Weight change after antiretroviral therapy initiation among adults living with human immunodeficiency virus in Northwest Ethiopia: A longitudinal data analysis

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Abstract

Objectives: The first objective was to explore weight change in the first two years after antiretroviral therapy (ART) initiation in adults living with human immunodeficiency (HIV). The second objective was to identify the predictors of weight change over time among adults living with HIV on ART.

Design: An institution-based retrospective longitudinal study was conducted.

Setting: The study was conducted at Debre Markos Comprehensive Specialized Hospital, Northwest Ethiopia.

Participants: The study included 848 randomly selected medical charts of adults living with HIV receiving ART between June 2014 and June 2020.

Primary and secondary outcomes: The primary outcome was weight change in the first two years after ART initiation. The secondary outcome was to identify predictors of weight change. Association between predictor variables and weight change was assessed using a linear mixed-effect model. Variables with p-values < 0.05 in the final model were considered as statistically significant predictors of weight change.

Results: Of 844 study participants, more than half (n=499; 58.8%) were female. Participants' mean weight increased from 54.2kg (SD± 9.6kg) at baseline to 59.5kg (SD± 10.7kg) at the end of follow-up. Duration of time on ART, sex, World Health Organization (WHO) clinical disease staging, functional status, nutritional status, and presence of opportunistic infections (OIs) were significant predictors of weight change at ART initiation. Significant interaction effects were observed between time and sex, WHO clinical disease staging, functional status, isoniazid preventive therapy (IPT), and nutritional status.

Conclusion: We found a linear increment of weight over 24 months of follow-up. Rate of weight gain over time was lower in patients with advanced disease stage and working functional status, whereas weight gain rate was higher in male and underweight patients.

Keywords: Adults living with HIV, ART, Ethiopia, weight change

Strengths and limitations of the study

- One of the strengths of this study is its large sample size (n=848), increasing precision.
- This study is the first of its kind to explore weight change in adults living with HIV in our study area.
- Longitudinal measurements on weight allowed us to thoroughly examine changes in weight over two years after ART initiation.
- Due to the retrospective nature of the study design, some important factors, such as dietary habits, physical activity, viral load (available only for 15% of all patients), and smoking status, were not available.
- We were unable to determine the anatomical distribution of weight gain, as data on body composition were not available.
- The generalizability of our results to other settings, particularly to developed countries, could be limited because we have defined adulthood as age ≥15 years.

Introduction

Human immunodeficiency virus (HIV)-associated weight loss and wasting syndrome are the most frequently occurring Acquired Immunodeficiency Syndrome (AIDS)-defining conditions and are associated with a higher risk of mortality and morbidity.[1-3] Conversely, weight gain after antiretroviral therapy (ART) initiation is a good prognostic sign and associated with lower risk of mortality in underweight and normal-weight patients.[4, 5] Though initiating highly active antiretroviral therapy (HAART) can significantly increase body weight and lean body mass, particularly within the first year,[6-8] the mechanisms are not fully understood.[9, 10] Weight gain after ART initiation could be due to the reversal of HIV-related catabolic effects (return-to-health). ART also reduces the occurrence and recurrence of opportunistic infections

(OIs) and enhances gastrointestinal function, increasing appetite and nutrient absorption [11]. It could also result from some antiretroviral regimens' side effects.[12, 13]

Weight is one of the World Health Organization's (WHO) clinical staging parameters used to classify HIV-infected patients.[14] Adult and adolescent patients with moderate unexplained weight loss (5-10%) are classified as stage II, patients with unexplained severe weight loss (>10%) are classified as stage III, and those with HIV wasting syndrome are classified as stage IV[15]. In developing countries, where monitoring the immunological and virological responses of patients is challenging (as routine viral load and CD4 cell count tests are expensive or simply unavailable),[16] regular weight measurement is one of the most cost-effective tools used to monitor patients' clinical responses to ART.[17]

Current Ethiopian ART treatment guidelines recommend that weight must be measured and recorded at each ART visit, demonstrating the importance of weight control[15]. However, these guidelines do not discuss what constitutes an optimal weight gain after ART initiation in this population. Moreover, even if weight gain after ART initiation is common, not all patients gain weight, and gains vary meaningfully across individuals.[11, 18, 19] Longitudinal studies investigating weight change over time after initiating ART are essential to inform treatment guidelines. Additionally, identifying modifiable risk factors of weight gain in this population can help to improve the overall treatment outcomes. However, studies on longitudinal weight change after ART initiation among adults living with HIV in Ethiopia are scarce. Due to this, evidence-based weight management guidelines and recommendations are not available in this population in the context of Ethiopia, as mentioned above. This study explored weight change in the first two years after ART initiation among adults living with HIV. The findings of this study will assist decision-makers, clinicians, and program planners to improve the quality of HIV patient care by enhancing the understanding of weight changes after initiating ART. Findings may also assist both adults living with HIV and clinicians in managing weight,

particularly in resource-limited stings, including Ethiopia. In such settings, access to laboratory tests are limited; identifying simple and cost-effective tools to monitor disease progression such as weight measurement is imperative.

Methods

Study setting, design, and period

An institution-based retrospective longitudinal study was conducted among adults living with HIV receiving ART between June 2014 and June 2020 at Debre Markos Comprehensive Specialized Hospital (DMCSH), Northwest Ethiopia. DMCSH is located in the East Gojjam administrative zone, Northwest Ethiopia, 300 km from Addis Ababa, the capital city of Ethiopia. It is currently the only referral hospital in East Gojjam Zone, with a catchment population of more than 3.5 million people. The total recorded number of PLHIV having ART initiated at DMCSH between June 2014 and June 2020 was 1,209, of which 1,177 (97.4%) were aged ≥ 15 years (adults). Despite ART care services are being uniform in all health facilities and provided by ART-trained persons, DMCSH hospital was selected because it provides ART follow-up and care services for a large proportion of HIV-positive patients (accounted for 36.6% (1,209) of all patients) in the East Gojjam Zone.

Study population

All adults living with HIV receiving ART between June 2014 and June 2020, who had at least two weight measurements (two visits) during ART follow-ups at DMCSH were eligible for inclusion. In this study, adulthood was defined as patients' ≥ 15 years of age since this population is considered and treated as adults in Ethiopia for treatment purposes. Patients transferred into DMCSH from other health institutions without baseline information and pregnant women were excluded. Pregnant women were excluded as pregnancy leads to weight gain, and nutritional assessment for pregnant women differs from other adults living with HIV.[20]

Sample size and sampling procedure

The sample size was determined using a formula for an independent cohort study, using Open Epi Version 3[21] by considering the following parameters: α of 5%; power of 80%; $Z_{\alpha/2}$ of 1.96; P_0 of 19%; P_1 of 27%; and r of 1:1. The values of parameters to calculate sample size were taken from a previously conducted study in Ethiopia.[22] The calculated sample size was 802. After considering 10% chart incompleteness, the final sample size was 892. Then, the study participants were selected using a computer-generated simple random sampling technique. A list containing the medical registration number (MRN) of all adults living with HIV (n=1,177) who started ART between June 2014 and June 2020 was obtained from the health management information system unit of the DMCSH. A random number was generated for each patient using Microsoft™ Excel. These numbers were used to randomly select a sample of 892 participants from all adults living with HIV who started ART at DMCSH between June 2014 and June 2020.

Patient and public involvement statement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Data collection procedures

Data abstraction tools were developed from the standard Ethiopian ART entry and follow-up forms currently used by Ethiopian hospitals to assure data quality.[15] The tool included socio-demographic characteristics, clinical and immunological characteristics, follow-up characteristics, and longitudinal weight measurements. Laboratory tests and measurements recorded at ART initiation were the baseline values. Data were collected by two epidemiologists with Master-level qualifications currently employed by DMCSH and specialized in HIV. An experienced biostatistician in secondary data collection supervised the data collection process.

Variables of the study

This study's outcome (dependent) variable was weight change in the first two years after ART initiation among adults living with HIV who started ART for the first time (treatment naïve). Weight was measured in kilogram (kg) at ART initiation (baseline) and then measured repeatedly every three months for 24 months. The follow-up time was recorded in months from ART initiation until 24 months (early ART phase).

Predictor (independent) variables were socio-demographic variables, baseline immunological and clinical variables, and follow-up variables.

Socio-demographic variables included age, sex, level of education, residence, marital status, occupation, family size, and HIV-status disclosure. Baseline immunological and clinical variables included baseline OIs, CD4 cell counts, WHO clinical disease staging, Hgb level, nutritional status, functional status, ART eligibility criteria, and baseline ART regimen.

Follow-up variables were OIs during follow-up, ART adherence, history of ART regimen change, taking CPT, taking isoniazid preventive therapy (IPT), HIV treatment failure based on viral load, and length of time on ART.

Operational definitions

The WHO BMI classification for underweight was used, defined a body mass index (BMI) of less than 18.5 kg/m^2 as underweight.[23]

ART adherence was classified as good, fair, or poor, according to the percentage of ART dosages taken, calculated from the total monthly dose of ART drugs (n=60). Good was defined as compliance equal to or greater than 95% or ≤ 3 missed doses per month; fair reflected 85-94% compliance or between 4 and 8 missing doses per month; and poor reflected less than 85% compliance or ≥ 9 missed doses per month.[15]

HIV treatment failures was classified as clinical, immunological, and virological failure. Clinical failure is diagnosed when the patient developed new or recurrent clinical events indicating severe immunodeficiency (WHO clinical stage IV condition and certain WHO clinical stage III conditions such as pulmonary TB and severe bacterial infections) after six months of effective ART treatment. Immunological failure was diagnosed when a patient had a CD4 count at or below 250 cells/mm^3 following clinical failure or persistent CD4 levels below 100 cells/mm^3. Virological failure was diagnosed when the viral load was above or equal to 1000 copies/mL under ART based on two consecutive viral load measurements in three months apart, with adherence support following the first viral load test.[15]

Functional status was classified as working, ambulatory, and bedridden. Working was defined as the capability of going out of home and participating in routine activities, including daily work. Ambulatory was defined as being capable of self-care and being able to use the toilet without support. Bedridden was defined as being unable to use the toilet without support [15].

Loss to follow-up (LTFU) is defined as adults living with HIV missing an ART appointment for at least one month.[15]

According to WHO, anaemia is defined as haemoglobin levels less than 12 g/dl in males and < 13 g/dl in females.[24]

Statistical analyses

Exploratory data analysis, including individual profile plots of weight for 50 (for better visualization) randomly selected participants and the smoothed mean profile plot of all participants, were constructed. Since we used unbalanced data, a locally weighted scatterplot smoothing (LOWESS) mean was used. In addition, the mean and standard deviation of weight at each ART visit (every three months) were calculated. Normality assumption was checked using a Q-Q plot. The autoregressive (AR1) covariance structure was used in the final model.

The two nested models (a model with only random intercept and a model with both random intercept and slope) were compared using the likelihood ratio (LR) test. Finally, a linear mixed-effect model (LMM) with random intercept and slope was applied to address the repeated measurements. The model goodness of fit was also assessed using a model diagnostic plot. Variables with $p \leq 0.25$ in the bivariate analysis were fitted into the multivariable analysis. For the LMM, statistical significance was set at $p < 0.05$. All statistical analyses were conducted using R Version 3.5.1 statistical software.

Results

Socio-demographic characteristics of participants

The final sample consisted of 848 adult records (see Figure 1). Of these, more than half (n=499; 58.8%) were female, and 45.3% (n=393) were married. More than three-quarters (n=665; 78.4%) of the study participants were from urban areas, and the median age of the study participants was 32 (IQR: 26-40) years. Nearly one-third (n=258; 30.4%) of the participants had no formal education. Furthermore, more than two-thirds (n=569; 67.1%) of the participants disclosed their HIV status (see Table 1).

Figure 1. Flow chart showing the study participants recruitment process at Debre Markos Comprehensive Specialized Hospital in Northwest Ethiopia, between June 2014 and June 2020.

Table 1. Socio-demographic characteristics of adults living with HIV on ART at Debre-Markos Comprehensive Specialized Hospital, Northwest Ethiopia (n=848).

Variables	Frequency (N)	Percentage (%)
Residence		
Urban	665	78.4
Rural	183	21.6
Age (years of age)		
15-24	186	21.9

25-34	284	33.5
35-44	269	31.7
≥45	109	12.9
Sex		
Male	349	41.2
Female	499	58.8
Marital status		
Single	155	18.3
Married	393	45.3
Divorced	217	25.6
Widowed	83	9.8
Level of education		
No formal education	258	30.4
Primary	219	25.8
Secondary	224	26.4
Tertiary	147	17.3
Occupation		
Daily labourer	139	16.4
Merchant	168	19.8
Farmer	119	14.0
Employed	184	21.7
Student	47	5.5
Housewife	144	17.0
Others	47	5.5
HIV-status disclosure		
Disclosed	569	67.1
Not disclosed	279	32.9
Family size		
<3	470	55.4
≥3	387	44.6

215 ***Baseline clinical and immunological profile of participants***

Approximately 40% (n=339) of the participants had baseline OIs (see Table 2), and more than a quarter (n=228; 26.9%) were underweight. The majority (n=707; 83.4%) were categorized as having a working functional status. Immunologically, 63.6% (n=406) of the participants had severe immunodeficiency (CD4<200 cell/m^3). Clinically, 72.2% (n=612) of participants were classified as mild disease stage (WHO stage I and II). Majority (n=634; 79.4%) participants were non-anaemic at ART initiation. More than half (n=470; 55.4%) of the study participants commenced ART through a test and treat approach.

Table 2. Baseline clinical and immunological profile of adults living with HIV on ART at Debre-Markos Comprehensive Specialized Hospital, Northwest Ethiopia (n=848).

Variables	Frequency (n)	Percentage (%)
Baseline OIs		
Yes	339	39.9
No	509	60.1
Baseline nutritional status		
Underweight	228	26.9
Normal-weight	620	73.1
Functional status		
Working	707	83.4
Ambulatory/ bedridden	141	16.6
CD4 Cell count		
Severe immunodeficiency (CD4 <200 cells/mm^3)	406	63.6
Mild immunodeficiency (CD4 ≥200 cells/mm^3)	232	36.4
WHO clinical staging		
Mild disease stage (Stage I&II)	612	72.2
Advanced disease stage (Stage III&IV)	236	27.8
Hemoglobin level		
Anaemic	164	20.6
Non-anaemic	634	79.4
ART eligibility criteria		
Immunological/clinical	378	44.6

Test and treat	470	55.4
Baseline ART regimens		
Efavirenz base	82	92.2
Nevirapine or Dolutegravir base	66	7.8

Follow-up characteristics of participants

The minimum and maximum length of time on ART for the study participants were six months (two visits) and 24 months, respectively. The median length of time on ART for the entire cohort was 12 months (IQR: 6-18). Almost one-third (n=269; 31.7%) of the participants developed OIs during the follow-up period. Three-quarters (n=637; 75.1%) of the participants had good adherence to their ART medication. Moreover, 62.5% (n=530) of the participants took prophylaxis for TB prevention (IPT). CPT was given to 73.2% (n=621) of the participants. Lastly, 2.7% (n=23) of participants had HIV treatment failure (see Table 3).

Table 3. Follow-up characteristics of adults living with HIV on ART at Debre-Markos Comprehensive Specialized Hospital, Northwest Ethiopia (n=848).

Variables	Frequency (n)	Percentage (%)
OIs during follow-up		
Yes	269	31.7
No	579	68.3
ART adherence		
Good	637	75.1
Fair/ poor	211	24.9
Regimen change		
Yes	266	31.4
No	582	68.6
Taking IPT		
Yes	530	62.5
No	318	37.5
Taking CPT		
Yes	621	73.2

No	227	26.8
HIV treatment failure		
Yes	23	2.7
No	825	97.3

Exploratory data analysis

The minimum and the maximum recorded weights throughout the follow-up period were 25kg and 98kg, respectively. Participants' mean weight increased from 54.2kg (SD± 9.6kg) at baseline to 59.5kg (SD± 10.7kg) at the end of follow-up. The average monthly weight gain was slightly higher (0.33kg/month) in the first year as compared to the second year (0.12kg/month) (see Table 4). The individual profile plots of 50 participants showed that considerable variability of weight change was observed between individuals (see Supplementary file1). Furthermore, the smoothed mean profile plot of all participants indicated a linear increment of weight over time (see Supplementary file 2).

Table 4. Mean and standard deviation of weight at each visit among adults living with HIV on ART at Debre Markos Comprehensive Specialized Hospital, Northwest Ethiopia.

Follow-up period (month)	(n)	Weight (in kg, mean ± SD))
Baseline	848	54.2 (± 9.6)
3rd month	848	55.7 (± 9.8)
6th month	779	56.7 (± 9.9)
9th month	649	57.6 (± 10.02)
12th month	590	58.1 (± 10.1)
15th month	543	58.4 (± 10.2)
18th month	509	58.7 (± 10.3)
21st month	484	58.9 (± 10.4)
24th month	445	59.5 (± 10.7)

Predictors of weight change

Initially, a bi-variable analysis was conducted, and variables with p-values ≤ 0.25 were included in the multivariable analysis. As presented in Table 5, the output from a multivariable LMM shows that duration of time on ART, sex, WHO clinical disease staging, functional status, nutritional status, and presence of OIs were factors significantly associated with weight change at ART initiation. Statistically significant interaction effects were observed between time and several variables, including sex, WHO clinical disease staging, functional status, IPT, and nutritional status. Specifically, with a one-month increase in ART treatment duration, mean body weight increased by 0.43kg (β=0.43, 95%CI: 0.35, 0.5). The mean weight of male participants at ART initiation was 4.8kg higher than female participants (β=4.8, 95%CI: 3.5, 6.0), and the rate of weight gain over time in male participants was 0.07kg/month higher than female participants (β=0.07, 95%CI: 0.02, 0.11). The mean weight of patients with advanced disease stage was 2.6kg lower than patients with mild disease stage at ART initiation (β=-2.6, 95%CI: -4.2, -1.0), and the rate of weight gain was 0.08kg/month less in patients with advanced disease stage than those with mild disease stage (β=-0.08, 95%CI: -0.14, -0.02).

The average weight of participants presented with working functional status was 3.9kg higher than the average weight of participants presented with ambulatory/bedridden functional status (β=3.9, 95%CI: 2.2, 5.7) at ART initiation. However, over time, the monthly weight gain rate in participants with working functional status was 0.08kg/month less than participants with ambulatory/bedridden functional status (β=-0.08, 95%CI: -0.16, -0.01). The mean weight of normal weight participants was estimated to be 8.6kg higher than underweight (BMI< 18.5kg/m^2) participants at baseline (β=8.8, 95%CI: 7.1, 10.1). However, the rate of weight gain over time in normal-weight participants was 0.11kg/month less than their underweight counterparts (β=-0.11, 95%CI: -0.17, -0.06). At ART initiation, the average weight in patients presenting with OIs was 2.6kg less than the average weight of patients presenting without OIs (β=-2.6, 95%CI: -3.9, -1.3). However, no statistically significant difference was observed in

the monthly weight gain rate over time between patients presenting with OIs and without OIs. There was no significant difference of mean weight between patients who took IPT and those who did not take IPT at baseline, but there was a higher rate of weight gain among participants who did not take IPT compared to those who took IPT (β=-0.05, 95%CI: -1.1, -0.001) (see Table 5).

Table 5. Multivariable linear mixed effect model to identify predictors of weight change among adults living with HIV on ART at Debre Markos Comprehensive Specialized Hospital, Northwest Ethiopia.

Variables	Coefficient	95%CI	P-values
Intercept	46.2	(43.5, 48.8)	<0.001
Residence			
Urban	0.9	(-0.7, 2.5)	0.2747
Rural	Ref	—	—
Sex			
Male	4.8	(3.5, 6.0)	<0.001
Female	Ref	—	—
WHO clinical staging			
Mild disease stage	Ref	—	—
Advanced disease stage	-2.6	(-4.2, -1.0)	0.0012
Functional status			
Working	3.9	(2.2, 5.7)	<0.001
Ambulatory/bedridden	Ref	—	—
ART eligibility criteria			
Immunological/clinical	Ref	—	—
Test and treat	-1.1	(-2.4, 0.2)	0.0875
ART adherence			
Good	Ref	—	—
Fair/poor	-0.7	(-2.1, 0.7)	0.3250
Baseline nutritional status			

Underweight	Ref	—	—
Normal weight	8.6	(7.1, 10.1)	<0.001
Taking IPT			
Yes	-0.2	(-1.5, 1.2)	0.8002
No	Ref	—	—
Baseline OIs			
Yes	-2.6	(-3.9, -1.3)	0.0001
No	Ref	—	—
Time on ART	0.43	(0.35, 0.5)	<0.001
Sex*time			
Male*time	0.07	(0.02, 0.11)	0.0073
Female*time	Ref	—	—
WHO clinical staging*time			
Mild disease stage*time	Ref	—	—
Advanced disease stage*time	-0.08	(-0.14, -0.02)	0.0073
Functional status*time			
Working*time	-0.08	(-0.16, -0.01)	0.0192
Ambulatory/ bedridden*time	Ref	—	—
Baseline nutritional status*time			
Underweight*time	Ref	—	—
Normal*time	-0.11	(-0.17, -0.06)	0.0001
Taking IPT*time			
Yes*time	-0.05	(-1.1, -0.001)	0.0434
No*time	Ref	—	—
Variance component			
Standard deviation (Intercept)	6.3		
Standard deviation (Time)	0.13		
Standard deviation (Residual)	5.0		
Corr (intercept)	0.343		

Discussion

In this longitudinal study of 848 participants, we found a linear increment of weight over 24 months of follow-up, with a higher rate of weight gain in the first 12 months. This study also showed that the duration of time on ART has a positive association with weight gain. The mean weight at ART initiation and the rate of weight gain over time was higher in male participants than female participants. The mean weight at ART initiation and weight gain rate over time was lower in patients with advanced disease stage than in patients with mild disease stage. Normal-weight patients had a higher mean weight at ART initiation but less weight gain over time than underweight patients. In addition, patients with working functional status had a higher mean weight at ART initiation but a lower rate of weight gain over time, compared to participants with ambulatory or bedridden functional status. Furthermore, patients presenting with OIs had less mean weight at ART initiation than patients presenting without OIs. However, no statistically significant difference was observed over time in the monthly weight gain rate between patients presenting with and without OIs. Lastly, at ART initiation, there was no significant difference in mean body weight between patients who received IPT and those who did not. However, the rate of weight gain was higher in participants who did not take IPT than in those who took IPT.

In this study, patients experienced a slightly higher weight gain rate in the first year of ART than in the second year (0.33kg/month vs 0.12kg/month). Similar patterns of higher weight gain in the first year of ART treatment were noted in previous studies conducted in similar low resource settings,[25] including Vietnam,[18] and Cambodia and Kenya.[4] Although the exact mechanisms of weight gain following ART remain unclear, reasons may include reversing HIV-related catabolic effects (return-to-health) and reducing the basal metabolic rate due to viral load suppression.[26] ART also significantly reduces the occurrence and recurrence of OIs and enhances gastrointestinal function, increasing appetite and nutrient absorption[11]. This study's finding of a one-month mean body weight increase of 0.43kg during ART

treatment is consistent with prior Ethiopian studies.[19, 27] This may be explained by patients on ART for a longer period demonstrating higher levels of healthy practices, including ART adherence and social support, thereby enhancing clinical outcomes.[28]

Men had a higher mean weight at baseline and a higher rate of weight gain over time than women. While this finding is consistent with a previous Ethiopian study,[19] it contradicts previous studies done elsewhere.[5, 11] Gender differences in weight gain might be associated with hormonal differences, and a higher likelihood of female patients living with HIV developing psychosocial issues such as anxiety and depression, negatively affecting body weight.[29, 30] In addition, a meta-analysis showed that the proportion of women reporting 90% adherence to prescribed ART was lower than that of their male counterparts.[31] Furthermore, lower weight gain in females might be due to higher levels of food insecurity among females in developing countries.[32, 33] This implies that gender-specific interventions and close follow-up are needed to improve weight among patients living with HIV on ART.

The mean weight of normal-weight participants was higher than underweight participants at baseline. However, the rate of weight gain over time was higher in underweight participants compared to their normal-weight counterparts, consistent with findings in previous studies.[7, 34, 35] This may be explained by underweight patients benefiting more directly from nutritional improvements resulting from ART initiation, such as increased nutritional intake and absorption by decreasing the occurrence and recurrence of OIs.[36] Moreover, underweight PLHIV are eligible for nutritional supplements,[37] as nutritional supplements in this population significantly increase weight.[38] Thus, the weight of underweight patients can be further improved by providing appropriate nutritional education, as recommended by the Ethiopian ART guidelines.[15]

This study also found that participants in advanced disease stages had a lower mean weight at baseline and gained less weight over time than participants presented with mild disease stage. This finding is supported by prior studies done in low-resource settings.[25, 27] Poor weight gain in patients with advanced disease stages might be due to (undiagnosed) OIs, especially TB, or high energy expenditure due to increased metabolic demand. Reported energy requirements for symptomatic adults living with HIV increased by 20-30% compared to a 10% increase in asymptomatic adults living with HIV.[39] Furthermore, the most common cause of swallowing difficulty, like oesophageal candidiasis, is a defining characteristic of stage IV, while unexplained chronic diarrhea and pulmonary TB are the main clinical manifestation of stage III.[15] These comorbidities indicate that weight management of HIV patients with advanced disease stages need special attention and can be addressed by preventing and treating OIs, improving ART adherence, and providing counselling to improve diet by consuming locally available foods.

At ART initiation, the mean weight was lower in patients presenting with OIs compared to patients without OIs, but no statistically significant difference was observed over time. OIs cause weight loss in PLHIV through impaired nutrient absorption due to chronic diarrhea or intestinal tract damage, or reduced dietary intake due to oral thrush and oesophageal candidiasis.[40] Moreover, patients presenting with OIs, especially tuberculosis, could have an inadequate response to ART due to common complications in people starting ART with co-infections and co-morbidities.[41] Our results suggested that if clinicians are proactive in prevention and treatment of OIs as early as possible, they could significantly improve the weight trajectory of HIV-infected patients on ART.

The average weight of participants with working functional status was higher than participants with ambulatory or bedridden functional status at ART initiation. However, the weight gain

rate over time in participants with working functional status was less than participants with ambulatory or bedridden functional status. This finding is consistent with studies conducted elsewhere[19, 42] and likely reflects HIV disease severity before ART initiation and the return to health in patients with more advanced disease. Lastly, there is a higher rate of weight gain among participants who did not take IPT compared to those who took IPT. This finding is directly associated with disease progression, as IPT is indicated for HIV-positive patients with advanced disease but has no confirmed TB infection.[15, 41] In addition, it may be directly related to the side effects of IPT, such as vomiting, loss of appetite, and nausea which are the most common side effects of IPT.[43]

Conclusion

In this study, we found a linear increment of weight over 24 months of follow-up, with a higher rate of weight gain in the first 12 months. Over time, the rate of weight gain was lower in patients with advanced disease stage, who took IPT and working functional status. However, male and underweight patients had a higher rate of weight gain. The clinical implication is that health professionals must continuously monitor and assess patients' weight with poor clinical conditions (i.e., patients presented with advanced disease stage and OIs) to find potential reasons for failure to gain weight. Further studies examining the effects of weight gain on treatment outcomes by incorporating some variables, such as dietary and exercise habits, are needed.

List of abbreviations

AIDS: Acquired Immune Deficiency Syndrome, **ART**: Antiretroviral Therapy, **BMI:** Body Mass Index, **CPT**: Co-trimoxazole Preventive Therapy, **DMCSH:** Debre Markos Comprehensive Specialized Hospital, **HAART**: Highly Active Antiretroviral Therapy, **Hgb**: Hemoglobin, **HIV**: Human Immunodeficiency Virus, **IPT:** Isoniazid Preventive Therapy, **IQR:** Interquartile Range, **Kg**: Kilogram, **LMM:** Linear Mixed Model, **OIs:** Opportunistic

Infections, **PLHIV**: People Living with Human Immunodeficiency Virus, **SD:** Standard Deviation, **TB**: Tuberculosis, and **WHO**: World Health Organization.

Declarations

Ethics approval and consent to participate

Ethical approvals and permissions were granted from the DMCSH Medical Director Office, the University of Technology Sydney Medical Research Ethics Committee (ETH20-5044), and the Amhara Regional Public Health Research Ethics Review Committee (Ref. no: 816). As the study was based on existing medical records of PLHIV, informed verbal or written consent from participants was not feasible. However, the data was entirely de-identifiable to authors since the participants' unique ART numbers and names were not included in the data abstraction tool.

***Consent for publication*:** Not applicable

***Availability of data and material*:** Data used for this study will be available upon reasonable request to the corresponding author.

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