Conceptual framework for understanding the bidirectional links between food insecurity and HIV/AIDS[1–4]

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ABSTRACT

Food insecurity, which affects >1 billion people worldwide, is inextricably linked to the HIV epidemic. We present a conceptual framework of the multiple pathways through which food insecurity and HIV/AIDS may be linked at the community, household, and individual levels. Whereas the mechanisms through which HIV/AIDS can cause food insecurity have been fairly well elucidated, the ways in which food insecurity can lead to HIV are less well understood. We argue that there are nutritional, mental health, and behavioral pathways through which food insecurity leads to HIV acquisition and disease progression. Specifically, food insecurity can lead to macronutrient and micronutrient deficiencies, which can affect both vertical and horizontal transmission of HIV, and can also contribute to immunologic decline and increased morbidity and mortality among those already infected. Food insecurity can have mental health consequences, such as depression and increased drug abuse, which, in turn, contribute to HIV transmission risk and incomplete HIV viral load suppression, increased probability of AIDS-defining illness, and AIDS-related mortality among HIV-infected individuals. As a result of the inability to procure food in socially or personally acceptable ways, food insecurity also contributes to risky sexual practices and enhanced HIV transmission, as well as to antiretroviral therapy nonadherence, treatment interruptions, and missed clinic visits, which are strong determinants of worse HIV health outcomes. More research on the relative importance of each of these pathways is warranted because effective interventions to reduce food insecurity and HIV depend on a rigorous understanding of these multifaceted relationships. *Am J Clin Nutr* 2011;94(suppl):1729S–39S.

INTRODUCTION

Food insecurity, defined as having uncertain or limited availability of nutritionally adequate or safe food or the inability to acquire personally acceptable foods in socially acceptable ways (1), is a leading cause of morbidity and mortality worldwide and is inextricably linked to the HIV epidemic. More than 1 billion people worldwide are estimated to lack sufficient dietary energy availability (2), and the prevalence of food insecurity is particularly high among PLWHA[5] in both resource-rich and resource-poor settings. For example, studies from Kenya and Uganda have shown that the vast majority of PLWHA are moderately or severely food insecure (3, 4). In San Francisco, Atlanta, and Vancouver, nearly one-half of HIV-infected patients on ART have been estimated to be food insecure (5–8). Women are the most affected by the parallel epidemics of HIV/AIDS and food insecurity, because of sex discrimination, poverty, and the absence of support as head of household (5, 9–13).

HIV/AIDS worsens family food insecurity because of the debilitation of the most productive household members, decreased individual and household economic capacity, and increased caregiver burden (14–17). Food insecurity, in turn, leads to both increased risk of HIV transmission and more rapid HIV disease progression across settings in both resource-rich and resource-poor countries. Specifically, food insecurity increases the likelihood of risky sexual practices, which exacerbates the horizontal spread of HIV/AIDS (13), and can also increase the likelihood of vertical transmission through risky infant-feeding practices (18) and malnutrition (19, 20). Among people already infected with HIV/AIDS, food insecurity has been associated with lower ART adherence (8, 21), declines in physical health status (7, 22), decreased viral suppression (8, 23), worse immunologic status (7, 24), increased incidence of serious illness (22), and increased mortality (6).

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[5] Abbreviations used: ART, antiretroviral therapy; HAART, highly active antiretroviral therapy; PLWHA, people living with HIV or AIDS.

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As a result of the bidirectional links between food insecurity and HIV/AIDS, numerous researchers, governments, and international organizations have proposed the integration of nutrition and HIV/AIDS programming activities (9, 25–28). A sound understanding of the complex linkages between food insecurity and HIV/AIDS is critical if we are to provide empiric evidence to guide the integration of food programs and HIV programs to decrease HIV acquisition, optimize treatment outcomes, and improve quality of life for PLWHA and their families. In this article, we propose a conceptual framework to explain the vicious cycle of food insecurity and HIV/AIDS, to inform research priorities and help in the development of effective interventions.

OVERVIEW OF CONCEPTUAL FRAMEWORK

Food insecurity and HIV/AIDS are intertwined in a vicious cycle through nutritional, mental health, and behavioral pathways. The complex relationships among these phenomena can best be portrayed with the use of a conceptual framework. Conceptual frameworks have been useful in the depiction and analysis of hypothesized causal associations in complicated health problems, especially those determined by social and biological factors such as malnutrition or infectious diseases in developing countries (29, 30).

Our conceptual framework spans 3 levels of determinants (ie, community, household, and individual) and draws on several existing models that describe the linkages between HIV/AIDS, food security, and socioeconomic well-being (**Figure 1**) (31–34). Broader structural factors influence food insecurity, including ecologic features (eg, drought, flooding), socioeconomic factors (eg, poverty, access to education), and social factors (eg, sex inequality, HIV-related stigma). Food insecurity typically operates at the level of the household and is influenced by other household-level factors such as family structure and social support. Food insecurity, in turn, shapes individual actions and health outcomes through nutritional, mental health, and behavioral pathways. Within this framework, an outcome within one sphere precipitates changes in outcomes within another sphere. For example, when a household loses a family member to HIV-related illness or death, the household may have less income, become more food insecure, or need to sell household assets for additional income. With fewer assets, surviving household members may fall into behavioral patterns that increase the risk of HIV transmission to others, which reinitiates the cycle of food insecurity and HIV/AIDS.

The nutritional, mental health, and behavioral pathways through which food insecurity negatively affects HIV acquisition and disease progression emerge directly from the USDA definition of food insecurity (35). Insufficient quality and quantity of food can lead to macronutrient and micronutrient deficiencies, which can affect both HIV acquisition and health outcomes among HIV-infected persons. Feelings of deprivation or anxiety about food supply can have mental health consequences, such as depression, that can contribute to HIV transmission risk as well as worse health outcomes among HIV-infected persons. The inability to procure food in socially or personally acceptable ways can, on one hand, lead to risky sex and enhanced HIV transmission, and, on the other hand, lead to ART nonadherence, treatment interruptions, and missed clinic visits, which can affect HIV health outcomes. Finally, HIV/AIDS and associated stigma can lead to decreased social support and greater food insecurity, which perpetuate the cycle between food insecurity and HIV/AIDS. In the sections that follow, we describe current research on the numerous links between food insecurity and HIV/AIDS, with an emphasis on the nutritional, mental health, and behavioral pathways through which food insecurity can lead to HIV acquisition and disease progression (**Figures 2** and **3**).

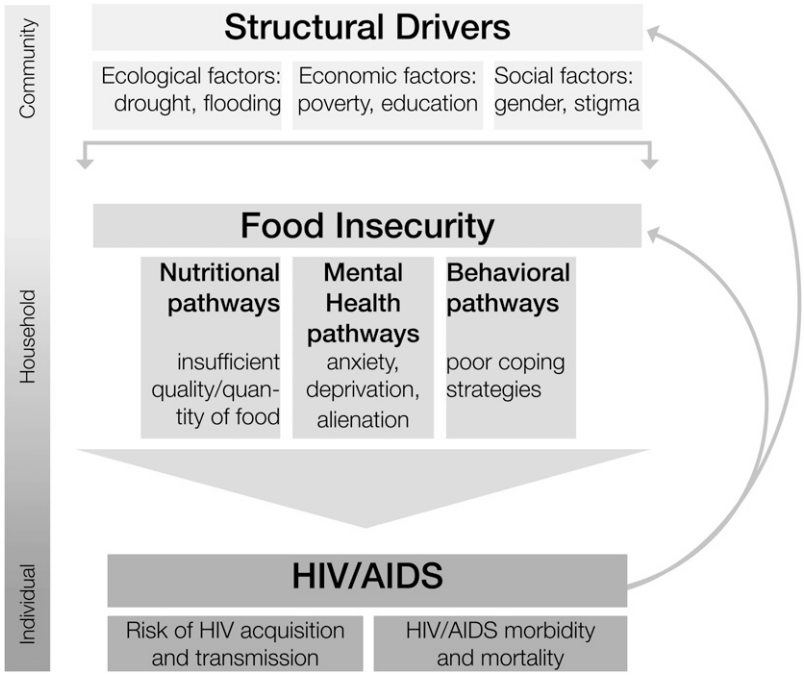

FIGURE 1. Conceptual framework for food insecurity and HIV/AIDS linkages.

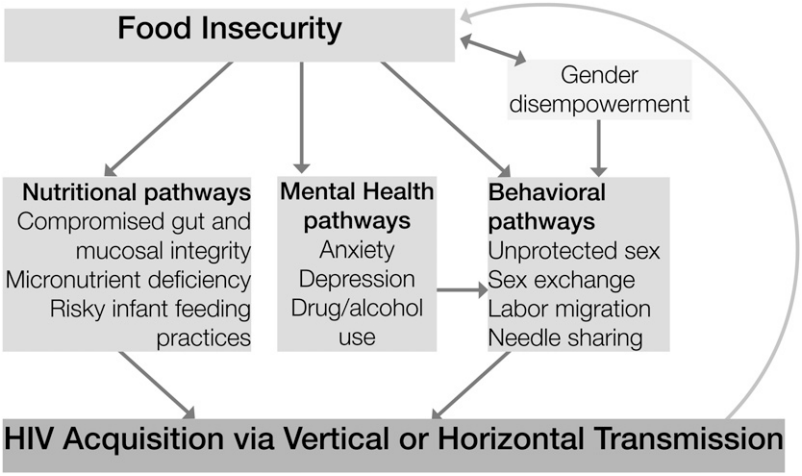

FIGURE 2. Food insecurity and HIV acquisition.

HIV/AIDS CONTRIBUTES TO FOOD INSECURITY

HIV/AIDS–related morbidity and mortality is well established as a cause of adverse social and economic consequences for households, including increased food insecurity (Figure 1) (16, 36). When working-age adults fall ill, households lose income, assets, labor, and skills; the subsequent treatment and funeral costs can be catastrophic (37–46). For example, national survey data from Kenya indicate that the net value of household crop production declined by 68% after the death of a male head of household, and that affected households adopted short-term survival strategies (such as the sale of productive assets and a shift from high-value to subsistence crops) that impaired financial viability in the long term (47). Even after people initiate ART, which can lead to rapid functional improvement (48), their livelihoods may have degraded to such a point that a return to previous levels of economic productivity is no longer possible (49). Furthermore, intergenerational transmission of poverty and food insecurity occurs when children are withdrawn from school to provide informal care, to compensate for lost adult labor, or because school fees become unaffordable (50, 51). Fewer assets (especially arable land), lower household earning potential, less education, and increased household expenses, in turn, worsen food insecurity.

Whereas households affected by HIV/AIDS are particularly susceptible to food insecurity, they are often least able to rely on social support for assistance. Borrowing and other transfers from kin and social networks typically serve as informal insurance against health and agricultural shocks (52–55). However, HIV, which is concentrated among the poor, continues to be heavily stigmatized in much of sub-Saharan Africa; this stigma can prevent HIV-affected households from drawing on informal support (56). For example, in a longitudinal study among HIV-infected ART-treated individuals in rural Uganda, both internalized HIV stigma (internalized negative views about HIV/AIDS by PLWHA) and enacted HIV stigma (experiences of discrimination related to HIV status) were strongly associated with food insecurity, which suggests that HIV stigma may contribute to the negative effects of HIV/AIDS on food security (57).

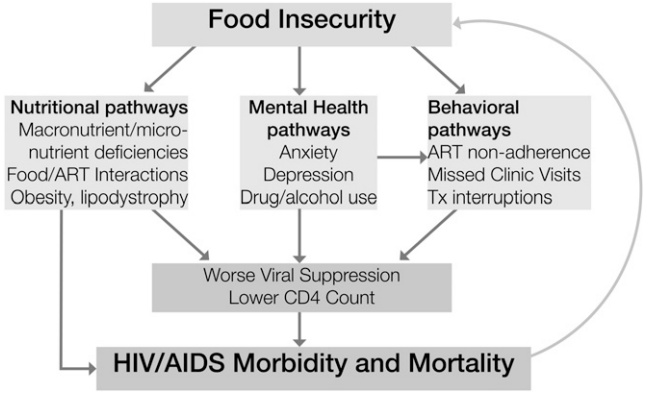

FIGURE 3. Food insecurity and HIV/AIDS morbidity and mortality. ART, antiretroviral therapy; Tx, treatment.

PATHWAYS THAT LINK FOOD INSECURITY AND HIV ACQUISITION

Data from a number of sources have suggested that food insecurity can increase susceptibility to HIV in resource-rich and resource-poor settings alike (13, 16, 58). Despite the observed association between food insecurity and HIV acquisition, the precise mechanisms that underlie potential causation are poorly understood. Our conceptual framework, which incorporates nutritional, mental health, and behavioral pathways, may provide a useful tool for the exploration of causal linkages between food insecurity and HIV acquisition (Figure 2).

Nutritional pathways

Food insecurity leads to general undernutrition (protein and energy deficiencies) as well as micronutrient deficiencies (59–64). Micronutrient deficiencies in uninfected, HIV-exposed individuals can impair the integrity of the gut and genital epithelial lining and the differentiation of target cells, and can cripple other host defense mechanisms, which can, in turn, increase susceptibility to infection in both adults and infants (65). In HIV-infected individuals oxidative stress caused by micronutrient deficiencies may cause HIV viral loads to increase (66), and thereby increase an individual's infectiousness and likelihood of transmission of HIV to others (67). Among those who receive ART, food insecurity has also been associated with unsuppressed viral loads (8), which are known to heighten the

risk of secondary HIV transmission via vertical and sexual routes and through the use of injection drugs. In terms of macronutrient deficiencies and infectivity, wasting and low weight gain during pregnancy were associated with increased mother-to-child transmission in a prospective study in Tanzania (19). Food insecurity can also increase vertical transmission of HIV/AIDS by increasing the prevalence of mixed formula and breastfeeding, a practice that has been shown to increase the risk of mother-to-child transmission 4-fold compared with exclusive breastfeeding (68). In Malawi, for example, women who experienced food insecurity felt that their breast milk production was inadequate and were more likely to supplement with other non–breast milk sources of nutrition before their children were 6 mo of age (18).

Mental health pathways

Qualitative studies conducted in diverse cultural contexts among non-HIV-infected persons have identified feelings of helplessness, shame, and humiliation as central to the experience of food insecurity (69–72). Correspondingly, quantitative studies among HIV-uninfected persons have confirmed an association between food insecurity and depression (73–76). Among PLWHA, several studies have similarly reported that food insecurity is associated with depression (77, 78) and decreased overall mental health status (7). At least one study has shown that the effects of food insecurity on depression were most pronounced among women (79). Food insecurity has also been associated with drug and alcohol use and tobacco dependence in a number of studies (5, 7, 78). Worse mental health and drug abuse, in turn, are strongly associated with HIV transmission risk behaviors (80–83). However, there has been little study of the role of mental health in mediating HIV transmission risk among food-insecure individuals.

Behavioral pathways

Some people engage in high-risk sexual behaviors as a means of coping with food insecurity, which contributes to enhanced HIV transmission risk (84, 85). In a large population-based cross-sectional study in Botswana and Swaziland, food insufficiency (not enough food to eat, per self-report) was independently associated with inconsistent condom use with a nonprimary partner, sex exchange, intergenerational sexual relationships, and lack of control in sexual relationships among women (13). In a cross-sectional study among 320 sex workers in Lagos, Nigeria, 35% of respondents said that poverty and lack of other means to get food were responsible for their decision to join the sex trade industry (86). Qualitative studies conducted in Botswana, Swaziland, and Uganda showed that women's control over sexual decision making is severely constrained as a result of their dependence on men for food and other resources (87, 88). Women in these settings often feel that they have to engage in unsafe sex to negotiate their subsistence needs, and food insecurity can contribute to sex exchange in situations in which women feel they have no other options for feeding themselves and their children.

Food insecurity has also been shown to contribute to sexual victimization in sub-Saharan Africa. In Botswana, food insufficiency was associated with >2-times-higher odds of sexual violence among women (89). In qualitative studies from Uganda, Botswana, and Swaziland, women said that they were compelled to remain in abusive relationships as a result of food insecurity and poverty (87, 88). A recent longitudinal study from British Columbia found that severe food insecurity was strongly correlated with unprotected sex among HIV-infected injection drug users (90).

For men and women in resource-poor settings, another possible mechanism through which food insecurity may lead to increased sexual risk taking is that lack of food often leads to migration for work (91, 92). Migration, in turn, has been shown in multiple studies to be associated with increased sexual risk taking and HIV prevalence for both men and women (93–96). In addition to the above mechanisms, food insecurity may contribute to unsafe injection practices among HIV-infected injection drug users if food insecurity interferes with access to clean syringes, needle exchange programs, or health and social support services; more studies are needed to assess this possibility.

PATHWAYS THAT LINK FOOD INSECURITY AND HIV DISEASE PROGRESSION

Food insecurity is associated with a range of negative health outcomes among people infected with HIV/AIDS. Studies from San Francisco and Vancouver have shown strong associations between food insecurity and incomplete viral load suppression and lower CD4 counts (7, 8, 23). In rural Uganda, severe food insecurity has been associated with increased hospitalizations (97), higher odds of self-reported opportunistic infections, and lower physical health composite scores from the validated Medical Outcome Study–HIV Physical Health Summary (22). In a large survival analysis of data from British Columbia, after adherence, CD4 cell counts, and socioeconomic variables were controlled for, food insecurity was associated with an increased hazard of nonaccidental mortality over a median follow-up time of 8.2 y (6). We posit that there are a number of nutritional, mental health, and behavioral pathways through which food insecurity leads to increased HIV morbidity and mortality (Figure 3).

Nutritional pathways

Nationally representative studies of adults in the United States (59–62) and Canada (63) have linked food insecurity to inadequate dietary intakes and serum nutrient levels. Additionally, among PLWHA, cross-sectional studies have identified an association between food insecurity and HIV wasting (64). General undernutrition (protein and energy) and micronutrient deficiencies are both associated with a higher risk of disease progression and mortality in HIV-infected individuals (65, 98–100). Specifically, weight loss, low BMI (in kg/m^2), low albumin, and micronutrient deficiencies have been shown to predict opportunistic infections, immunologic decline, and shorter survival time in both untreated and HAART-treated individuals (101–112). HIV increases metabolic requirements (107, 113) and is associated with diarrhea and malabsorption of fat and carbohydrates (113–116), which further compound the links between malnutrition and disease progression. Furthermore, PLWHA are at increased risk of malnutrition because of reduced energy intake from anorexia and early satiety; systemic effects from infections; impaired swallowing from oral and esophageal opportunistic infections; and progressive disability, which leads to unemployment and difficulties in the procurement of food (15, 113, 117). Finally, lack of food may impede optimal absorption of certain antiretroviral medications (118–120), which may, in

turn, contribute to treatment failure. Several protease inhibitors, such as nelfinavir and ritonavir, require food for maximal absorption, and the absence of food may negatively affect the pharmacokinetics of these drugs (119, 121).

Among HAART-treated patients in Vancouver, we observed that whereas the effect of food insecurity on mortality was most pronounced among malnourished individuals (adjusted HR = 1.94; 95% CI: 1.10, 3.40), individuals who were malnourished but food secure were not more likely to die, and there was a trend toward increased mortality among individuals who were food insecure but had normal weights (adjusted HR = 1.40; 95% CI: 0.91, 2.05) (6). This suggests that undernutrition is not the only pathway through which food insecurity negatively affects health outcomes.

Food insecurity also exerts negative effects on health through its effects on obesity and poor diet quality (122). In cross-sectional studies of data from the US general population, food insecurity has been associated with hypertension (123), obesity (124), diabetes (122), and self-reported diagnosis of hyperlipidemia (123). Researchers have hypothesized that these associations are driven by substitutions of cheaper, energy-dense foods (125, 126), overconsumption during periods of food availability (127, 128); and compensatory changes in metabolism (129). HIV infection may be an adverse moderator of the relation between food insecurity and worsened metabolic outcomes, because HIV infection itself is known to be associated with a range of metabolic abnormalities, including endothelial dysfunction, atherogenic dyslipidemia, and abnormal glucose metabolism (130–132). Furthermore, treatment with certain antiretroviral medications has been linked to these same metabolic abnormalities (130–132). Thus, it is likely that the effect of food insecurity on metabolic outcomes may be even more pronounced among PLWHA. These abnormalities, together with the fact that the prevalence of obesity among PLWHA is increasing (133), underscores the need to study the relationships between food insecurity and metabolic outcomes so that preventive interventions can be implemented.

Mental health pathways

Food insecurity can also negatively affect health outcomes through mental health pathways, although longitudinal studies will be needed to confirm this. As described above, food insecurity has been strongly associated with depression and poor mental health status (5, 7, 77, 78, 134). Depression and anxiety disorders, in turn, have been shown to predict reduced uptake of, and nonadherence to, HAART (135–142), as well as higher viral loads and higher activated $CD8^+$ cell counts (143). The effects of depression on HIV treatment outcomes are not fully explained via its effects on ART adherence. Even after adjustment for ART adherence, depression has been associated with worsened HIV treatment outcomes, including $CD4^+$ T lymphocyte count decline (144, 145), increased probability of AIDS-defining illness (146), and AIDS-related mortality (145, 147). The role of depression in the acceleration of disease progression is strengthened by the fact that the treatment of depression has been observed to improve ART adherence (148, 149) and viral suppression (149). A number of studies (5, 7, 78) have shown that food insecurity, in addition to its links with depression and worse mental health status, has bidirectional associations with drug and alcohol use and tobacco dependence, which are known to contribute to decreased adherence and worse HIV/AIDS health outcomes (135, 150).

Behavioral pathways

Among low-income adults, food insecurity and other competing subsistence needs (eg, unstable housing) are associated with worsened access and adherence to care (151–154) because competing subsistence priorities such as obtaining food and shelter often interfere with adherence to regular medication use or attendance at outpatient appointments (15, 155–163). Research on adherence to other long-term medication regimens, such as tuberculosis, has also indicated the importance of food security to adherence and treatment outcomes (164, 165).

Both cross-sectional quantitative and qualitative studies have documented strong links between food insecurity and ART adherence among HIV-infected individuals. In cross-sectional studies among urban poor PLWHA in San Francisco, Vancouver, and Atlanta, food insecurity has been associated with ART nonadherence as measured by both unannounced pill counts and pharmacy refill (8, 23, 166, 167). In Atlanta, food insecurity was also associated with common barriers to adherence, such as lack of social support, drug use, and inability to afford medications (23). In a large nationally representative sample of ~5000 HIV-infected individuals in France, food privation was associated with increased odds of self-reported ART nonadherence among heterosexual men, and a trend toward increased odds of nonadherence among heterosexual women (168). Whereas few quantitative studies to date have documented associations between food insecurity and nonadherence in resource-poor settings (169), qualitative studies in Kenya, Uganda, Botswana, and Swaziland have observed that food insecurity is one of the most commonly cited barriers to ART treatment adherence (15, 87, 160, 170). In addition to food insecurity, poverty and the attendant inability to afford user fees and transport fees are well known to adversely affect ART adherence in resource-limited settings (159, 169). HAART treatment interruptions (171–174) and average HAART adherence (175–177), in turn, are well-known determinants of HIV treatment outcomes.

Other studies have specifically looked at whether food supplementation affects ART adherence. One study in Zambia compared adherence among patients in 4 clinics that provided food supplementation with patients in 4 clinics that did not. They showed that 70% of patients in the food supplementation group achieved $\geq$95% adherence compared with only 48% in control groups (178). A qualitative study in Kenya also showed greater ART adherence among patients enrolled in a food support program compared with individuals not enrolled (25). Further rigorous studies are needed to explore the mechanisms by which such supplementation may improve adherence and HIV treatment outcomes.

In addition to ART nonadherence and treatment interruptions, as a result of competing demands between food and other resources, it has been shown that food-insecure individuals often miss scheduled clinic visits and may have decreased uptake of HAART (97, 160, 170, 179). In a national survey of low-income adults from the general United States population, food insecurity was associated with postponement of needed medications and care and with increased emergency department use and hospitalizations (151). Another study showed that competing subsistence needs were associated with

worse access to health care among HIV-infected individuals (155). In rural Uganda, severe food insecurity was associated with decreased outpatient clinic visits, and many participants had forgone ART (15%), other medications (22%), outpatient care (28%), and inpatient care (28%) to secure food (97). An even greater proportion of study participants reported that they had prioritized medical care; participants had forgone food to obtain ART (83%), access outpatient care (76%), and access inpatient care (44%). This suggests that the relatively high levels of adherence reported among HAART-treated individuals in resource-poor settings (157, 180, 181) may not be sustainable in the long term unless food insecurity and poverty reduction become essential components of comprehensive HIV care programs. Longitudinal studies are needed to confirm the extent to which ART adherence, treatment interruptions, and missed clinic visits are on the causal pathway between food insecurity and worse HIV treatment outcomes in both resource-rich and resource-poor settings.

THE CYCLE OF FOOD INSECURITY AND HIV/AIDS: IMPLICATIONS FOR FUTURE RESEARCH

We have suggested that nutritional, mental health, and behavioral pathways explain how food insecurity affects HIV acquisition and HIV/AIDS treatment outcomes. The next step is to understand how these pathways operate across the spectrum of socioeconomic settings and the relative importance of each pathway. Here we identify specific priorities for future research and suggest lessons for both practitioners and policy makers who work in related fields (**Figure 4**).

Whereas there is a rich body of literature in support of the various associations in the conceptual model, no longitudinal studies to date have confirmed these pathways. For example, studies have linked food insecurity to poor nutrition (under- and overnutrition), worse mental health, and nonadherence to treatment and care recommendations; yet no studies to date in either resource-rich or resource-poor settings have specifically assessed the extent to which each of these are on the causal pathway between food insecurity and poor health outcomes. Longitudinal studies based on larger, more representative samples are needed to further assess the relative importance of each mechanism that underlies the relationships between food insecurity and HIV acquisition and HIV health outcomes. We also need to understand whether the mechanisms by which food insecurity adversely affects HIV health outcomes and prevention differ between resource-rich and resource-poor settings. Further clarification of these mechanisms can have important policy and programmatic implications.

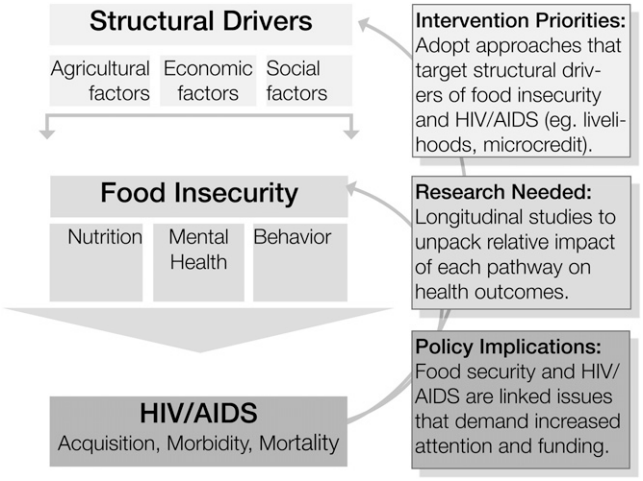

FIGURE 4. Implications for research, policy, and practice.

In terms of links between food insecurity and HIV acquisition, there are limited data on the effect of food security on sexual risk taking among PLWHA, which highlights an important gap in secondary HIV prevention. There is also a dearth of literature that examines these associations in resource-rich settings and among other populations such as men who have sex with men. We also need to understand more about the mechanisms by which malnutrition may enhance biological susceptibility to HIV among exposed individuals, particularly the role of micronutrient deficiencies. Likewise, research is needed to examine the relation between food insecurity and unsafe injection practices among HIV-infected and uninfected individuals, and whether food insecurity contributes via risky sex and needle sharing to other sexually transmitted infections and hepatitis C. Finally, we need to better understand the mechanisms by which food insecurity may increase the risk of mother-to-child transmission before birth, during labor, and in the first years of life.

There are limited data on the magnitude and extent of the effect of food insecurity on HIV clinical outcomes in resource-poor settings. There are still few data on the role of food insecurity in comorbidities such as hypertension, diabetes, hypercholesterolemia, and cardiovascular complications of HIV in any setting. This research is particularly important in light of the increasing contribution of cardiovascular and metabolic complications of HIV to overall morbidity and mortality among HIV-infected individuals. Finally, food insecurity may also contribute to increased inflammation and T cell activation, mediated by increased gut bacterial translocation (30), but this has not yet been evaluated in studies.

NEED FOR INTERVENTION STUDIES

Policy makers have long acknowledged the potential for food security interventions to positively affect the HIV/AIDS epidemic. For example, according to a 2003 policy statement by the World Food Program, "achieving food security is an important way to decrease transmission of HIV and improve outcomes among those infected" (90). Furthermore, the World Food Program has been working with governments and nongovernmental organizations to ensure that food assistance is incorporated into HIV/AIDS programs where appropriate. The United Nations Standing Committee on Nutrition in 2001 committed to the integration of food security and nutrition considerations into HIV/AIDS programming, to implementation of nutrition care and counseling as part of the essential HIV/AIDS package, and to implementation of optimal approaches to food assistance, processing, and production activities as part of larger HIV/AIDS care programs (182).

Despite these recommendations, little research exists to document the efficacy, effectiveness, or cost effectiveness of food-security interventions on HIV clinical outcomes or HIV acquisition risk in either resource-rich or resource-poor settings. A recent Cochrane review identified no randomized controlled trials conducted in developing countries that examined the effects

of either macronutrient supplementation or sustainable food production strategies on HIV morbidity and mortality (183). Such research is critical if we are to provide empiric evidence to guide policies to integrate structural interventions into the expansion of HIV care, treatment, and prevention programs.

Existing intervention approaches to improve HIV treatment outcomes via food security are limited in their scalability and sustainability (184). A few small nonrandomized studies have shown the potential for macronutrient supplementation to affect health outcomes among PLWHA (25, 28, 178, 185–187). Yet macronutrient supplementation, although it provides critical nutritional support, does not address all of the downstream health consequences of food insecurity, and also causes dependency on health programs for receipt of food aid (25). Moreover, reliance on health programs for food may be socially unacceptable or may contribute to ongoing anxiety and uncertainty about food supply and feelings of deprivation and alienation. Finally, the provision of clinic-based food supplementation is costly, and may be difficult to scale up in a variety of settings (188).

Livelihood interventions, which address upstream causes of food insecurity, may have a better chance of improving health outcomes and decreasing HIV transmission by addressing the numerous pathways (nutritional, mental health, and behavioral) through which food insecurity negatively affects health. As an example of this approach, a small study in rural Kenya showed that an intervention that used a microirrigation water pump combined with a microfinance loan led to increases in crop yields, household income, BMI, and CD4 counts (189). More research is needed on structural interventions to address the root causes of poverty and food insecurity, to improve HIV health outcomes, and decrease HIV transmission risk (26, 49, 90, 182).

The development of comprehensive food security interventions that are well integrated with HIV programs will require multidisciplinary partnerships among health, agricultural, and economic experts. For example, because studies have shown that microcredit programs can improve health and prevent disease acquisition by helping address poverty and sex inequality (190–192), experts have recommended an integration of microfinance and other livelihood approaches to maximize health and to reduce HIV transmission and poverty (193, 194). Creative solutions will be required to best meet the food needs of impoverished populations in different parts of the world to prevent HIV transmission and to improve the health and well-being of those who live with HIV/AIDS.

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