Weight and body composition in a cohort of HIV-positive men and women

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Abstract

Objective: At issue is whether weight loss in HIV infection is a cachectic process, characterised by loss of lean body mass with conservation of fat, or a process of starvation. We present data on body composition from 516 persons at different stages of HIV infection as determined by CD4 counts.

Design: Cross-sectional analyses of body composition in relation to CD4 count.

Setting: The baseline data from a prospective cohort study of outcomes in HIV/AIDS in relation to nutritional status in Boston, Massachusetts, USA.

Subjects: The first 516 subjects with HIV/AIDS to enrol in the study.

Results: Differences in weight in relation to CD4 counts were present only at CD4 counts of 600 or less (slope below CD4 $\geq$ 600: 1.9 kg per 100 CD4 cells, $P < 0.0001$): On average, 68% of the difference in weight over CD4 counts was fat (slope: 1.3 kg fat per 100 CD4 cells, $P < 0.0001$).

Conclusions: This cross-sectional analysis suggests that weight loss consists principally of fat loss in those persons with adequate fat stores. This observation will need to be confirmed in longitudinal analyses.

Keywords

Body composition
HIV
Nutritional status

HIV wasting, or an unintentional weight loss of more than 10% of normal weight, is a common AIDS-defining condition. HIV-associated weight loss is an independent predictor of opportunistic infections, hospitalisation and mortality. Loss of lean body mass, however, is a better predictor of survival than weight loss. The importance of lean body mass to survival in HIV has led to an interest in the changes in body composition that accompany disease progression, and the ability of appetite stimulants, anabolic steroids and human growth hormone to restore lean body mass.

Early in the AIDS epidemic, Kotler and colleagues found that homosexual men with advanced AIDS had less body cell mass (the intracellular component of lean body mass), but similar amounts of body fat, compared with healthy homosexual men. It was postulated that HIV wasting is a cachectic process in which weight loss is disproportionately loss of lean body mass, with relative conservation of fat. Loss of fat was deemed a poor marker of AIDS wasting. Proposed mechanisms for muscle wasting include altered cytokine levels and alterations in circulating levels of anabolic sex hormones.

While some subsequent studies have, indeed, found that weight loss is mainly loss of lean body mass, other studies have found principally fat loss or a loss of both fat and lean. A loss of lean body mass with conservation of fat suggests a cachetic process; a loss of mainly fat would be consistent with wasting due to malnutrition. The discrepancies among these studies may be due to differences in the stage of disease and, possibly, differences in initial body composition. Studies of healthy adults who have lost weight due to caloric restriction have shown that loss of lean body mass is a function of body fat. Mulligan and colleagues, based on studies of 32 men, proposed that loss of lean body mass in persons with HIV, like healthy adults, is dependent on the percentage of body fat prior to the weight loss.

Here, we report findings from a cross-sectional analysis of weight and body composition in relation to CD4 cell counts from the baseline data of a three-year longitudinal, observational study of a cohort of more than 500 ambulatory persons with HIV. This cohort includes 130 women, a group that has been under-represented in previous studies.

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Methods

Participants
The Tufts University Nutrition for Healthy Living Study, initiated in February of 1995, aims to describe the natural history of HIV wasting and to determine the role of nutrition in the progression of HIV disease. Recruitment of participants was done through advertisements on the radio, in local newspapers, health clinics and physician networks. Persons 18 years of age and older who were HIV-positive and consented to participate were considered eligible. People who met any one of the following criteria were excluded: pregnant at recruitment, diagnosed diabetes mellitus, thyroid disease, or malignancies (other than HIV-associated malignancies), inadequate English language fluency. Clinic visits occurred at three sites: the New England Medical Center and the Fenway Community Health Center in Boston, and the Miriam Hospital in Providence, Rhode Island.

Assessments
The baseline measurements were made during two clinic visits approximately 10 days apart. Those persons who completed the full two-visit baseline protocol were considered to have enrolled in the study. Height (±0.1 cm) and weight (±0.1 kg) were measured at the first visit using standard techniques. Body composition by bioelectrical impedance analysis (BIA) was determined at the second visit, after an overnight fast, following the manufacturer's recommended procedures (RJL Systems Inc., Clinton, MI) and using the equations of Lukaski to derive measures of fat-free mass (principally lean body mass) and body fat. Body mass index (BMI) was calculated as weight (kg)/HT$^2$ (m$^2$). CD lymphocyte subset counts were done by standard techniques at clinical laboratories of the participating hospitals. Confidentiality of records was preserved according to regulations stipulated by human studies review committees at each participating institution. The protocol was approved by institutional review boards at each site.

Statistical analyses
The data were double entered and checked using MS Access (Microsoft Corp., Seattle, WA). All analyses were done in the generalised linear models program of SAS version 6.1 (SAS Institute, Cary, NC). We compared weight and body composition separately for men and women, categorised by level of CD4 count. Differences in weight, BMI, fat mass and fat-free mass across the CD4 count categories were tested for significant trends by assigning each subject to one of three CD4 categories: less than 200, 200 to 499, or greater than or equal to 500. A score of one, two or three was assigned to the CD4 categories, respectively, and each of the four outcomes (weight, BMI, fat mass and fat-free mass) was regressed on the score.

In order to examine the shape of the relationship between weight, body composition and CD4 counts, weight, fat and fat-free mass were regressed on CD4 counts treated as a continuous variable. To account for possible non-linear relationships, linearity was assessed using the technique of restricted cubic splines with three-, four- and five-knot models. When the hypothesis of linearity was rejected at $P < 0.1$, a non-linear regression model was fit by least squares to a change-point model to locate the point where the slope of the line changed. Residuals of all models were checked for violations of assumptions. Influential points were identified by Cook's distance. Variables describing the use (yes/no) of protease inhibitors, non-nucleoside reverse transcriptase inhibitors and anabolic steroids were included in the models. The medication variables were used as interaction terms (with CD4 counts) to assess whether the slopes observed differed between persons taking these medications and persons not taking such medications. Nucleotide and nucleoside reverse transcriptase inhibitors were not evaluated, as the majority (76%) of the study subjects was taking them. Separate analyses were performed for men and women. The data for men and women were combined if analyses showed no significant between-gender difference in the estimated slopes. Alpha (two-tailed) was set at 0.05 unless otherwise stated.

Data on body composition were missing for six men. CD4 counts were unavailable for three women because the phlebotomist was unable to draw blood. Two of these women reported their CD4 counts to be less than 200; their CD4 counts were set to a value of 100 (midpoint of 0 and 200). CD4 counts from the six-month protocol visit (six-month visit CD4 count = 541) were used for the third woman.

Results
As of December 1997, 516 persons were enrolled in the study. Three-hundred-and-eighty-six (75%) of the participants were men and 130 (25%) were women. The racial composition of the men was as follows: 276 (71%) Caucasian, 72 (19%) African-American, 23 (6%) Hispanic, 15 (4%) other races. Fifty-seven (44%) of the women were Caucasian, 50 (38%) African-American, 15 (12%) Hispanic and eight (6%) were of other races. One-hundred-and-sixty-three (42%) of the men in the cohort and 87 (67%) of the women reported incomes ≤$10,000 per year.

Forty-nine per cent (193/394) of the subjects were taking one of a protease inhibitor class, non-nucleoside reverse transcriptase inhibitor class or an anabolic steroid class of medications. Information on these medications was missing for 122 of the subjects, in most cases (76%) because the participant was concurrently enrolled in a blinded clinical trial.

The mean weight, body mass index (BMI) and body composition of the men and women in relation to CD4 counts treated as a continuous variable. To account for possible non-linear relationships, linearity was assessed using the technique of restricted cubic splines with three-, four- and five-knot models. When the hypothesis of linearity was rejected at $P < 0.1$, a non-linear regression model was fit by least squares to a change-point model to locate the point where the slope of the line changed. Residuals of all models were checked for violations of assumptions. Influential points were identified by Cook's distance. Variables describing the use (yes/no) of protease inhibitors, non-nucleoside reverse transcriptase inhibitors and anabolic steroids were included in the models. The medication variables were used as interaction terms (with CD4 counts) to assess whether the slopes observed differed between persons taking these medications and persons not taking such medications. Nucleotide and nucleoside reverse transcriptase inhibitors were not evaluated, as the majority (76%) of the study subjects was taking them. Separate analyses were performed for men and women. The data for men and women were combined if analyses showed no significant between-gender difference in the estimated slopes. Alpha (two-tailed) was set at 0.05 unless otherwise stated.

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The mean weight, body mass index (BMI) and body composition of the men and women in relation to CD4
count categories are shown in Table 1. There was a significant trend towards lower weight and BMI with lower CD4 counts. The differences in weight and BMI among the CD4 groups were due to both lower body fat and lower fat-free mass at lower CD4 counts, although the difference in body fat was greater than the difference in fat-free mass, as reflected by the higher per cent fat-free mass in the CD4 count category 200 compared with the higher CD4 count categories.

When we treated CD4 counts as a continuous variable to examine the shape of the relationship between weight, body composition and CD4 counts, we found that, in the men, the cross-sectional relation between CD4 counts and the outcome was non-linear for weight ($P = 0.028$) and fat-free mass ($P = 0.030$), and of borderline significance for body fat ($P = 0.13$) (Figs 1–3). In the women, the hypothesis of non-linearity did not reach statistical significance, implying that the relationships between CD4 counts and weight, fat and fat-free mass were linear in the women (Figs 1–3). However, since the curves for men and women were of similar shape, we treated the relations between CD4 counts and weight, fat and fat-free mass as non-linear for women in subsequent analyses.

In the subgroup with CD4 cell counts above 600, there was no significant difference in weight among subjects at different levels of CD4 counts (slope: 0.30 kg per 100 CD4 counts, SE: 0.73, $P = 0.68$). Among those persons whose CD4 counts were below 600, average weight was 1.9 kg lower for each decline of 100 CD4 cells ($P < 0.0001$). There was no difference between men and women in the slope describing the relationship between weight and CD4 counts (difference in slopes: 2.05 kg per 100 CD4 counts, SE: 0.85, $P = 0.32$) in the subgroup with CD4 counts below 600, so the estimate of 1.9 kg per 100 CD4 cell difference comes from a model that combined the data from both men and women. Among those persons whose CD4 counts were below 600, the

### Table 1 Age, body weight and body composition in relation to CD4 class (mean ± SD)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>&lt;200</th>
<th>200–499</th>
<th>≥500</th>
<th>$P$ for trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number in subgroup</td>
<td>M 136</td>
<td>171</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F 30</td>
<td>63</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>M 40 (7.3)</td>
<td>41 (7.6)</td>
<td>38 (7.9)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F 39 (7.9)</td>
<td>39 (7.7)</td>
<td>37 (6.8)</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>M 72.1 (11.5)</td>
<td>76.8 (11.1)</td>
<td>80.5 (12.6)</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>F 62.8 (13.5)</td>
<td>69.3 (16.7)</td>
<td>72.8 (15.7)</td>
<td>0.0090</td>
</tr>
<tr>
<td>Body mass index (kg m$^{-2}$)</td>
<td>M 23.2 (3.1)</td>
<td>24.9 (3.1)</td>
<td>25.8 (3.8)</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>F 23.8 (4.6)</td>
<td>26.9 (6.6)</td>
<td>27.2 (6.0)</td>
<td>0.025</td>
</tr>
<tr>
<td>Body fat (kg)</td>
<td>M 13.4 (6.8)</td>
<td>16.8 (7.5)</td>
<td>19.8 (9.4)</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>F 20.5 (9.1)</td>
<td>25.6 (12.7)</td>
<td>26.2 (11.5)</td>
<td>0.045</td>
</tr>
<tr>
<td>Fat-free mass (kg)</td>
<td>M 58.5 (7.3)</td>
<td>60.2 (7.2)</td>
<td>60.7 (6.4)</td>
<td>0.030</td>
</tr>
<tr>
<td></td>
<td>F 42.4 (6.7)</td>
<td>43.8 (6.2)</td>
<td>46.6 (6.2)</td>
<td>0.0066</td>
</tr>
<tr>
<td>% Body fat</td>
<td>M 18.0 (6.9)</td>
<td>21.3 (7.1)</td>
<td>23.7 (8.0)</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>F 31.5 (8.3)</td>
<td>35.2 (9.6)</td>
<td>34.6 (8.3)</td>
<td>0.15</td>
</tr>
<tr>
<td>% Lean body mass</td>
<td>M 82.0 (6.7)</td>
<td>78.7 (7.1)</td>
<td>76.2 (8.0)</td>
<td>0.0001</td>
</tr>
<tr>
<td></td>
<td>F 68.5 (8.3)</td>
<td>64.8 (9.6)</td>
<td>65.4 (8.3)</td>
<td>0.15</td>
</tr>
</tbody>
</table>

**Fig. 1** The relation of weight (kg) to CD4 counts. The dotted line indicates a slope not significantly different from zero.

**Fig. 2** The relation of fat (kg) to CD4 counts. The dotted line indicates a slope not significantly different from zero.
average difference in fat was 1.3 kg (P < 0.0001) and
difference in fat-free mass was 0.65 kg (P = 0.011) per
difference of 100 in CD4 cells. Similar to the results for
weight, there was no difference between men and
women in the slope of the line describing the cross-
sectional relationship between CD4 counts and kilograms
of fat or fat-free mass (between-sex difference in slopes –
for fat: 0.84 kg per 100 CD4 counts, SE = 0.58, P = 0.15;
for fat-free mass: −0.10 kg per 100 CD4 counts, SE =
0.48, P = 0.83). Thus, fat accounted for an average of 68%
(1.3 kg fat/1.9 kg weight) of the difference in weight
across CD4 counts in those persons with CD4 values
below 600. The addition of interaction terms showed no
evidence that the estimated slopes differed between those
persons on protease inhibitors, non-nucleoside reverse
transcriptase inhibitors and/or anabolic steroids and those
who were not taking medications of this type (P for the
difference in slopes: 0.62).

Discussion

Differences in weight and body composition were
observed in subjects with CD4 counts less than 600.
These data support the notion that weight loss starts early
in HIV infection while CD4 counts are still above the
range associated with opportunistic infections. Our cross-
sectional data also suggest that weight loss in HIV
infection is mostly fat loss in those persons with adequate
fat stores. Our data do not support the theory that HIV
wasting is principally a loss of lean body mass with fat
conservation, believed to be typical of a cachectic
process.

Some previous studies have found HIV-associated
weight loss to consist of greater loss of lean body mass
than fat mass12–14,18,19. Other studies have shown a
greater loss of fat than lean body mass or loss of both
fat and lean20–25. The apparent contradictions may be
explained, in part, by differences in the average per cent
body fat of the study subjects. Mulligan and colleagues24,
in a longitudinal analysis of weight loss in 32 men with
HIV, found that both fat and lean were lost and that the
composition of the weight loss depended on the baseline
body fat composition, such that the men with initially
higher per cent body fat lost greater amounts of fat than
lean body mass. The high average per cent body fat in the
men and women in our study within all CD4 count classes
would explain the predominance of a cross-sectional
difference in fat vs. lean. Our data also suggest that the
pattern of weight differences across CD4 counts is similar
in men and women.

The differences observed in body composition across
CD4 classes in these people with HIV appear to be
qualitatively similar to the changes expected in healthy
people who have lost weight due to caloric restriction.
Forbes25, summarising data from several independent
studies, hypothesised that in healthy persons losing
weight due to caloric restriction, the proportion of weight
loss due to loss of lean body mass is inversely related to
body fat. Dulloo and colleagues26 found that, in healthy
men undergoing semi-starvation, weight loss was princi-
ually fat in those with adequate fat stores.

It is, perhaps, not surprising that our estimates of the
cross-sectional relation between weight, body composi-
tion and CD4 counts did not differ between those persons
on protease inhibitor therapies and/or anabolic steroids
and those not taking these medications. Protease inhibitor
therapy does not inevitably increase CD4 counts, nor
does it have a large effect on weight30. Clinical trials of
treatments for wasting using appetite stimulants, anabolic
steroids and growth hormone have shown only modest
increases in weight and lean body mass8–11.

Our participants were all healthy enough to participate
in a rigorous protocol, and so these results cannot be
generalised to HIV patients who were too ill to participate
in our study. There may be important differences in the
changes in body composition that occur as the disease
advances, between persons who have AIDS or are
suffering from active opportunistic conditions and those
who are not. These findings may also be of limited
generalisability, quantitatively, to persons with untreated
HIV infection or to persons with pre-existing malnutrition,
as would be common in developing countries. Qualita-
tively, however, the evidence of weight differences
between CD4 groups at CD4 counts well above 200,
and the predominance of differences in fat (vs. fat-free
mass), should be generalisable to persons who have
similar fat stores and who are in the early stages of HIV
infection, whether the infection is treated or untreated.

More data from large-scale longitudinal studies are
needed to examine the changes in body composition that
accompany HIV disease progression, and to determine if
the maintenance of adequate fat stores early in HIV
infection will help prevent the loss of lean body mass and
improve long-term survival. In countries where the use of protease inhibitors for the treatment of HIV infection is widespread, the reported changes in body composition and fat distribution associated with therapy may complicate such studies. Nevertheless, studies of this type are feasible, are of relatively low cost, and the results potentially important for countries where expensive medications are not available.

Contributions

JEF contributed to the analyses, interpretation and writing of the manuscript. DS contributed to the study design, analyses and interpretation of the results. MW contributed to the study design and interpretation of the data collection. TK contributed to the study design and coordination of the data collection. JMF contributed to the analyses and interpretation of the results. SLG contributed to the study design and oversaw the project.

Acknowledgements

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