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Improving the measurement of food insecurity among people with HIV in South Africa: a psychometric examination

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Abstract

Objective: Food insecurity is a structural barrier to HIV care in peri-urban areas in South Africa (SA), where approximately 80 % of households are moderately or severely food insecure. For people with HIV (PWH), food insecurity is associated with poor antiretroviral therapy adherence and survival rates. Yet, measurement of food insecurity among PWH remains a challenge.

Design: The current study examines the factor structure of the nine-item Household Food Insecurity Access Scale (HFIAS, isiXhosa-translated) among PWH in SA using a restrictive bifactor model.

Setting: Primary care clinics in Khayelitsha, a peri-urban settlement in Cape Town, SA.

Participants: Participants (n 440) were PWH who received HIV care in Khayelitsha screening for a clinical trial. Most were categorised as severely (n 250, 56·82 %) or moderately (n 107, 24·32 %) food insecure in the past 30 d.

Results: Revised parallel analysis suggested a three-factor structure, which was inadmissible. A two-factor structure was examined but did not adequately fit the data. A two-factor restrictive bifactor model was examined, such that all items loaded on a general factor (food insecurity) and all but two items loaded on one of two specific additional factors, which adequately fit the data (comparative fit index = 0·995, standardised root mean square residual = 0·019). The two specific factors identified were: anxiety/insufficient quality and no food intake. Reliability was adequate ($\omega = 0{\cdot}82$).

Conclusions: Results supported the use of a total score, and identified two specific factors of the HFIAS, which may be utilised in future research and intervention development. These findings help identify aspects of food insecurity that may drive relationships between the construct and important HIV-related variables.

Keywords
Food insecurity
Measurement
HIV
Sub-Saharan Africa
South Africa

Food insecurity is an increasingly problematic global public health problem. Defined as having 'both physical and economic access to sufficient food to meet their dietary needs for a productive and healthy life[1,2], food insecurity is the lack of this access at any time. Following this definition, categories of food insecurity have been created based on varying levels of severity[1]. Households with severe food insecurity often experience reductions in meal size or number of meals, and/or experience going to bed hungry or having no food at all to eat. Households with moderate food insecurity sometimes or often have lower quality foods, and/or rarely or sometimes experience reductions in meal size or number of meals. A mildly food insecure household sometimes or often worries about not having enough food, and/or only rarely is unable to eat their preferred food. However, a mildly food insecure household

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would not have to reduce the size or number of meals and does not experience having insufficient food. Lastly, a food secure household may rarely experience worry about having enough food and does not experience any other food insecurity conditions[1]. Prevalence of food insecurity varies around the world, as well as within different regions of the same country[3]. A common misconception regarding food insecurity is that it occurs only in rural areas, yet urban and peri-urban areas are becoming increasingly food insecure[3,4]. In a large survey of eleven cities in nine sub-Saharan African countries, the African Food Security Urban Network found prevalence rates of severe food insecurity ranging from 21 % to 79 % of households[4].

One such urban area with a high prevalence of food insecurity is Cape Town, South Africa (SA) – specifically, the peri-urban settlements that surround Cape Town[5]. Findings suggest that approximately 80 % of households in peri-urban settlements outside of Cape Town are either severely or moderately food insecure[5]. Within the Khayelitsha township, located east of Cape Town and considered SA's second largest peri-urban settlement, food insecurity is even more prevalent than in similar settlements. In Khayelitsha, only 8 % of households were classified as food secure[4].

The high rates of food insecurity in Khayelitsha and other peri-urban settings outside of Cape Town are alarming not only independently but also in the context of high HIV prevalence rates. SA accounts for approximately 19 % of all people with HIV (PWH) and 11 % of all AIDS-related mortality worldwide[6]. And, Khayelitsha has a higher HIV prevalence rate than the rest of the province in which it is located; in 2013, the antenatal HIV prevalence in Khayelitsha was 34·4 %, compared with 18·7 % in the Western Cape[7]. Given the high prevalence of both food insecurity and HIV in Khayelitsha, food insecurity may be a major structural barrier to HIV care[8]. Not only are PWH more likely to be food insecure than people without HIV due to morbidity, the need for chronic medical care and HIV-related inequities[9,10], food insecurity is associated with poorer access to care among PWH[8]. Even among PWH who are engaged in care, food insecurity is associated with worse antiretroviral therapy (ART) adherence, lower absolute CD4 cell count, having a detectable viral load and decreased survival[8]. Research also suggests that women with HIV in sub-Saharan Africa are more likely than men to experience food insecurity[8,11]. As such, it is possible that either men or women experience differing levels of food insecurity or that gender-related bias exists in the measurement of food insecurity.

There are numerous approaches to measuring food insecurity, which include both indirect (e.g., dietary intake, household expenditures, anthropometry, food availability, etc.) and experiential assessments of an individual's or household's experience of food insecurity[12–15]. For instance, in the general global population, one commonly employed measure of food insecurity is the Household Food and Nutrition Security Survey Module[16,17]. A number of psychometric studies of this measure of food insecurity, predominantly conducted in North and South America, generally suggest a one- or two-factor structure[17]. Even among widely used measures of food insecurity utilised among the general population, divergent findings on the factor structure of these measures exist. Understanding the factor structure of measures of food insecurity is an important step in better understanding the relationship between food insecurity and other prevalent health problems, such as HIV.

Although several measures have been used to examine the relationship between food insecurity and HIV outcomes, and extant literature demonstrates the negative effects of food insecurity on viral load, CD4 cell counts, medication adherence and retention in care[18–20], there exists a paucity of research examining the psychometric properties of experiential measures of food insecurity among populations with HIV. As such, it is unclear whether frequently used experiential measures of food insecurity such as the Household Food and Nutrition Security Survey Module[16], the Radimer/Cornell measure[21] or the Household Food Insecurity Access Scale (HFIAS)[1] are valid measures of food inescurity among PWH.

The HFIAS[1] measures a household's ability to access food[22] and indicates the frequency of both experiences of and behavioral responses to food insecurity in the past 30 d[1]. The measure categorises items into three different domains: anxiety and uncertainty about the household food supply (one item), insufficient quality (including the variety and preferences of the type of food; three items) and insufficient food intake (five items). The indicator guide also suggests the use of a total score and establishes categories of food insecurity (i.e., food secure, or mildly, moderately or severely food insecure) based on certain response patterns indicating increasing severity. One benefit of the HFIAS is the 30-d recall period, compared with other measures such as the Household Food and Nutrition Security Survey Module, which uses a 12-month recall period[16]. The 30-d recall period aligns with the optimal recall period for HIV medication adherence[23] as well as the operational definition of recent viral load utilised in the present study[24], which therefore makes the HFIAS an ideal measure of food insecurity to utilise among PWH.

However, prior research on the HFIAS outside of the USA has yielded results that are incongruent with the three domains specified by the HFIAS indicator guide[1]. For example, a principal components analysis of the HFIAS in an urban setting in Iran yielded two factors, insufficient food quality and insufficient food intake, which together explained 77·5 % of the total variance[25]. Another principal components analysis of the HFIAS in rural Tanzania revealed the same two factors and accounted for 69 % of the total variance[26]. And, yet another principal components analysis conducted among rural and urban populations in Ethiopia also suggested two factors[27]. However, inconsistent with previous research, this Ethiopian study found that items relating to no food intake at all comprised one factor, and all other items relating to limited food intake, insufficient quality and anxiety comprised the other factor[27]. These studies conducted in various low- and middle-income countries outside of the USA revealed only two factors, which differs from both the one general domain of food insecurity that is outlined in both the HFIAS indicator guide[1] and other measures of food insecurity (e.g., Household Food and Nutrition Security Survey Module[16]) and the three specific domains of the HFIAS. These findings raise the question: how many factors should be used when employing the HFIAS to examine the relationship between food insecurity and HIV in low- and middle-income countries? Moreover, none of these studies examined the validity of the HFIAS among PWH, for whom food security is associated with important HIV-related outcomes.

Despite findings that suggest food insecurity is a major structural barrier to HIV care[18–20], measurement of food insecurity among PWH remains a challenge[8]. To our knowledge, although the HFIAS has been used in SA previously[4,5], no studies have examined the factor structure of this measure among PWH in SA. The present study is also the first study to conduct an item analysis and differential item functioning analyses of the HFIAS among PWH, which offers insight on whether items are associated with differing severities in different contexts. Given the established relationships among food insecurity, ART adherence and viral load, it is important to determine if the factor structure of the HFIAS holds for PWH in SA, or if not, how future research may better examine food insecurity in this context. Improving our understanding of the measurement of food insecurity among PWH may enable future studies to more accurately examine the relationships between food insecurity and important HIV-related disease outcomes, which in turn may inform intervention development.

Method

Participants and procedure

The current study combined baseline data from two studies of PWH in Khayelitsha, a peri-urban community outside Cape Town, SA. Participants (n 440) completed either the baseline visit as part of a protocol of a randomised controlled trial to improve depression and medication adherence[24] or a cross-sectional survey in the same clinics. Interested individuals were eligible for either study if they: were HIV-positive, received HIV care from one of six primary care clinics in Khayelitsha, were 18 years of age or older and were fluent in isiXhosa or English. Participants who were eligible for the randomised controlled trial were currently prescribed ART and had failed first-line ART, had screened positive for current major depressive disorder on the MINI[28] and did not have any other current untreated major mental illness that could interfere with study participation.

For both assessments, clinic patients who were interested in the study were screened in a private area, and if they met preliminary inclusion criteria, were scheduled for a baseline visit. If participants were available, assessments could occur on the same day as screening. All participants provided written informed consent prior to completing the assessment and were reimbursed for their time. All materials used in the study were translated into isiXhosa from English using Brislin's[29] back-translation method, and materials were available in either language, based on participant preference. The self-reported assessment battery was administered in interview format by bilingual (i.e., English and isiXhosa speaking) study staff to ensure accurate data collection. Although participants were able to complete the self-reported assessment battery in either English or isiXhosa, all participants chose to complete the battery in isiXhosa. Data were collected, stored and managed using Research Electronic Data Capture tools[30,31]. Research Electronic Data Capture is a secure, web-based software platform designed to support data capture for research studies. All procedures were approved by the Institutional Review Board at the University of Miami (Protocol number 20150399) and the Human Research Ethics Committee at the University of Cape Town (Protocol number 010/2014).

Measure

Food insecurity

Food insecurity was assessed via the nine-item HFIAS[1]. Participants indicated the frequency of their household's experience of food insecurity over the past 30 d using a Likert-type scale with the following response options: 0 (*never*), 1 (*rarely*), 2 (*sometimes*) or 3 (*often*). A visual analogue scale was created to represent the Likert response options, with four circles of growing sizes representing never, rarely, sometimes and often. The HFIAS assesses various aspects of food insecurity, including worry about food, inability to eat preferred foods, eating just a few kinds of foods, eating foods one does not want to eat, eating a smaller meal, eating fewer meals in a day, having no food of any kind in the household, going to sleep hungry and going a whole day and night without eating. Based on prior research specified in the HFIAS indicator guide[1], a total score was calculated by summing responses to each item. Additionally, categories denoting severity of food insecurity were created following the indicator guide instructions, and participants were categorised as food secure, or mildly, moderately or severely food insecure based on their response patterns. A detailed description is available in the HFIAS indicator guide[1]. However, for example, per the HFIAS indicator guide, a participant would be classified as food secure if they endorsed experiencing worry about food only rarely and not experiencing any other elements of food insecurity, whereas another would be classified as severely food insecure if they endorsed experiencing not having enough food to eat at any frequency[1].

Data analysis

Analyses were conducted in R, version 3.5.1[32], using the following packages: qgraph[33], lavaan[34], magrittr[35], nFactors[36], itemanalysis[37] and VGAM[38]. Descriptive statistics were calculated to characterise the sample. Polychoric correlations, which are appropriate for categorical data[39], were computed to examine the marginal relationships among the HFIAS items.

To conduct the analyses described below, data from two baseline assessments of separate individuals, as described above, were combined. Although participants who completed the baseline visit of the randomised control trial were eligible to complete the cross-sectional assessment study, those who completed both assessments were removed from the cross-sectional assessment dataset to eliminate overlap. Participants who completed both assessments were removed from the cross-sectional assessment dataset because, chronologically, the cross-sectional assessment happened after the randomised control trial, and participants may have received an intervention through the randomised control trial that could have impacted their experience of food insecurity in the past 30 d. Therefore, for people who participated in both the cross-sectional study and the randomised control trial, we utilised the initial report of food insecurity (from the baseline visit of the randomised control trial) that would not be affected by potential receipt of an intervention. The overall dataset was then randomly split in half to allow for both exploratory and confirmatory analyses on independent datasets.

Using one half of the sample, dimensionality assessment was performed to assess for the number of factors underlying these data. A number of methods exist for determining dimensionality[40], such as the point at which the scree plot of the eigenvalues elbows[41], or the number of eigenvalues that are greater than one[42]. These methods are considered less preferable than revised parallel analysis[43], which was employed to assess for factor structure in the present study. Revised parallel analysis empirically tests the likelihood that the kth observed eigenvalue is statistically significantly larger than the kth eigenvalue of randomly generated data, under the assumption of k-1 factors[43]. The current analysis suggests dimensionality when the observed eigenvalues are no longer statistically significantly larger than the generated eigenvalues. For example, if the first observed eigenvalue is larger than the generated eigenvalue, but the second is not, there is likely one underlying factor that best fits the data. After assessing for underlying dimensionality, factor analyses were performed to assess factor structure. Exploratory factor analysis (EFA) was utilised to initially examine the factor loadings. An oblique rotation (promax) was used in the EFA to allow for correlation between factors[44,45].

After examining the results of the EFA, a confirmatory factor analysis (CFA) using maximum likelihood estimation on the other half of the sample tested congeneric models of the factor structure suggested by EFA. Restrictive bifactor models were also examined in the context of CFA. The restrictive bifactor model does not allow for correlation among factors, such that each item loads on a general factor and, at most, one specific factor, which may suggest the use of a total score despite the presence of multidimensionality[46]. Restrictive bifactor models may also be useful when unidimensional models are suggested for multidimensional data[47] and to model construct-relevant multidimensionality[48]. Given that the overall dimension of the measure may be unidimensional, but prior research using the HFIAS has revealed two factors relevant to food insecurity, a restrictive bifactor model may be well-suited to examine these varying structures. Results of a restrictive bifactor model may suggest the use of a total score, subscale scores or both.

Model fit was assessed by examining the comparative fit index, the root mean square error of approximation, the standardised root mean square residual and the Akaike information criterion. The explained common variance (ECV) was also calculated to estimate the degree of unidimensionality[48]. Given that congeneric models were examined, McDonald's ω was calculated to determine the reliability of the HFIAS in this sample[49].

In addition, using the complete dataset, item analysis was conducted to investigate the endorsement level of each item. Endorsement level was calculated by dividing the average item score by the maximum possible score for the item (i.e., 3 for the HFIAS). Response category analysis was also conducted by examining biserial correlations to assess for an ordinal relationship between categories. Biserial correlations provide estimates of the correlation between the respondents' observed total score and the latent score for each specific item[50]. Biserial correlations are also appropriate for response options beyond dichotomous items (i.e., for ordinal data). In addition, results of item analyses are needed for differential item functioning analysis[50].

Lastly, to determine the presence of construct-irrelevant variance by gender (i.e., gender-related bias), differential item functioning analysis was conducted using the full sample. Given that prior research has demonstrated more severe food insecurity among women with HIV relative to men[8], item scores by gender, conditioned on the total score, were compared using a series of ordinal regression models in which men were treated as the reference group. These analyses were conducted on the 438 participants who identified as either a cisgender man or woman; the two transgender men participants were removed from the calculations because there were not enough transgender men to conduct separate analyses on this group. For each item, the following regression models were

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examined: an intercept only model, a total score main effect, a gender main effect and an interaction between total score and gender.

Results

Descriptive statistics

Descriptive statistics of participants' (*n* 440) demographic and HIV-related disease indicators (i.e., viral load and CD4) are presented in Table 1. Briefly, approximately three-quarters of the participants were women (76·1 %), almost all self-identified as Black (99·09 %), the majority were unemployed (72·0 %) and lived in a family house (38·4 %) or a shack (51·6 %). Participants had an average age of 39 (SD = 9·05) years old. With respect to the HFIAS, the mean total score was 11·37 (SD = 7·12, range = 0–27). Additionally, 64 (14·55 %) participants were classified as food secure, 19 (4·32 %) as mildly food insecure, 107 (24·32 %) as moderately food insecure and 250 (56·82 %) as severely food insecure.

Preliminary analyses: item correlations

Polychoric correlations were computed using the entire sample to assess the associations between HFIAS items (see Table 2). As expected, items of the HFIAS were statistically significantly and strongly correlated with each other (all Ps < 0·001).

Dimensionality assessment

Eigenvalues are presented in Table 3 and Fig. 1, and the scree plot of the eigenvalues is presented in Figure 1. Results of the revised parallel analysis revealed that the first, second and third observed eigenvalues (7·44, 0·77 and 0·24, respectively) were greater than the 95th percentile of the randomly generated eigenvalues (1·42, 0·59 and 0·23, respectively), suggesting that the first, second and third factors were statistically significant. Of note, the third observed eigenvalue was extremely close to the 95th percentile of the generated eigenvalues. However, the fourth observed eigenvalue (0·17) was not greater than the 95th percentile (0·20), which suggested both that the fourth factor was not statistically significant and that all other factors beyond the fourth would not reach statistical significance. Taken together, the revised parallel analysis suggested a three-factor solution given that the first, second and third observed eigenvalues were greater than the 95th percentile of the randomly generated eigenvalues. Accordingly, a three-factor solution was examined.

Exploratory factor analysis

EFA was utilised initially (with one half of the data) to examine the factor loadings of the nine items and to determine onto which of the three factors each item loaded. Given the results of the revised parallel analysis, the three-factor solution was examined. However, the three-factor solution was inadmissible due to a factor loading greater than 1 with uniqueness near zero[45]. Moreover, the three-factor solution contained only one item in the third factor, and that item had a stronger loading in the first factor, thus providing no additional information. As such, the two-factor solution was examined. Results of the EFA for the two-factor solution suggested that items 1, 2, 3, 4, 5 and 6 loaded onto one factor, and items 7, 8 and 9 loaded onto the other factor.

Confirmatory factor analysis

Using a congeneric model (with the other half of the data), CFA was then employed to examine this two-factor solution (Table 3, Fig. 2). The two-factor solution did not adequately fit the data (root mean square error of approximation = 0·259 (95 % CI 0·237, 0·281), comparative fit index = 0·858, standardised root mean square residual = 0·045). Thus, a one-factor, unidimensional solution was examined using CFA. However, the one-factor solution also did not adequately fit the data (root mean square error of approximation = 0·364 (95 % CI 0·349, 0·379), comparative fit index = 0·755, standardised root mean square residual = 0·080). Given that the majority of prior research on food insecurity in general has suggested either a one- or two-factor structure[17] and that research specifically on the HFIAS outside of the USA has suggested a two-factor structure[25–27], a restrictive bifactor model was examined. We also examined factor-based discriminant validity for the two-factor structure and a violation was found. Although convergent correlations within each of the two factors were somewhat higher than the divergent correlations, all items had strong (i.e., $r > 0·5$) divergent correlations for both factors, thus supporting use of a restrictive bifactor model. The structure of the two-factor restrictive bifactor model is depicted in Fig. 2. In this model, items loaded onto one general factor and, at most, one (of two) additional specific factor. An initial two-factor restrictive bifactor model was examined in which all items loaded onto the general factor and one of the two specific factors. However, this model resulted in two items (items 5 and 6) having irregular loading patterns (as described in[51]) on the first specific factor. As such, a subsequent two-factor restrictive bifactor model was examined in which items 5 and 6 did not load onto any specific factor, and only loaded onto the general factor. All other items loaded onto the general factor and one of the specific factors. This two-factor restrictive bifactor model adequately fit the data (root mean square error of approximation = 0·039 (95 % CI 0·000, 0·076), comparative fit index = 0·996, standardised root mean square residual = 0·016, Akaike information criterion = 3786·574). Results of this two-factor restrictive bifactor model are presented in Table 3.

Factor loadings with an absolute value ≥ 0·30 are reported as follows[44]. All items had substantial (≥ 0·30) loadings on the general factor. Items 1, 2, 3 and 4 had

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Table 1 Demographic and HIV-related disease indicator descriptive statistics

Variable	*n*	%
Gender		
Man	103	23·4
Woman	335	76·1
Transgender man	2	0·5
Highest education level		
Grade 6 or below	40	9·1
Grade 7–12	377	85·7
Vocational training	11	2·5
University	11	2·5
Employment status*		
Unemployed	317	72·0
Seeking employment	57	13·0
Casual employment	47	10·7
Full-time employment	45	10·2
Student	5	1·1
Disabled	3	0·7
Retired	5	1·1
Homemaker	4	0·9
Housing type		
Homeless	1	0·2
Shack	227	51·6
Wendy house/backyard dwelling	10	2·3
Own/family house	169	38·4
Other	33	7·5
Race*		
Black	436	99·09
Coloured	5	1·14

Variable	Mean	SD	Range
Age (years)	39·88	9·51	18–70
Monthly income before tax (ZAR)	2422·67	2692·03	0–20 000
Monthly income before tax (USD)	130·09	144·55	0–1073·92
Number of children	2·37	1·22	0–7
Number of rooms in home	3·08	1·65	1–10
Number of people sleeping in the same house	3·73	2·18	1–13
Number of people sleeping in the same room	2·58	1·41	1–11
Absolute CD4 cell count	319·13	231·78	0–1200
Viral load (raw)	40 673	125 525·29	0–1 241 488
Viral load (log-transformed)	2·69	1·91	0–6·09

*Totals for employment status and race may not equal 440 as participants could select more than one response option. In the race category, the term 'Coloured' refers to a racial category during the apartheid era and remains relevant in describing present health disparities in South Africa.

Table 2 Polychoric item correlations of the HFIAS*

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9
Item 1	1	–	–	–	–	–	–	–	–
Item 2	0·813	1	–	–	–	–	–	–	–
Item 3	0·787	0·878	1	–	–	–	–	–	–
Item 4	0·821	0·890	0·935	1	–	–	–	–	–
Item 5	0·740	0·789	0·835	0·887	1	–	–	–	–
Item 6	0·751	0·810	0·838	0·873	0·932	1	–	–	–
Item 7	0·595	0·627	0·684	0·690	0·723	0·767	1	–	–
Item 8	0·629	0·704	0·686	0·715	0·740	0·769	0·853	1	–
Item 9	0·652	0·673	0·709	0·694	0·734	0·770	0·815	0·896	1

*All *P* values for these correlations are $P < 0{\cdot}001$. Item numbers correspond to the order of items in the HFIAS indicator guide (Coates *et al.*, 2007). The items are as follows. In the past 30 d:
1. Did you worry that your household would not have enough food?
2. Were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?
3. Did you or any household member have to eat a limited variety of foods due to a lack of resources?
4. Did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?
5. Did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?
6. Did you or any household member have to eat fewer meals in a day because there was not enough food?
7. Was there ever no food to eat of any kind in your household because of lack of resources to get food?
8. Did you or any household member go to sleep at night hungry because there was not enough food?
9. Did you or any household member go a whole day and night without eating anything because there was not enough food?

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Table 3 Two-factor restrictive bifactor analysis results

Eigenvalues	7·437	0·774	0·241	0·171	0·118	0·112	0·099	0·047	0·002
	General factor	Factor 1	Factor 2						
	λ	λ	λ	Ψ^2					
Item 1	**0·659**	**0·356**	–	0·397					
Item 2	**0·653**	**0·440**	–	0·202					
Item 3	**0·721**	**0·370**	–	0·232					
Item 4	**0·719**	**0·412**	–	0·095					
Item 5	**0·919**	–	–	0·141					
Item 6	**0·953**	–	–	0·141					
Item 7	**0·585**	–	**0·456**	0·348					
Item 8	**0·573**	–	**0·659**	0·123					
Item 9	**0·634**	–	**0·523**	0·266					
RMSEA (95 % CI)	0·045 (0·000–0·079)								
CFI	0·995								
SRMR	0·019								
AIC	3787·673								

Factor loadings with an absolute value ≥ 0·30 are presented in bold, corresponding to the factors reported in text. λ are standardised factor loadings and Ψ^2 are variances. Item numbers correspond to the order of items in the HFIAS indicator guide (Coates *et al.*, 2007).

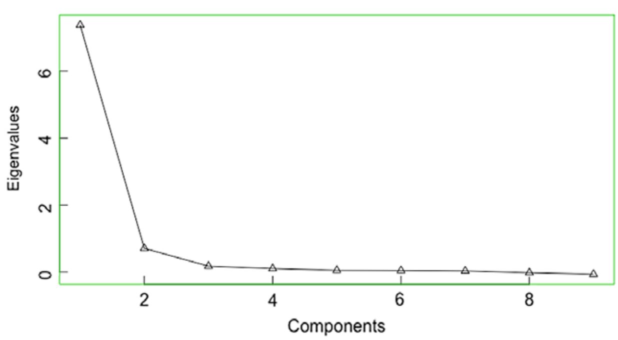

Fig. 1 (colour online) Scree plot of the eigenvalues

substantial loadings on factor 1 (anxiety/insufficient quality), and items 7, 8 and 9 had substantial loadings on factor 2 (no food intake). Consideration was given to calculating and examining factor scores. However, the factor score of the general factor was strongly and significantly correlated with the total score (r 0·949, $P<0·001$), indicating this would provide redundant information. Moreover, there is strong evidence for consideration of unidimensionality of these data given the ECV is high (ECV = 0·754).

Lastly, the reliability of the two-factor restrictive bifactor model was calculated. Given the use of a congeneric model, McDonald's ω was used to examine the proportion of variance accounted for by the underlying latent construct in the total scores. The reliability of the HFIAS in this sample was acceptable ($\omega = 0·82$ (95 % CI 0·766, 0·876)).

Item analysis

Results of the item analysis (Table 4) revealed that participants were slightly more likely to endorse experiencing items 1 through 4 (items pertaining to worry and insufficient quality) than to not endorse these items. Conversely, participants were less likely to endorse items 5 through 9 (items pertaining to having less or no food). Biserial correlations of the response categories revealed a consistent increasing order across response options for items 1 through 5, indicating an ordinal hierarchy among response options. For items 6 through 9, there was a consistent increasing order across response options, except for the last response option that indicates often experiencing the symptom of food insecurity. This is likely due to the low base rate of endorsement for these items (10·4 %, 2·5 %, 3·0 %, 3·4 %, respectively). However, an ordinal hierarchy was observed among the other response options for items 6 through 9.

Differential item functioning analyses

Differential item functioning analyses assessed the possibility of construct-irrelevant variance due to gender (i.e., gender-related bias) (Table 5). The average HFIAS total score was 12·81 (SD = 6·98) for men and 10·91 (SD = 7·14) for women. The mean total scores significantly differed by gender ($t(172·63) = 2·39$, $P = 0·018$), such that men had a significantly higher HFIAS total score than did women. Results of the differential item functioning ordinal regression models for each item are presented in Table 5. Item 9 had a significant main effect of gender suggesting that women were more likely than men to go without any food ($\beta = 0·585$, SE = 0·28, $P = 0.037$).

Discussion

The current study sought to examine psychometric properties of a measure of food insecurity among PWH receiving HIV care from primary care clinics in Khayelitsha. The vast majority of participants (81·14 %) were moderately or severely food insecure in the preceding 30 d. This finding

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Table 4 Item analysis

	Average item score	Median item score	Endorsement level	SD
Item 1	1·570	2	0·523	0·887
Item 2	1·550	2	0·517	0·941
Item 3	1·523	2	0·508	0·966
Item 4	1·602	2	0·534	0·990
Item 5	1·416	2	0·472	0·978
Item 6	1·393	2	0·464	0·986
Item 7	0·723	0	0·241	0·867
Item 8	0·764	0	0·255	0·849
Item 9	0·832	0	0·277	0·897

	Response category biserial correlation			
	Never (0)	Rarely (1)	Sometimes (2)	Often (3)
Item 1	−0·682	−0·144	0·315	0·501
Item 2	−0·701	−0·189	0·404	0·491
Item 3	−0·752	−0·134	0·406	0·507
Item 4	−0·721	−0·244	0·430	0·496
Item 5	−0·765	−0·112	0·481	0·489
Item 6	−0·779	−0·130	0·499	0·488
Item 7	−0·682	0·127	0·560	0·319
Item 8	−0·719	0·153	0·554	0·349
Item 9	−0·720	0·104	0·566	0·362

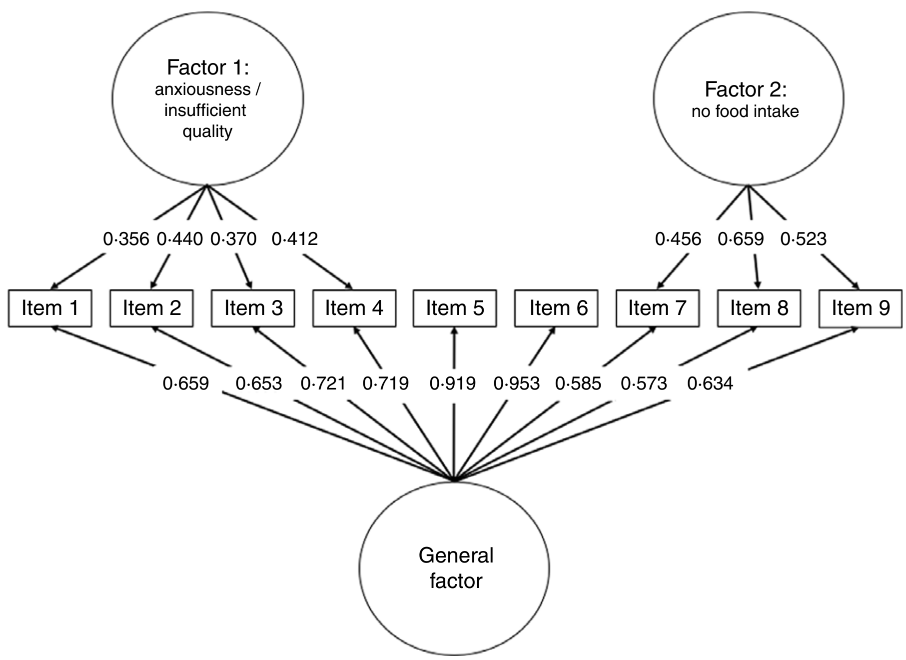

Fig. 2 Factor structure of the three-factor restrictive bifactor model. Factor loadings presented here correspond with those presented in Table 3

replicates and extends previous estimates of food insecurity in peri-urban settlements outside of Cape Town (80–89 %)[4,5]. Revised parallel analysis, using one half of the sample, initially suggested a three-factor solution; however, the three-factor solution was inadmissible. It is also possible that, due to the extreme closeness of the third observed eigenvalue to the 95th percentile of the generated eigenvalues, this was a statistical artifact due to rounding. Subsequently, a two-factor solution was examined. In a subsequent CFA that used the other half of the sample, the two-factor solution did not adequately fit the data. Finally, a restrictive bifactor model with one general factor and two specific factors was examined, and this model did adequately fit the data. In the initial two-factor restrictive bifactor model, although all items loaded onto the general factor and one of the two specific factors, two items (items 5 and 6) had irregular loading patterns[51] on the first specific factor. One remedy for irregular loading patterns on

Table 5 Differential item functioning analysis

	Intercept only model $Y = \alpha$		Total score main effect model $Y = \alpha + \beta_1 X_{totalscore}$		Gender main effect model $Y = \alpha + \beta_1 X_{totalscore} + \beta_2 X_{gender}$		Interaction effect between total score and gender model $Y = \alpha + \beta_1 X_{totalscore} + \beta_2 X_{gender} + \beta_3 X_{totalscore} \times X_{gender}$	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Item 1								
β_0 (rarely)	−1·257	0·12***	1·695	0·23***	1·712	0·32***	1·44	0·58**
β_0 (sometimes)	−0·622	0·10***	3·240	0·28***	3·257	0·35***	2·992	0·49***
β_0 (often)	1·821	0·14***	7·967	0·48***	7·984	0·52***	7·718	0·62***
β_1	–		−0·392	0·03***	−0·392	0·03***	−0·371	0·05***
β_2 (men)	–		–		−0·021	0·26	0·322	0·52
β_3 (men)	–		–		–		−0·028	0·04
Residual deviance	1063·75		633·31		633·30		632·75	
Item 2								
β_0 (rarely)	−1·325	0·12***	2·039	0·26***	2·360	0·37***	2·037	0·52***
β_0 (sometimes)	−0·663	0·10***	4·155	0·35***	4·494	0·44***	4·177	0·57***
β_0 (often)	2·167	0·16***	10·674	0·67***	11·018	0·74***	10·702	0·82***
β_1	–		−0·504	0·03***	−0·507	0·03***	−0·482	0·05***
β_2 (men)	–		–		−0·377	0·30	0·033	0·57
β_3 (men)	–		–		–		−0·034	0·04
Residual deviance	1009·89		489·23		487·65		486·96	
Item 3								
β_0 (rarely)	−1·154	0·11***	2·812	0·30***	3·144	0·41***	3·119	0·63***
β_0 (sometimes)	−0·612	0·10***	4·702	0·38***	5·048	0·48***	5·023	0·67***
β_0 (often)	2·049	0·15***	11·126	0·71***	11·479	0·78***	11·454	0·91***
β_1	–		−0·540	0·04***	−0·544	0·04***	−0·542	0·05***
β_2 (men)	–		–		−0·380	0·30	−0·348	0·67
β_3 (men)	–		–		–		−0·002	0·05
Residual deviance	1025·00		469·11		467·58		467·58	
Item 4								
β_0 (rarely)	−1·468	0·17***	2·072	0·27***	2·506	0·40***	2·498	0·58***
β_0 (sometimes)	−0·777	0·14***	5·104	0·44***	5·595	0·56***	5·587	0·69***
β_0 (often)	2·167	0·19***	13·447	0·92***	13·977	1·01***	13·969	1·09***
β_1	–		−0·649	0·05***	−0·657	0·05***	−0·656	0·06***
β_2 (men)	–		–		−0·519	0·34	−0·509	0·61
β_3 (men)	–		–		–		−0·001	0·05
Residual deviance	985·84		382·39		379·95		379·95	
Item 5								
β_0 (rarely)	−0·929	0·11***	3·879	0·38***	4·104	0·48***	4·193	0·74***
β_0 (sometimes)	−0·436	0·10***	5·678	0·46***	5·908	0·55***	5·997	0·78***
β_0 (often)	2·325	0·18***	12·567	0·84***	12·800	0·90***	12·889	1·07***
β_1	–		−0·587	0·04***	−0·590	0·04***	−0·596	0·06***
β_2 (men)	–		–		−0·259	0·32	−0·372	0·78
β_3 (men)	–		–		–		0·009	0·05
Residual deviance	1012·27		435·04		434·37		434·35	
Item 6								
β_0 (rarely)	−0·863	0·10***	4·275	0·41***	3·901	0·47***	3·365	0·66***
β_0 (sometimes)	−0·341	0·10***	6·230	0·49***	5·935	0·55***	5·413	0·70***
β_0 (often)	2·167	0·16***	12·750	0·85***	12·438	0·87***	11·927	0·97***
β_1	–		−0·612	0·04***	−0·613	0·04***	−0·573	0·05***
β_2 (men)	–		–		0·463	0·31	1·212	0·74
β_3 (men)	–		–				−0·058	0·05
Residual deviance	1050·45		440·35		438·15		436·92	
Item 7								
β_0 (rarely)	0·322	0·10***	6·489	0·56***	7·242	0·60***	6·335	1·01***
β_0 (sometimes)	0·975	0·11***	7·952	0·62***	7·713	0·65***	7·807	1·04***
β_0 (often)	3·659	0·31***	12·744	0·94***	12·506	0·96***	12·604	1·29***
β_1	–		−0·486	0·04***	−0·484	0·04***	−0·490	0·07***
β_2 (men)	–		–		0·302	0·27	0·182	1·08
β_3 (men)	–		–		–		0·008	0·07
Residual deviance	907·25		528·28		527·02		527·01	
Item 8								
β_0 (rarely)	0·211	0·10*	7·370	0·62***	7·483	0·67***	8·465	1·20***
β_0 (sometimes)	0·918	0·11***	9·181	0·70***	9·296	0·75***	10·283	1·25***
β_0 (often)	3·487	0·28***	14·397	1·07***	14·514	1·11***	15·570	1·54***
β_1	–		−0·567	0·04***	−0·568	0·04***	−0·639	0·08***

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Table 5 *Continued*

	Intercept only model $Y=\alpha$		Total score main effect model $Y=\alpha+\beta_1 X_{totalscore}$		Gender main effect model $Y=\alpha+\beta_1 X_{totalscore}+\beta_2 X_{gender}$		Interaction effect between total score and gender model $Y=\alpha+\beta_1 X_{totalscore}+\beta_2 X_{gender}+\beta_3 X_{totalscore}\times X_{gender}$	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
β_2 (men)	–		–		–0·126	0·28	–1·321	1·21
β_3 (men)	–		–		–		0·076	0·08
Residual deviance	942·44		498·23		498·03		496·95	
Item 9								
β_0 (rarely)	0·119	0·12	6·899	0·58***	6·433	0·62***	6·480	1·00***
β_0 (sometimes)	0·735	0·13***	8·466	0·65***	8·025	0·67***	8·072	1·03***
β_0 (often)	3·339	0·30***	13·773	1·01***	13·360	1·02***	13·410	1·32***
β_1	–		–0·552	0·04***	–0·551	0·04***	–0·554	0·07***
β_2 (men)	–		–		0·585	0·28*	0·524	1·05
β_3 (men)	–		–		–		0·004	0·07
Residual deviance	956·74		508·78		504·31		504·31	

SE are presented in the column to the right of the standardised parameter estimates.
*Indicates 0·01 < P < 0·05.
**Indicates 0·001.
***Indicates P < 0·001.

specific factors in a restrictive bifactor model is to remove irregular loadings from the specific factors as these may lead to theoretically inconsistent results[51]. As such, the subsequent two-factor restrictive bifactor model, for which results are reported, was examined. In this model, items 5 and 6 did not load onto any specific factor but loaded onto the general factor. All other items loaded onto the general factor and one of the specific factors.

The restrictive bifactor model of the HFIAS, with one general factor and two specific factors, differs from previous research conducted in the USA[1], but extends research conducted in Ethiopia[27]. The HFIAS indicator guide, which was created in the USA, identifies three factors: anxiety, insufficient quality and insufficient food intake[1]. In contrast, results of the factor analyses in the present study revealed the following two factors: anxiety/insufficient quality (items 1–4) and no food intake (items 7–9). Our results combine the anxiety and insufficient quality domains into a single factor. The other factor is comprised of items reflecting no food intake. Previous research on the psychometric properties of the HFIAS among rural and urban populations in Ethiopia also found a similar factor structure, such that only two specific factors were present[27]. However, the results of the present study also differ from extant literature in that items 5 and 6, which pertain to limited food intake, did not load on a specific factor.

These findings appear to suggest the importance of having any food to eat at all, rather than the quality or quantity, in this peri-urban sample of PWH. One possible explanation for the relative importance of having any food at all to eat in Ethiopia and SA, which are both sub-Saharan African countries and resource limited settings, is that income and access to food may be more limited. As such, the importance of quality and limited quantity is decreased and the relative importance of having any food at all to eat is increased. In the present study, among PWH, 72 % (*n* 317) of the sample reported being unemployed and the average income before tax was 2422·67 ZAR (SD = R2692·03), or $130·09 USD (SD = $144·55), per month. Indeed, high unemployment rates and low income decrease one's ability to access food altogether, making having any food at all to eat an important consideration when examining food insecurity in sub-Saharan contexts.

With respect to the psychometric properties of the HFIAS, the present study provides strong support for the use of a total score, despite the indication of a multidimensional solution within the scale. The reliability of the HFIAS was high ($\omega = 0{\cdot}82$ (95 % CI 0·766, 0·876)), as was the ECV in this bifactor structure (ECV = 0·754). The factor score of the general factor was strongly and statistically significantly associated with the total score (r 0·949, P < 0·001), indicating that the general factor score and total score provide overlapping information. Taken together, the restrictive bifactor model, reliability, ECV and the correlation between the general factor score and the total score suggest an underlying unidimensionality and support the use of a total score. In addition to use of a total score, future research among PWH in SA using the HFIAS should further examine specific domains of food insecurity identified by the two specific factors in the present study, anxiety/insufficient quality and no food intake, in larger samples to better understand how these factors might contribute to poorer HIV outcomes. For example, in a qualitative study, participants reported a reluctance to take ART on an empty stomach due to potential side effects such as nausea, emesis and dizziness[52]. ART

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users in Uganda, Tanzania and Botswana indicated being unable to afford food to satisfy their increased appetites after starting treatment, especially in the early stages when their bodies required extra nutrition to regain lost body mass. The regularity of ART doses may also be affected by lack of food as some patients report only taking their medication on occasions when food was available[53].

Additionally, given that prior research has found gender differences among PWH in rates of food insecurity[8], it was important to examine the HFIAS for potential gender-related biases. Differential item functioning allows for examination of potential sources of construct-irrelevant variance, such as gender. Results of the differential item functioning analyses revealed significant differences between men and women in responding to HFIAS item 9. Specifically, women were more likely than men to endorse going a whole day and night without eating anything because there was not enough food. However, the average HFIAS total scores for men and women significantly differed, such that men had a higher HFIAS total score than did women. These findings suggest that, although women were more likely than men to endorse having gone a whole day and night without eating, men were more likely than women to experience significantly higher levels of food insecurity more broadly. One explanation for this is that women may disproportionately experience the most severe forms of food insecurity (i.e., going a whole day and night without eating because there was not enough food) when these forms of food insecurity are present, whereas men may experience less severe forms of food insecurity more frequently.

Although the restrictive bifactor model with one general factor and two specific factors adequately fit the data, caution should be used when interpreting the factor structure. All items had significant factor loadings on the general factor. However, items 5 and 6 did not demonstrate a loading on either specific factor. Additionally, though an ordinal relationship of the response options was confirmed for five items, four of the items (items 6 through 9) did not display an ordinal relationship at the last response option (indicating often experiencing that problem). This may have been due to low base rates of endorsement, and future research should purposively sample individuals who experience more extreme levels of food insecurity to further investigate the psychometric properties of the HFIAS among those with severe food insecurity.

The present study was not without limitations. All data were self-reported, and objective measures of food insecurity were not available. Future research on food insecurity should strive to collect both objective (e.g., dietary intake) and self-reported measures to further validate the use of the HFIAS in populations with HIV. Additionally, the restrictive bifactor solution adequately fit the data among a sample with a high prevalence of moderate and severe food insecurity. Samples with more diverse distributions of food insecurity and security may exhibit differences in the factor structure of the HFIAS. Future research should validate the HFIAS among a sample of PWH with various level of food insecurity.

Taken together, findings of the present study suggest a restrictive bifactor model with one general factor and two specific factors for the HFIAS among a sample of PWH in Khayelitsha. The two specific factors were anxiety/insufficient quality (items 1–4) and no food intake (items 7–9). The HFIAS demonstrated high reliability in this sample. The presence of the general factor, in combination with the high reliability and high ECV, also suggests that use of the HFIAS total score is appropriate. Future studies may, in addition to utilizing the total score, also specifically examine the relationships of each of the two specific factors with HIV outcomes. Overall, the HFIAS appears to function similarly for both men and women with HIV in SA, though differences were observed between men and women on one of the nine items, and men had significantly higher levels of food insecurity than did women. Understanding the psychometric properties of a common measure of food insecurity, the HFIAS is an important step in improving research on the relationship between HIV outcomes and food insecurity, a major structural barrier to care in resource-limited settings such as SA.

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Research Ethics Committee. Written informed consent was obtained from all participants.

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