# Body mass index changes during highly active antiretroviral therapy in Nigeria

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**تغيرات منسب كتلة الجسم أثناء العلاج الشديد المفعول بمضادات الفيروسات القهقرية في نيجيريا**

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**الخلاصة:** لا يزال الهزال حالة مهمة يعاني منها الأفراد المصابون بفيروس الإيدز ممن يتلقون العلاج الشديد المفعول بمضادات الفيروسات القهقرية. وفي هذه الدراسة جرى التقييم مقدَّماً لـ 120 مريضاً ممن تم تشخيص حالاتهم حديثاً بالإيدز لتحديد أثر العلاج الشديد المفعول بمضادات الفيروسات القهقرية على منسب كتلة الجسم. وقد زاد وزن 83.1٪ من المرضى، بينما لم يتغير وزن 4.7٪ منهم وفقد 13.2٪ منهم الوزن. وكانت هناك زيادة يُعتدُّ بها في أوساط المرضى الذين يعانون من فرط الوزن والسمنة. ووفقاً للتحليل المتعدد المتغيرات، فقد ارتبط تعداد حديث للخلايا التائية CD4 ومنسب أكثر ارتفاعاً لكتلة الجسم بزيادة أكبر في منسب كتلة الجسم. وترابَطَ فقر الدم عند التشخيص بزيادة يُعتدّ بها في منسب كتلة الجسم. ولم تلاحظ آثار يُعتدّ بها للعمر أو الجنس أو درجة وخامة المرض أو الحمل الفيروسي أو التعليم على إحداث تغيرات في منسب كتلة الجسم. وظهر على حوالي 27٪ من المصابين بفيروس العوز المناعي البشري علامات فقد الوزن، وهو ما يؤكد على أهمية فقد الوزن والهزال باعتبارهما حالتين من الحالات المحددة والمعرفة للإيدز على الرغم من ظهور العلاج الشديد المفعول بمضادات الفيروسات القهقرية. ولوحظ ترابط خطي بين التعداد الحديث للخلايا التائية والزيادة في منسب كتلة الجسم. ويشير الارتباط بين التعداد الحديث للخلايا التائية وزيادة أكبر في منسب كتلة الجسم إلى إمكانية اعتبار منسب كتلة الجسم بديلاً عن تعداد الخلايا التائية في رصد الاستجابة للعلاج في الأوساط ذات الموارد المحدودة.

ABSTRACT Wasting remains an important condition in HIV-infected patients receiving highly active antiretroviral therapy (HAART). In this study, 120 patients with newly diagnosed HIV infection were prospectively evaluated to determine the effect of HAART on body mass index (BMI). Eighty-nine (83.1%) patients gained weight, 5 (4.7%) had no weight change, and 13 (12.2%) lost weight. There was a significant increase in overweight and obese patients. On multivariate analysis, time-updated CD4 count and higher baseline BMI were associated with a greater increase in BMI. Anaemia at diagnosis was associated with a significant increase in BMI. There were no significant effects of age, sex, disease severity, viral load or educational status on BMI changes. About 27% of the HIV patients presented with weight loss, which emphasizes that weight loss and wasting remain important AIDS-defining conditions, despite the advent of HAART. A linear association was observed between time-updated CD4 count and increase in BMI. The association between time-updated CD4 count and greater increase in BMI suggests that BMI could be a surrogate for CD4 count in monitoring treatment response in resource-limited settings.

**Modifications de l'indice de masse corporelle pendant le traitement antirétroviral hautement actif au Nigéria**

RÉSUMÉ L'émaciation est un problème de santé important chez les patients infectés par le VIH sous traitement antirétroviral hautement actif. Dans la présente étude, 120 patients auxquels on a récemment diagnostiqué une infection à VIH ont été évalués de manière prospective pour déterminer l'effet du traitement antirétroviral hautement actif sur l'indice de masse corporelle (IMC). Quatre-vingt-un patients (83,1 %) ont pris du poids, cinq patients (4,7 %) ont conservé le même poids et treize patients (12,2 %) ont maigri. Le nombre de patients en surpoids ou obèses s'est fortement accru. À l'analyse multivariée, la numération récente des CD4 et un IMC initial plus élevé étaient corrélés à une plus grande augmentation de l'IMC. L'anémie lors du diagnostic était associée à une hausse importante de l'IMC. L'âge, le sexe, la sévérité de la maladie, la charge virale ou le niveau d'études n'avaient pas d'effets significatifs sur l'évolution de l'IMC. Près d'un quart des patients infectés par le VIH avaient maigri, ce qui souligne que la perte de poids et l'émaciation restent des manifestations importantes définissant le sida, malgré l'introduction du traitement antirétroviral hautement actif. Nous avons observé une association linéaire entre la numération récente des CD4 et l'augmentation de l'IMC. Cette association semble indiquer que l'IMC pourrait remplacer la numération des CD4 pour ce qui est du suivi de la réaction au traitement dans les contextes où les ressources sont limitées.

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## Introduction

Highly active antiretroviral therapy (HAART) has resulted in a decline in AIDS-defining illnesses, including wasting. However, wasting is a feature of patients with HIV infection [1–3]. Weight loss continues to be a threat to patients and a challenge to clinicians, and it may be catastrophic if progressive [4–8]. Patients and physicians need to understand the dynamics of weight loss in the era of HAART in order to manage it appropriately [9]. There is now a trend in western countries for HIV-infected patients to become overweight or obese due to the beneficial effects of HAART [9,10]. This is thought to be caused by suppression of viral replication, which leads to improvements in weight and body mass index (BMI); however, there are limited prospective data to support this hypothesis [11–13]. In addition, alterations in body shape (e.g. central fat deposition and subcutaneous fat atrophy) have been noted in HIV-infected patients, particularly those who are receiving HAART, but the role of therapy in these changes is not clear [14]. Most prior studies had significant limitations including cross-sectional or retrospective design, or shorter period of study [11,12,14].

Understanding and managing weight loss are complicated because of the impact of HAART use on HIV RNA load, CD4 cell count, and body weight. Lipohypertrophy and lipoatrophy are known side-effects of antiretroviral therapy but can be mistaken for weight gain and loss, respectively. No study to date has provided data on the trends in BMI in HIV-infected patients receiving HAART in Nigeria. Therefore, we carried out this prospective study to assess weight trends in patients on HAART.

## Methods

### Patients

In an observational cohort study, we prospectively collected data from patients with newly diagnosed HIV infection who were eligible for HAART. We enrolled 120 patients with newly diagnosed HIV infection from March to December 2007 at the University of Maiduguri Teaching Hospital, a tertiary institution in Northeastern Nigeria. Patients already receiving HAART were excluded. Thirteen patients defaulted or were lost to follow-up; 10 within 6 months and three within 12 months of recruitment, leaving 107 patients to participate in the study. All study participants provided written informed consent. Permission was obtained from the institutional ethical committee.

### Data collection

Participants were evaluated on a 6-monthly basis and data on body weight, medical conditions, and medications, including HAART, were obtained utilizing standardized collection procedures. Data collected at HIV diagnosis (baseline) included body weight (clothed) and height, and demographics (age, sex, and self-reported educational status). Weight was measured at each subsequent 6-month visit, with a final measurement at 30 months. BMI categories were: underweight < 18.5 kg/m$^2$; normal weight 18.5–24.9 kg/m$^2$; overweight 25–29.9 kg/m$^2$; and obese ≥ 30 kg/m$^2$, as described previously [15,16]. All participants were evaluated for baseline BMI ($n$ = 120) and participants were also evaluated longitudinally from time of HIV diagnosis (baseline) to last study visit ($n$ = 107). BMI was determined at 6-monthly intervals, and changes in BMI within the defined weight category were confirmed by two consecutive measurements during follow-up. The incident cases of becoming underweight, overweight, or obese were confirmed by two consecutive measurements during follow-up. Data collected at each follow-up visit included body weight, CD4 counts, and HIV RNA levels.

### HAART

The HAART regimen comprised two nucleoside reverse transcriptase inhibitors (NRTIs) and one non-nucleoside reverse transcriptase inhibitor (NNRTI). The most common NRTI/NNRTI combinations were zidovudine/lamivudine/nevirapine (57%), emtricitabine/tenofovir/evirapine (20.5%), zidovudine/lamivudine/efavirenz (12.3%), and lamivudine/abacavir/nevirapine (10.2%).

### Blood analysis

Blood was collected at each 6-month visit between 09:00 and 10:00 h and assayed within 6 h of collection. CD4$^+$ T cell count was measured using a CyFlow flow cytometer (Partec, Germany). Haemoglobin was measured using a Sysmex Haematology Analyser (Kobe, Japan). Plasma HIV RNA level was measured using freshly frozen plasma specimens separated within 6 h of phlebotomy with the Amplicor HIV-1 Monitor Test version 1.5 (Roche, Germany), with a minimum cutoff value of 200 copies/mL.

### Statistical analysis

Statistical analyses utilized Fisher's exact tests for categorical variables and Kruskal–Wallis tests for continuous variables. Predictors of BMI at baseline were tested in a multivariate linear regression model. Least mean squares (adjusted to the sample's marginal frequencies) were calculated for predicted BMI by baseline subgroups. The multivariate model was adjusted for age, sex, year of HIV diagnosis, and baseline CD4 count and HIV RNA level. Change in BMI from baseline was determined at each 6-month follow-up visit. Using a longitudinal linear mixed effects model with random intercept and random slope across months of follow-up for each participant, regressions for change in BMI were fitted using all follow-up data. Factors of interest included age, sex, baseline BMI, CD4 count, haemoglobin, HIV RNA

level, AIDS-defining illness, and time on HAART. All time-updated covariates represented the most recently observed value at or prior to each BMI measurement. The multivariate model was adjusted for all factors of interest, as well as for follow-up time. Least mean squares (adjusted to the sample's marginal frequencies) were calculated for predicted changes in BMI during follow-up for each categorical factor. Missing BMI values were not inputted. Results were considered statistically significant for $P < 0.05$. *SPSS*, version 16 (*SPSS*, Chicago, USA) was used for analysis, Microsoft Excel was used to plot graphs where necessary.

## Results

### Baseline characteristics stratified by weight category

Baseline characteristics according to weight are shown in Table 1. There were 47 men (39.2%), with a mean age (SD) of 41.38 (8.39) years, who were significantly older than the 73 women (60.8%), with a mean age of 37.5 (10.2) years ($P < 0.05$). At diagnosis prior to commencement of HAART, 32 (26.7%) patients were underweight, 70 (58.3%) were normal weight, 15 (12.5%) were overweight, and three (2.5%) were obese. The mean BMI at diagnosis was 21.39 kg/m$^2$ (range 12.04–32.46, SD 3.96). Among the men, seven (14.9%) were underweight, 31 (66.0%) were normal weight, eight (17%) were overweight, and one (2.1%) was obese. In comparison, women were more likely to be underweight (25/73, 34.2%, $P < 0.0001$), but less likely to be overweight (7/73, 9.6%, $P < 0.0001$). Overall, the baseline mean (SD) BMI of the men was not significantly different from that of the women [21.06 (3.57) vs. 21.05 (4.96) kg/m$^2$, $P < 0.0001$).

### Changes in BMI during the study period

Over the study period, the percentage of participants overweight and obese at baseline increased (Figure 1) as did the mean BMI (Figure 2). The percentage of participants overweight after 30 months of HAART increased significantly in comparison to baseline (22% vs 14.4%), while obesity increased almost three-fold (6.4% vs 2.5%). The incidence of normal weight remained stable throughout the 30-month study period (57.6% at baseline and 59.9% at 30 months. At baseline, 27% of patients were underweight, but this declined significantly at each 6-monthly measurement to 11.4% at the end of the study ($P < 0.05$). During the course of the study, 99 (83.1%) patients gained weight, six (4.7%) had no weight change, and 15 (12.2%) lost weight. Among the patients who gained weight, mean (SD) annual increase in BMI was 1.11 (0.90) kg/m$^2$, compared with a decrease of 0.30 (0.21) kg/m$^2$ among those who lost weight ($P < 0.05$). Among patients initially underweight at baseline, 40.63% remained underweight at last visit, while 53.13% reached normal weight, 6.25% became overweight, and none became obese. Thirteen (18%) who were normal weight at baseline were overweight, three (4.29%) were obese at last visit ($P < 0.05$), and six (8.75%) of those with normal weight progressed to underweight ($P < 0.05$). The majority of normal weight, overweight or obese patients at baseline remained in these categories.

### BMI at last visit

At their last visit, 14 (11.4%) of patients were underweight, 72 (59.9%) were normal weight, 27 (22%) were overweight, and seven (6.4%) were obese. Women were more likely than men to be underweight (15% vs. 9.5%, $P = 0.01$) or obese (8.3% vs 4.8%, $P < 0.0001$). Conversely, men were more likely to be overweight (31% vs 18.3%, $P < 0.0001$). Mean BMI at last visit was significantly higher in men than in women (23.77 vs 22.79 kg/m$^2$, $P = 0.04$).

### Factors associated with longitudinal trends in BMI

In the multivariate analysis, age, sex, educational status, CD4 cell count, and HIV RNA viral load were not associated with differences in baseline BMI (Table 2).

A repeated measures analysis was performed to identify factors associated with changes in BMI from baseline over the course of HIV infection (Table 3). All factors had estimated mean changes in BMI that were positive and significantly different from zero (all $P < 0.05$) in the multivariate model, but there was no significant difference between the reference categories and other variables within factors, except having haemoglobin < 10 g/dL, which was associated with a significant increase in BMI in comparison to haemoglobin ≥ 10 g/dL ($P = 0.02$) but there was no significant difference between the reference categories and other variables within factors.

Time-updated CD4 cell count was associated with a greater increase in BMI between baseline and last visit (Table 4). A positive correlation was observed between changes in BMI and CD4 cell count ($r^2 = 0.402$, $P < 0.0001$) as shown in Figure 3. For every unit (cells/μL) increase in CD4 count, there was a corresponding 0.402 kg/m$^2$ increase in BMI and vice versa.

Additionally, higher baseline BMI was associated with a greater increase in BMI: patients who were underweight had an average (SD) annual increase of 1.32 (1.37) kg/m$^2$, and participants who were normal or overweight/obese had an average increase of 1.65 (2.0) and 2.99 (3.0) kg/m$^2$, respectively (Table 5). Regarding antiretroviral medication use, cumulative time (months) on ART was associated with increases in weight gain among all patients stratified by weight category (Table 5).

**Table 1 Baseline characteristics by weight of 120 patients in north-east Nigeria with HIV infection initiating HAART**

| Variable | Underweight | Normal | Overweight | Obese | *P*-value |
|---|---|---|---|---|---|
| ***Patients [No (%)]*** | 32 (26.7%) | 70 (58.3%) | 15 (12.5%) | 3 (2.5%) | < 0.05 |
| ***Age (years)*** | | | | | |
| Mean (SD) | 38.83 (7.88) | 43.91 (8.81) | 38.33 (9.25) | 36.67 (11.15) | > 0.05 |
| ***Age group [No (%)]*** | | | | | |
| < 30 | 4 (40.0%) | 3 (30.0%) | 2 (20.0%) | 1 (10.0%) | < 0.05 |
| 30–39 | 10 (30.3%) | 17 (51.5%) | 6 (18.2%) | 0 | < 0.05 |
| > 40 | 17 (22.7%) | 49 (65.3%) | 7 (9.3%) | 2 (2.7%) | < 0.05 |
| ***Sex [No (%)]*** | | | | | |
| Male | 7 (14.9%) | 31 (66.0%) | 8 (17.0%) | 1 (2.1%) | < 0.05 |
| Female | 25 (34.2%) | 39 (53.4%) | 7 (9.6%) | 2 (2.7%) | < 0.05 |
| ***Haemoglobin (g/dL)*** | | | | | |
| Mean (SD) | 11.59 (1.62) | 10.96 (2.21) | 11.14 (1.88) | 11.67 (0.58) | > 0.05 |
| < 10 | 4 (15.4%) | 19 (73.1%) | 3 (11.5%) | 0 | < 0.05 |
| ≥ 10 | 28 (30.8%) | 49 (53.8%) | 11 (12.1%) | 3 (3.3%) | < 0.05 |
| ***CD4 cell count (cells/μL)*** | | | | | |
| Mean (SD) | 223.0 (178.06) | 221.74 (147.32) | 233.67 (193.42) | 237.6 (176.4) | > 0.05 |
| < 200 | 20 (29.9%) | 36 (53.7%) | 8 (11.9%) | 3 (4.5%) | < 0.05 |
| 200–499 | 10 (21.3%) | 32 (68.1%) | 5 (10.6%) | 0 | < 0.05 |
| ≥ 500 | 2 (33.3%) | 2 (33.3%) | 2 (33.3%) | 0 | > 0.05 |
| ***CDC clinical category [No (%)]*** | | | | | |
| Asymptomatic | 2 (11.1%) | 13 (72.2%) | 3 (16.7%) | 0 | < 0.05 |
| ARC | 11 (28.2%) | 21 (53.8%) | 6 (15.4%) | 1 (2.6%) | < 0.05 |
| ADI | 20 (30.8%) | 35 (53.8%) | 6 (9.2%) | 4 (6.2%) | < 0.05 |
| ***WHO clinical stage [No (%)]*** | | | | | |
| I | 1 (9.1%) | 9 (81.8%) | 1 (9.1%) | 0 | < 0.05 |
| II | 9 (24.3%) | 20 (54.1%) | 6 (16.2%) | 2 (5.4%) | < 0.05 |
| III | 12 (37.5%) | 16 (50.0%) | 3 (9.4%) | 1 (3.1%) | < 0.05 |
| IV | 11 (26.2%) | 24 (57.1%) | 5 (11.9%) | 2 (4.8%) | < 0.05 |
| ***Viral load log10 (copies/mL) [No (%)]*** | | | | | |
| Mean (SD) | 4.98 (3.07) | 4.84 (3.30) | 4.82 (3.05) | 4.87 (3.98) | > 0.05 |
| ≤ 200 | 2 (13.3%) | 12 (80.0%) | 1 (6.7%) | 0 | < 0.05 |
| 200–1000 | 2 (40.0%) | 3 (60.0%) | 0 | 0 | > 0.05 |
| 1001–10 000 | 8 (22.9%) | 22 (62.9%) | 5 (14.3%) | 0 | < 0.05 |
| 10 001–100 000 | 11 (27.5%) | 21 (52.5%) | 6 (15%) | 2 (5.0%) | < 0.05 |
| > 100 000 | 9 (36.0%) | 12 (48.0%) | 3 (12.0%) | 1 (4.0%) | < 0.05 |

*ADI = AIDS-defining illness; ARC = AIDS-related complex; CDC = 1993 Revised Classification System for HIV Infection and Expanded Surveillance Case Definition for AIDS Among Adolescents and Adults.*

## Discussion

We demonstrated a high prevalence of underweight among patients with newly diagnosed HIV infection, which was similar to a previous study from Central Nigeria [17]. This is in contrast to a high prevalence of overweight and obesity in a US study [9]. We found that 27% of patients were underweight at the time of HIV diagnosis, which steadily decreased to 11.4% after 30 months of HAART. Some previous studies have found that obesity is more common than wasting in HIV infection [18,19]. However, our findings agree with other studies that suggested that wasting remains a common feature in HIV patients [20–22].

We investigated the effect of 30 months HAART on weight changes in HIV patients. Most patients gained weight during the course of our study, rather than experiencing weight loss or becoming underweight. Weight gain among HIV-infected patients may be

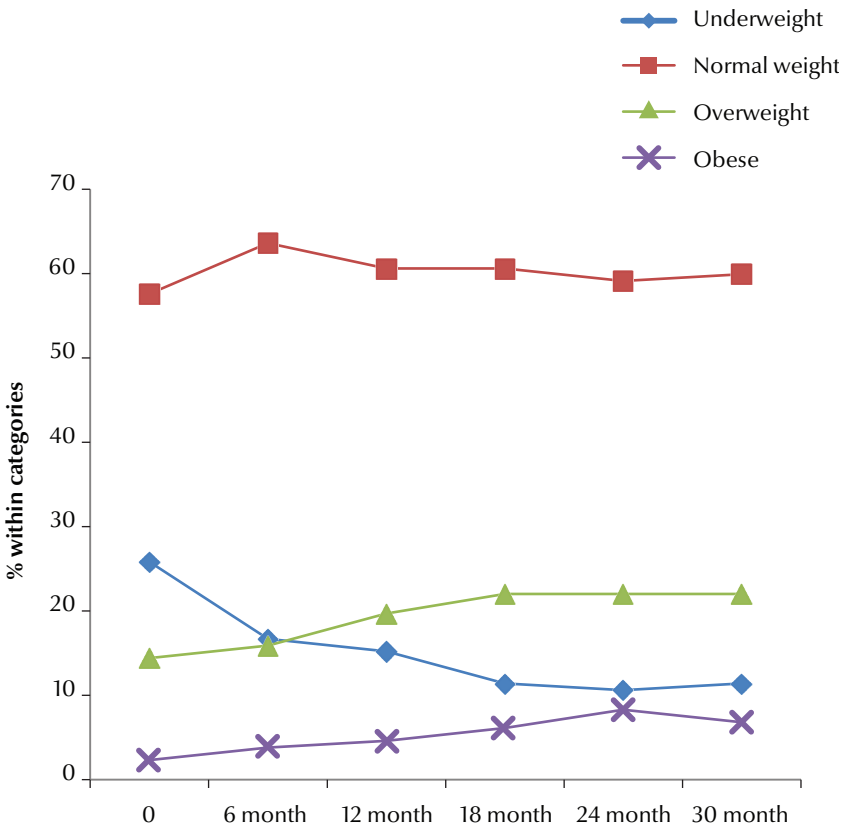


**Figure 1** **Trend of the distribution of the participants by weight category over time**

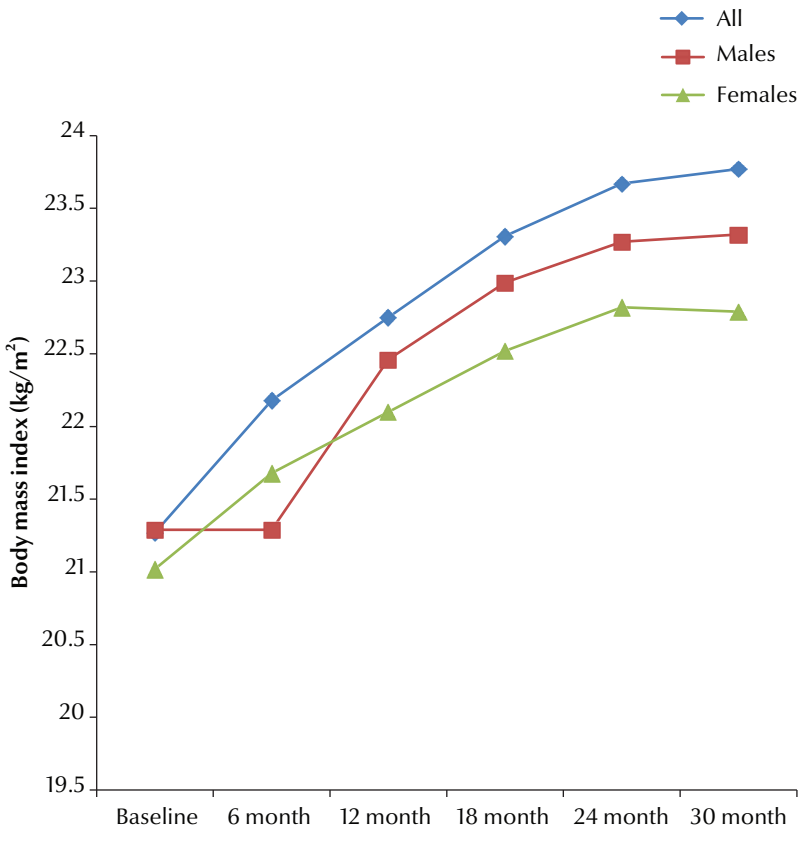


**Figure 2** **Trend in mean body mass index measurements over time**

a sign of the efficacy of HAART in reducing the occurrence of AIDS and wasting. Previous studies have demonstrated weight gain after antiretroviral medication, with a correlation between increased weight and successful virological response [23,24]. Others have implicated potential poor self-esteem [18]. Being underweight was common in our study population with 32/120 (26.7%) patients having a BMI < 18.5 kg/m$^2$. We did not collect data on whether the weight loss was intentional. Our finding is similar to a previous study that showed that 18% of patients lost > 10% of their body weight [21], but is in marked contrast to another study that reported only a 1% prevalence of underweight [9]. The difference in the latter study may be because it had patients with early diagnosis of HIV who had free access to medication, compared with our patients who had more-advanced disease.

Although antiretroviral therapy can reduce the occurrence of end-stage disease and wasting, clinicians now need to be aware of weight excess among their patients. About two-thirds of our patients were in the normal weight category and this remained unchanged throughout the study. However, nearly one-third of patients were overweight or obese at the last visit. This percentage is similar to that in the normal population [17]. This suggests that, as HIV has become a chronic disease, patients' weights may be normalizing to that of the general population. Patients with HIV may be now facing similar issues as the general population with regard to excess weight gain due to poor diet and lack of exercise [25,26].

In the pre-HAART era, being underweight was associated with lower CD4 cell counts and shorter survival, while higher weight was associated with slower disease progression [6,7,27–29]. However, the frequency of wasting has declined in patients receiving HAART [3,19,30,31]. We

**Table 2 Factors associated with baseline body mass index (BMI) among HIV-infected patients initiating HAART: multivariate analysis**

| Variable | Mean BMI (SD) kg/m² | Estimated difference[a] (SD) kg/m² | *P*-value[b] |
|---|---|---|---|
| ***Age group (years)*** | | | |
| < 30 | 21.37 (4.26) | Reference | |
| 30–39 | 20.84 (3.82) | –0.22 (0.94) | 0.81 |
| ≥ 40 | 21.06 (4.81) | 0.31 (1.52) | 0.84 |
| ***Sex*** | | | |
| Male | 21.06 (3.57) | 0.0093 (0.011) | 0.27 |
| Female | 21.07 (4.96) | Reference | |
| ***Educational status*** | | | |
| No formal education | 21.45 (4.55) | 1.42 (1.03) | 0.56 |
| Primary | 20.98 (4.65) | 1.90 (0.99) | 0.38 |
| Secondary | 21.32 (3.52) | 1.34 (1.04) | 0.41 |
| Tertiary | 22.02 (4.76) | Reference | |
| ***CD4 cell count (cells/µL)*** | | | |
| < 200 | 20.84 (5.27) | –1.49 (1.91) | 0.43 |
| 200–499 | 21.25 (3.18) | –1.09 (1.94) | 0.57 |
| ≥ 500 | 22.33 (2.91) | Reference | |
| ***Viral load (log10 copies/mL)*** | | | |
| ≤ 200 | 19.30 (6.35) | –1.44 (1.44) | 0.31 |
| 200–1 000 | 24.71 (2.62) | –3.97 (2.2) | 0.06 |
| 1 001–10 000 | 20.83 (4.29) | 0.89 (1.16) | 0.94 |
| 10 001–100 000 | 21.67 (4.34) | 0.92 (1.11) | 0.41 |
| > 100 000 | 20.74 (3.46) | Reference | |

*[a] The estimated difference is the difference in mean BMI at baseline between the group and the reference.*
*[b] Represents the difference in mean BMI at baseline between the group and the reference.*
*SD = standard deviation.*

investigated the relationship between longitudinal weight measurements, CD4 count, viral load and haemoglobin. After HAART initiation, CD4 cell counts increased in each weight category. Overweight/obese compared to underweight or normal weight patients had significantly higher CD4 cell counts after HAART initiation, in contrast to a previous similar comparison that reported a decrease [8,22,29,30]. Our study demonstrates that weight does affect CD4 cell count during HIV infection, unlike in previous studies [11,18,30].

In addition, we noted that patients who were overweight/obese at baseline had the highest CD4 cell count increase and highest BMI at the last clinic visit. This suggests that those who do not experience end-stage HIV disease are more likely to be overweight. This agrees with the relationship between end-stage AIDS and the development of wasting that was seen in the pre-HAART era [32]. Likewise, HIV patients who were overweight/obese, as well as those who gained weight during the course of infection, were more likely to have higher CD4 cell counts at the last visit. This may be related to the fact that those who do not experience end-stage disease or low CD4 cell counts are less likely to have wasting or unintentional weight loss. Concurrent with our findings, prior studies in HAART-naive patients found that higher weight was associated with more significant increases in CD4 counts as well as slower HIV progression and improved survival [6,27,28]. It is hypothesized that nutritional reserves, in the form of fat stores, may prevent severe wasting and lean body loss at the time of AIDS-related crises and preserve immune cell counts [29]. As the incidence of wasting and end-stage AIDS has significantly declined due to HAART use [3,19,30–32], the potential benefits of maintaining higher weight may have changed. We specifically examined type of HAART regimen and found no relationship with weight among our cohort (data not shown).

Several factors were associated with a greater increase in BMI in our study. Greater increase in weight was likely related to the positive effect of HAART in preventing HIV-related complications, including wasting. High CD4 cell count was also associated with increased weight gain,

**Table 3 Factors associated with changes in body mass index (BMI) in HIV-infected patients initiating HAART**

| Variable | Estimated mean change in BMI | Estimated mean difference in change in BMI (SE) | *P*-value |
|---|---|---|---|
| ***Age group (years)*** | | | |
| < 30 | 1.47 | Reference | |
| 30–39 | 2.01 | –0.54 (1.08) | 0.62 |
| ≥ 40 | 2.35 | –0.88 (1.02) | 0.40 |
| ***Sex*** | | | |
| Male | 2.44 | 0.60 (0.47) | 0.21 |
| Female | 1.85 | Reference | |
| ***Baseline anaemia status [(haemoglobin (g/dL)]*** | | | |
| < 10 | 3.16 | 1.31 (0.56) | 0.02 |
| ≥ 10 | 1.85 | Reference | |
| ***CD4 cell count (cells/μL)*** | | | |
| < 200 | 2.29 | –0.28 (0.93) | 0.76 |
| 200–499 | 1.97 | 0.03 (0.96) | 0.97 |
| ≥ 500 | 2.00 | Reference | |
| ***Baseline WHO clinical stage*** | | | |
| I–III | 1.76 | 0.45 | 0.37 |
| IV | 2.21 | Reference | |
| ***Viral load (log10 copies/mL)*** | | | |
| ≤ 200 | 2.10 | 0.29 (1.02) | 0.82 |
| 200–1 000 | 0.84 | 1.48 (1.23) | 0.23 |
| 1 001–10 000 | 2.29 | 0.04 (0.69) | 0.96 |
| 10 001–100 000 | 2.11 | 0.66 (0.74) | 0.74 |
| > 100 000 | 2.33 | Reference | |

*SE: standard error.*

similar to other studies [11–13]. However low viral load and improved HIV status, as measured by the absence of AIDS diagnosis, was not associated with weight gain in our study. Other studies on weight patterns have shown no clear relationship between weight and HAART [11,18,30]. Taken together, these data suggest that HAART may not play a direct role in causing excess weight, and the weight gain seen with HAART may rather be related to improved health status as a result of therapy. An additional reason for weight gain may be the increased prevalence of weight excess in the general population [33]. Underweight at HIV diagnosis was linked to similar weight gain as for normal weight ($P > 0.05$) but it was significantly lower than for the overweight and obese categories ($P < 0.05$). Although the exact nature of this finding is unclear, patients who initially had more advanced disease and lower weight may have become healthier and gained weight over time. Another possible explanation is that HIV-infected patients who perceive that they have a low BMI may gain

**Table 4 Adjusted model for association between time-updated body mass index (BMI) category and change in CD4 cell count**

| BMI category (time-updated) | Estimated mean change (SE) (cells/μL) | Estimated difference (cells/μL) | 95% CI (cells/μL) | *P*-value |
|---|---|---|---|---|
| Underweight | 239.55 (234.52) | 43.55 | 150.43–328.76 | < 0.0001 |
| Normal weight | 293.73 (229.17) | 29.84 | 234.00–353.45 | < 0.0001 |
| Overweight/obese | 359.67 (318.03) | 74.96 | 201.51–717.01 | < 0.0001 |

*Models adjusted at last visit for age, sex, baseline CD4 cell count and HIV RNA, and time-updated months on HAART. Results presented for each BMI category represent average CD4 changes based on BMI at presentation.*
*CI = confidence interval; SE = standard error.*

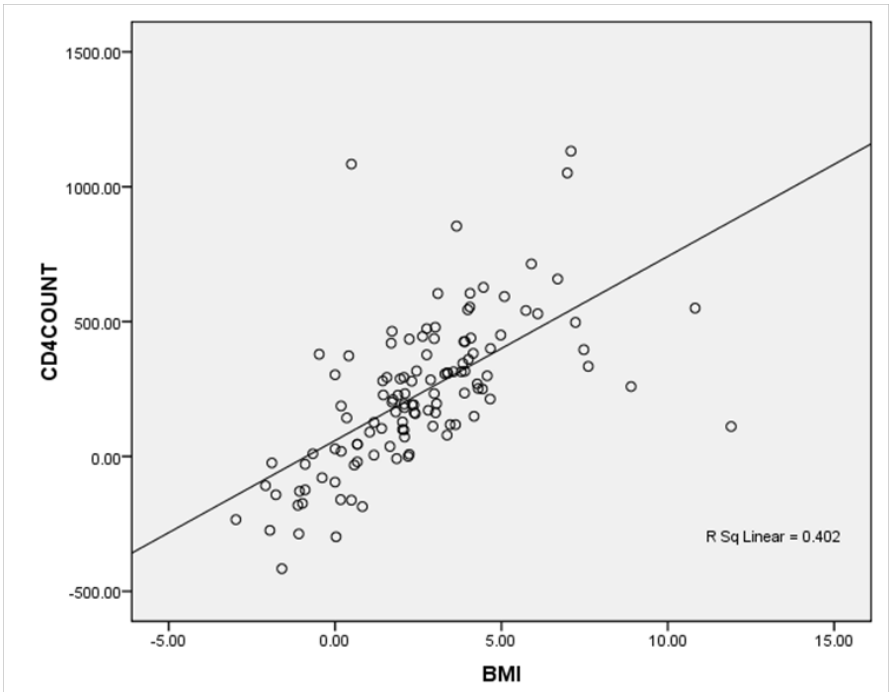


**Figure 3 Relationship between changes in body mass index (BMI) and CD4 cell count**

more weight in an attempt to obscure their diagnosis [28].

Compared to cross-sectional or retrospective studies, our study had the advantage of examining longitudinal ART use in a clinical practice setting. To the best of our knowledge this is the first study to investigate the pattern of weight changes in patients on HAART in Nigeria. Our study had some limitations: (1) the observation period was only 30 months and the sample size was small; (2) we did not evaluate the impact of different antiretroviral regimens on weight changes; (3) it was not a case–control study with antiretroviral naïve patients; and (5) weight gain could have been caused by lipohypertrophy, which is a known side effect of antiretroviral medication.

In conclusion, about 27% of the patients with newly diagnosed HIV infection presented with weight loss in our study. This emphasizes that weight loss and wasting remain important AIDS-defining conditions, despite the advent of HAART. The association between time-updated CD4 cell count and greater increase in BMI suggest a linear relationship between weight gain and immunological improvement suggests that BMI could be a surrogate marker for CD4 cell count in monitoring treatment response in resource-limited settings.

**Table 5 Change in parameters stratified by weight category in HIV-infected patients initiating HAART**

| Body mass index (BMI) category | Mean change (SD) | SE | 95% CI | *P*-value[a] | *P*-value[b] |
|---|---|---|---|---|---|
| ***Underweight*** | | | | | |
| BMI change (kg/m²) | 1.32 (1.37) | 0.51 | 1.60–3.68 | 0.012* | < 0.001* |
| CD4 cell count (cells/μL) | 239.55 (234.52) | 43.55 | 150.43–328.76 | 0.09 | < 0.001* |
| Viral load (log10 copies/mL) | 3.81 (4.0) | 0.63 | –5.0 to –4.43 | 0.47 | < 0.001* |
| Haemoglobin (g/dL) | 2.35 (2.66) | 0.49 | 1.33–3.36 | 0.06 | < 0.001* |
| ***Normal weight*** | | | | | |
| BMI change (kg/m²) | 1.65 (2.0) | 0.26 | 1.13–2.17 | | < 0.001* |
| CD4 cell count (cells/μL) | 293.73 (229.17) | 29.84 | 234.0–353.45 | | < 0.001* |
| Viral load (log10 copies/mL) | –4.02 (–5.35) | 0.66 | –5.23 to –4.57 | | < 0.001* |
| Haemoglobin (g/dL) | 1.28 (1.35) | 0.18 | 0.92–1.63 | | < 0.001* |
| ***Overweight/obese*** | | | | | |
| BMI change (kg/m²) | 2.99 (3.0) | 0.71 | 1.5–4.49 | < 0.001* | < 0.001* |
| CD4 count (cells/μL) | 359.67 (318.03) | 74.96 | 201.51–717.80 | 0.45 | < 0.001* |
| Viral load (log10 copies/mL) | 3.53 (4.59) | 0.70 | 4.73–4.17 | 0.93 | < 0.001* |
| Haemoglobin (g/dL) | 1.50 (1.50) | 0.36 | 0.75–2.25 | 0.91 | < 0.001* |

**Statistically significant.*
*[a]Statistical significance versus normal weight category; least-squares difference of one-way analysis of variance.*
*[b]Statistical significance of change within a factor between baseline versus end of study; least-squares difference of one-way analysis of variance.*
*SD = standard deviation; SE = standard error; CI = confidence interval.*

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