showed a significant direct association with QoL ($\beta = 0.746$, 95% CI [0.597, 0.897]), while none of the other four determinants showed a significant direct association. Personal factors showed the strongest indirect association with QoL through nutritional status ($\beta = 0.349$, CI [0.256, 0.473]), followed by metacognitive ability ($\beta = 0.329$, CI [0.221, 0.463]), environmental factors ($\beta = 0.302$, CI [0.208, 0.409]), and behavioural factors ($\beta = 0.249$, CI [0.145, 0.343]).

The structural model explained 66.2% of the variance in QoL ($R^2 = 0.662$), a moderate effect size by the PLS-SEM benchmarks applied throughout this manuscript. A moderate R^2 on its own does not establish that nutritional status is a key clinical factor: shared method variance across self-report instruments, unmeasured confounders common to both nutritional status and QoL, and construct overlap between nutritional status and QoL (reflected in the elevated HTMT value reported in the Results) could each inflate this figure beyond what a true causal effect would produce. Read cautiously, the explained variance indicates that nutritional status is statistically important within this model rather than proof of its clinical primacy. These results are broadly consistent with Social Cognitive Theory, which frames health outcomes as products of interacting individual, behavioural, and environmental influences, and with prior work linking metacognitive skills such as planning, monitoring, and evaluation to health outcomes (55). SCT-informed interventions have been widely tested in other populations, but applications specific to PLHIV remain limited, and long-term studies tracking SCT-derived mediators such as self-efficacy alongside QoL are still scarce.

Comparison with Previous Studies

The direct association between nutritional status and QoL observed here ($\beta = 0.746$) is consistent in direction with several cross-sectional studies from other PLHIV populations, though direct comparison is limited by differences in design and measurement. A study in Nepal reported that PLHIV with better nutritional status experienced higher QoL, particularly in physical and psychological domains, using continuous nutritional and QoL scores rather than the categorised indicators and structural model applied here. A facility-based study in Nigeria similarly linked nutritional status to QoL among PLHIV (15). The consistency in direction across these differing methods offers modest corroboration, though it does not resolve whether the relationship in any of these studies, including the present one, reflects nutritional status affecting QoL, QoL affecting nutritional intake and status, or both being driven by shared clinical severity.

Similar findings have been reported in Ethiopia, where nutritional knowledge and dietary practice among adults on antiretroviral therapy have been documented alongside their associated factors (56). Beyond anthropometric indicators, food access and diet quality have also been linked to QoL among PLHIV in Uganda (9), and a nutrition-education intervention has been shown to improve QoL among adults living with HIV (57). Collectively, these studies support the observation that nutritional status is associated with QoL among PLHIV, consistent with the direct effect found here ($\beta = 0.746$, 95% CI [0.597, 0.897]). Environmental and social factors also appear relevant: several studies report that social support is positively associated with QoL among PLHIV, consistent with a systematic review and meta-analysis conducted in Ethiopia linking social support to health-related quality of life among PLHIV on antiretroviral therapy (58).

Most previous studies modelled social support and other psychosocial factors as direct predictors of QoL, without a biological mediator in the model, and several report significant direct effects. The present study instead found that environmental factors were associated with QoL only indirectly, through nutritional status ($\beta = 0.302$, 95% CI [0.208, 0.409]), with the direct path itself non-significant once nutritional status was included. Three explanations seem plausible and are not mutually exclusive: nutritional status may genuinely carry part of the effect of environmental support on QoL; the direct effect may have been fully accounted for once the indirect path was added, consistent with attenuation of the direct path to non-significance; or the direct-path coefficient may have been suppressed by shared variance between environmental support and nutritional status, given the moderate correlation between these constructs (Table 5a). Cross-sectional data cannot distinguish between these

explanations. Research showing that social support lowers psychological stress (10,59) offers a plausible mechanism consistent with the indirect pathway found here, though it does not confirm it.
In the present study, behavioural factors showed a significant association with nutritional status (β = 0.334, 95% CI [0.155, 0.435]) and an indirect association with QoL through nutritional status (β = 0.249, CI [0.145, 0.343]). These healthy behaviours are also associated with better nutritional status among PLHIV receiving antiretroviral therapy. Most previous studies evaluated these relationships using direct regression approaches, whereas mediation analysis within a structural model remains uncommon. Prior formative research in Nigeria has documented stigma and community-level concerns as barriers to engagement with HIV prevention services such as pre-exposure prophylaxis (60), highlighting the role of social and contextual factors alongside individual ones, and treatment adherence itself remains an extensively studied clinical outcome among PLHIV in sub-Saharan Africa and North America (61). In the present study, personal factors showed the strongest association with nutritional status (β = 0.468, 95% CI [0.355, 0.572]) and the strongest indirect association with QoL through nutritional status (β = 0.349, CI [0.256, 0.473]), suggesting that nutritional status among PLHIV is closely tied to individual capacity and self-management ability, an area that remains less studied than adherence-focused outcomes in this population.
This study integrates metacognitive ability, distinct here from self-efficacy and self-regulation as described in the Introduction, into a SEM-PLS mediation model of PLHIV QoL. Most existing PLHIV research has examined self-efficacy and self-management behaviour rather than the planning, monitoring, and evaluation processes that the Metacognitive Awareness Inventory was originally developed to measure in learning contexts; applying it to HIV self-management is a conceptual extension that this study cannot fully validate on its own, and it is best understood as an exploratory step rather than a confirmed measurement adaptation. With that caveat, prior work has linked social support, self-efficacy, self-esteem, and self-management behaviours to better clinical outcomes and health behaviours in PLHIV (62), and self-efficacy specifically has been identified as a predictor of self-management behaviour among adults on active antiretroviral therapy. In this sample, metacognitive ability was indirectly associated with QoL through nutritional status (β = 0.329, 95% CI [0.221, 0.463]), a finding that motivates further work on metacognitive approaches in HIV care rather than establishing their effectiveness.
Most previous research has examined the direct relationship between nutritional status and QoL, or between psychosocial factors and QoL, separately. Fewer studies have modelled nutritional status as a mediating variable within a structural equation framework, and adolescent HIV self-management research suggests that self-management capacity is linked to treatment adherence, viral suppression, and health-related quality of life (63). We did not conduct a systematic review of this literature, so we frame this study as one of relatively few attempts, rather than definitively the first, to integrate metacognitive ability into a structural mediation model linking multidimensional determinants, nutritional status, and QoL among PLHIV.

Interpreting the Direction of the Nutritional Status Path

The sensitivity analysis reported in the Results has a direct bearing on how the nutritional status path should be read. If a higher BMI category reflected clinical adequacy in the conventional sense, in which both underweight and overweight represent departures from health, the collapsed adequacy indicator should have shown the strongest association with QoL; instead, that collapsed indicator showed a weak, non-significant association, while the original three-level ordinal coding showed a strong, monotonically increasing relationship with QoL from underweight through normal to overweight. For MUAC, the NACS categories are defined by malnutrition severity rather than a U-shaped adequacy curve, so a monotonic relationship with QoL is consistent with how the categories are defined rather than an unexpected finding on its own; taken together with the BMI pattern, this is still plausible in a PLHIV population specifically: increases in BMI and MUAC following ART initiation are commonly documented as a 'return-to-health' phenomenon, reflecting recovery from HIV-related wasting instead of the excess-adiposity risk pattern typically associated with overweight in the general population (64). On this reading, the positive path from nutritional status to QoL in the primary model should be understood as capturing recovery from a state of nutritional deficit toward and somewhat beyond the normal range for BMI, and toward reduced malnutrition severity for MUAC, rather than movement toward a single optimal midpoint in both cases; this interpretation is specific to a treatment-experienced PLHIV sample and should not be extended to populations or life stages in which excess weight, not recovery from wasting, is the dominant clinical concern.
By identifying a statistical pattern consistent with mediation, this study contributes evidence that personal, behavioural, environmental, and metacognitive factors are associated with QoL through their association with nutritional status, within an integrated structural model. This is best understood as a hypothesis-generating finding: it identifies nutritional status as a variable worth testing further, including in longitudinal or intervention studies, rather than establishing that changing nutritional status will improve QoL. Any application to intervention design should treat nutrition-centred strategies as a testable proposition, not yet as an evidence-based recommendation, and should target recovery from nutritional deficit, not unlimited weight gain, given that the sensitivity analysis above cannot distinguish a genuine benefit of higher BMI/MUAC from a return-to-health artefact specific to this treatment-experienced sample.

Limitations and Cautions

This study has several limitations. First, the cross-sectional design cannot establish temporal order or causal direction; the statistical mediation pattern reported here is compatible with, but does not prove, the hypothesised sequence from determinants to nutritional status to QoL. Second, the purposive, clinic-based sampling strategy and the resulting participation pattern (127 of the 147 reachable and eligible individuals enrolled, with 20 declining; 203 registry members were screened in total, of whom 56 were excluded before reachability or eligibility for participation could be assessed) may have introduced selection bias. Restricting the sample to PLHIV aged 30 years and above who remained engaged in care means the findings may not extend to younger PLHIV or to those who have disengaged from treatment; unlike the ART-duration criterion, this age threshold was a pragmatic sampling decision without a specific evidence-based clinical rationale and is treated here as a limitation on generalisability rather than a validated eligibility criterion. Third, participants with acute or chronic comorbidities other than HIV were excluded, which limits inference to a relatively healthy subgroup of PLHIV and does not reflect the full clinical spectrum seen in routine care; in this sample, all comorbidity-related exclusions were for acute illness identified at screening, and no chronic non-HIV comorbidity was identified. Fourth, the HTMT confidence interval between nutritional status and QoL extended above the conservative 0.90 threshold (Table 5c), so these two constructs cannot be confirmed as fully distinct; some of the reported association between them may reflect shared measurement variance rather than a purely biological pathway. A domain-specific sensitivity check (Results) showed the association holds consistently across all six QoL domains rather than being concentrated in one, which argues against a domain-specific artefact, but this check cannot rule out shared variance at the item or measurement-model level, so this concern remains open. Fifth, the ordinal coding of nutritional status (underweight/low, normal, overweight/high) is not clinically monotonic in general, and although the sensitivity analysis reported in the Results supports treating it as monotonic in this specific treatment-experienced PLHIV sample, this assumption should be re-tested in samples with a different clinical composition, for example a longer-treated cohort with a higher prevalence of ART-associated excess weight gain. Sixth, all data were collected from a single regency in South Sulawesi through self-reported, face-to-face interviews, which carries some risk of common-method variance and social-desirability bias despite the mitigation steps and the Harman's single-factor test described in the Methods. Seventh, several instruments were newly developed or adapted for this study without a full validation programme (formal translation-back-translation, pilot testing, or a quantitative content validity index), so their psychometric properties should be considered provisional pending further validation. Eighth, the structural model did not include demographic or clinical covariates such as ART duration, regimen, disease stage, viral load, CD4 count, opportunistic infections, or time since diagnosis; the reported paths should therefore be read as unadjusted associations that could change once such covariates are accounted for.

Ninth, Personal, Behavioural, and Environmental determinants were specified as reflective constructs on a priori theoretical grounds, particularly for Environmental determinants given the heterogeneity of its five indicators (interpersonal support, stigma, culture, and socioeconomic status); this specification was not tested against a formative alternative using outer weights and redundancy analysis, so the structural coefficients for these three determinants should be read as consistent with, rather than as proof of, a reflective measurement direction. Tenth, nutritional status (BMI and MUAC) was specified as a reflective construct on a priori theoretical grounds; a supplementary analysis (Results) re-estimating BMI and MUAC as two separate single-indicator mediators produced a similar combined indirect association through both measures, which argues against the reflective specification driving the reported mediation pattern, but a formal formative (Mode B) re-specification of the original two-indicator construct was not tested, so some residual measurement-model uncertainty remains, particularly given that nutritional status is the central mediator on which the reported indirect effects depend. Eleventh, all constructs were entered into the SEM-PLS model as three-level categorical indicators derived from summated Likert-type item scores rather than as continuous scores; a supplementary rank-based robustness check (Results) found this treatment did not materially change path coefficients or R^2 values relative to a purely ordinal treatment of the same categories, though this check is not a substitute for re-estimation using the underlying continuous item-level scores, which were not part of the verified analysis dataset used for the reported results. Finally, although the model explains a moderate share of variance in QoL under the benchmark applied in this manuscript (49) ($R^2 = 0.662$), QoL is almost certainly influenced by other factors not measured here, and the explained variance should not be read as evidence of clinical importance or intervention potential on its own.

Recommendations for Future Research

Future studies should employ longitudinal designs to clarify causal relationships among the studied variables, with larger and more diverse samples to enhance generalisability across sociocultural and healthcare settings.

CONCLUSION

In this sample of PLHIV aged 30 years and above, receiving ART for at least six months, and recruited nonprobabilistically from healthcare facilities in one regency, nutritional status showed a statistical pattern consistent with mediating the relationships between personal, behavioural, environmental, and metacognitive factors and QoL. All four determinants were significantly associated with nutritional status, with significant indirect associations and non-significant direct associations with QoL once nutritional status was included in the model, for this sample and model specification; consistent with the cross-sectional design, this pattern is reported as indirect association rather than a full-versus-partial mediation classification. A sensitivity analysis indicated that, in this sample, the ordinal BMI/MUAC coding used in the model tracks QoL monotonically, plausibly reflecting ART-associated recovery from nutritional deficit rather than a general benefit of higher body weight; this pattern should not be assumed to hold in other PLHIV populations or life stages. These findings should not be generalised beyond the population and design studied here. Rather than establishing an intervention sequence, this study identifies nutritional status, individual capacity, health behaviour, environmental support, and metacognitive ability as variables worth testing further in longitudinal and intervention research aimed at improving QoL among PLHIV.

DECLARATIONS

Author contributions: H: conceptualization, methodology, investigation, data curation, formal analysis, visualization, writing–original draft; IN: methodology, validation, formal analysis, writing–review and editing; JP: supervision, resources, formal analysis, writing–review and editing; RA: supervision, project administration, validation, writing–review and editing; N: investigation, methodology, writing–review and editing; ASW: investigation, data curation, writing–review and editing. All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work, ensuring the accuracy and integrity of the research.

Conflicts of interest: The authors declare that there are no conflicts of interest regarding the publication of this manuscript. The authors have no financial or personal relationships that could have appeared to influence the work reported here.

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process: During the preparation of this manuscript, the authors used ChatGPT (OpenAI), QuillBot (free version), Grammarly (free version), and Claude (Anthropic) for language refinement, grammar checking, paraphrasing, and improving the clarity and readability of the manuscript; the exact model version used for each tool at each point in the writing process was not recorded. The authors carefully reviewed and edited all content generated or suggested by these tools and take full responsibility for the integrity, originality, and accuracy of the final manuscript.

Source of Funding Statements: This research received no external funding. The study was self-funded by the corresponding author.

Acknowledgments: The authors thank the Health Office (*Dinas Kesehatan*), hospitals, and community health centres (*Puskesmas*) across Sidrap Regency, including the HIV/AIDS programme managers, for their support during data collection. The authors also thank all people living with HIV who participated in this study.

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