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Assessment of the psychometric properties of HIV knowledge items across five countries

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Abstract

HIV knowledge is commonly measured in HIV prevention research and program evaluations, but rigorous measurement standards are not always applied. Using item response theory methods, we examined the psychometric functioning of five commonly-used HIV knowledge questions in five countries with varying HIV prevalence. We evaluated the internal consistency and measurement invariance of the items. The items performed poorly in all samples and the scale as a whole did not perform equally across samples. We conclude that current ways of measuring HIV knowledge are not adequate and recommend new items be developed, tested, and validated using psychometric methods.

Keywords

HIV knowledge; scales; item response theory; internal consistency; measurement invariance

Introduction

Knowledge about HIV transmission is commonly measured in HIV prevention research and program evaluations. Behavioral theories postulate, and empirical evidence supports, that knowledge is at least a pre-requisite, and sometimes a determinant, of health-promoting behaviors (1). One of the earliest behavioral models for HIV risk reduction included ‘HIV Transmission Knowledge’ as a primary construct (2). Since then measurement of HIV knowledge has been pervasive in HIV prevention research and is often a major component of behavioral interventions and surveillance efforts (3–10).

Over the years, there have been numerous studies that use HIV knowledge to evaluate the success of an intervention (11–17). Other studies have looked at HIV knowledge among specific risk groups (18–21), over time in countries such as India, Zambia, and France (22–

24), or comparing between males and females (25–27). For example, one study in Nigeria compared HIV knowledge for males and females and concluded that there was a ‘large HIV knowledge gap between males and females’ (p. 283) (28). Comparisons have also been made across settings (29,30), including a USAID report using Demographic and Health Survey data that compared HIV knowledge across 10 sub-Saharan African countries (31). The report concluded that HIV knowledge has increased over time and that West African countries lag behind other African countries in their HIV knowledge. A similar study with nine African countries conducted by Glick and Sahn found that HIV knowledge was lower among rural populations and women, as well as noting differences between countries (32). Despite the HIV prevention field’s prevalent use of the HIV knowledge construct in research, programs and service delivery, the utility of our research findings depend on our ability to accurately measure it.

While HIV knowledge is considered an important construct to assess, predict, and improve HIV prevention behavior, there have been few efforts to assess the psychometric properties of the HIV knowledge measures being used. For example, when measurement quality is addressed, most public health articles, including articles about HIV knowledge, only evaluate reliability by reporting a Cronbach’s coefficient alpha (33–36). While coefficient alpha is the most widely used reliability coefficient, its limitations are well documented (36–39). Authors rarely report on other important indicators of internal consistency such as examining the average item correlations, item discrimination, or confirming the unidimensionality of the scale (38,39). Consequences of using scales that are measured with error—those with low consistency among the items or low discrimination—can lead to biased estimates (attenuated towards the null) in regression analyses and therefore incorrect results. Moreover, comparisons of the means from scales measured in two or more populations or over time in the same population—as commonly done in public health research—are only valid if one can assume measurement invariance. A test of measurement invariance tells us whether the same construct is being measured across different groups (or over time) (40). Item Response Theory (IRT) methods can be used to rigorously assess the psychometric properties of scales, such as those measuring HIV knowledge (38,41).

The aim of this paper is to assess how commonly used HIV-knowledge survey items perform in five different populations across the globe. We used IRT to examine the internal consistency and measurement invariance of the items in five countries with varying HIV prevalence: 0.30% to 5.80% (42). The sampled populations in these countries are often the targets of broad-based HIV prevention education efforts: high risk men and youth. By rigorously evaluating HIV knowledge items, the analysis presented in this paper will help to improve measurement of HIV knowledge in future research, a critical element for evaluating prevention strategies and implementing programs and policies to reduce HIV incidence.

Methods

For this analysis, five items commonly used to measure HIV knowledge were subjected to an item IRT analysis to learn if and how these items provide information about HIV knowledge. The same five items were measured in five separate cross-sectional samples in five different cities: 1. São Paulo, Brazil, 2. Kathmandu, Nepal, 3. Dakar, Senegal, 4. Mbeya,

Tanzania, and 5. Tema, Ghana. In each of the first three sites, 1,000 youth aged 16–25 years were as part of population-based households surveys conducted in each city to evaluate the impact of MTV's 2002 Staying Alive campaign (43). In the Tanzanian and Ghanaian sites, men aged 18–49 with at least three sexual partners in the last three months were selected using venue-based sampling as part of a cross-sectional research study on heterosexual men who are at high-risk for HIV (44,45).

For this analysis, we conduct an IRT analysis to examine each of the five item's discrimination and difficulty. The five HIV knowledge items were:

1. Can a person have HIV, even if they look healthy? (Healthy)
2. Can using a condom protect against HIV? (Condom)
3. Will abstaining from sexual intercourse protect against HIV? (Abstain)
4. Does having one uninfected, faithful sex partner protect against HIV? (Faithful)
5. Can a person get HIV by using drugs with a needle that was already used by someone else? (Inject)

Respondents were allowed to refuse to answer any question they did not want to answer and were permitted to give “don't know” responses. Refusals were treated as missing data, and “don't know” responses were treated as an incorrect answer.

We used Mplus (46) to fit a two-parameter logistic (2PL) item response model to the unweighted data from each site using weighted least squares estimation with means and variance adjustments (WLSMV). We first ran a model with all samples allowing all the parameters to be freely estimated to see how items performed in each site. Specifically, the item characteristic curves (graphical representations of item discrimination and difficulty) and item information curves (indicating level of information provided for each latent construct value) for each of the five items was examined and compared across sites. Given the exploratory nature of this analysis, a 2PL model was selected over a one-parameter logistic (1PL) model to allow the slopes to vary. A 2PL model was selected over a three-parameter logistic (3PL) model (which would accommodate guessing) because the nature of the questionnaire and the testing environments were not expected to promote guessing.

Finally, capitalizing on a situation where the same five questions were asked in the five different samples, we aimed to conduct a statistical test to determine if these items perform similarly across the five study populations. We constrained parameter estimates to be equal across sites in order to test measurement invariance. The constrained model with all five sites was unable to converge. Subsequent exploration identified one parameter in São Paulo as problematic. As a result, we subsequently tested measurement invariance between the remaining four samples, and between youth samples from Kathmandu and Dakar and high-risk men samples from Tema and Mbeya, using a chi-squared difference test.

Results

The items and proportion of correct responses for each item by country are displayed in Table I. In Kathmandu, Dakar, and Tema, participants answered about 4 questions correctly

on average, with the São Paulo sample having a slightly lower average (3.7) and the Mbeya sample being higher (4.7). Item 5, which asks about needle sharing, and item 1, which asks if a healthy-looking person can have HIV, are answered correctly by the highest proportion of respondents in all the samples.

The estimated IRT item parameters are displayed in Tables II for each sample. The a parameter is the item's discrimination. It refers to the slope and tells us how discriminating the item is—the larger the a parameter, the steeper the slope and the more discriminating that item is. The b parameter is the difficulty, or threshold, and indicates at what value of the latent variable (HIV knowledge) the item is answered correctly by half of the population.

The first column of Figure 1 shows the item characteristic curves for each item by sample. These curves are graphical representations of the a and b parameters. The x-axis, referred to as θ in IRT, represents the latent construct that the five items have in common. The hypothesis is that θ is measuring knowledge of HIV and should stem from the commonalities in those five items. We interpret the results to see if θ is measuring what we hope it is measuring. The y-axis is the probability of answering the item correctly. We expect an individual with low latent HIV knowledge (θ) to answer an item incorrectly, therefore we would expect the curve line to be flat and low on the left side of the graph indicating that the y-axis value (probability of a correct answer) is close to zero. The middle of the graph represents x-axis θ values indicating an average level of latent HIV knowledge. We expect a high-functioning item to do an effective job at separating those with low latent HIV knowledge from those with higher latent HIV knowledge. Therefore, as the curve moves to the right, we should see a sharp increase with a high slope value since a steep slope indicates that the item is effectively separating individuals into high (correct answer) and low (incorrect answer). Further to the right we should see the slope flattening out where the y-axis value is close to one, indicating that the probability of a correct answer for individuals with a high latent HIV knowledge score will be close to 1.

Item 4 (Faithful) in Dakar is an example of an item characteristic curve that suggests that the item is high functioning. Item 4 in Dakar has a reasonably steep slope at its steepest point. This slope is the a value in Table II and suggests that the item is effectively discriminating, or separating, those with a high latent HIV knowledge score and those with a low latent HIV knowledge score. Examining the b parameter, or item difficulty, is the threshold at which the item separates high and low individuals. The b parameter for that item is -0.56 , or the value of θ (latent HIV knowledge) at which the probability of a correct answer is .50 (this is also the value of θ when the slope is its steepest). So, for those with a latent HIV knowledge score greater than -0.56 (or 0.56 SD below the mean) will have a 50% chance or greater of answering the item correctly. Since we expect the latent HIV knowledge to be approximately normal and bell-shaped with a standard deviation of one and mean of zero, item difficulties (b) for a high functioning item would fall between -1 and 1 . Item 4, and to a lesser extent, item 2 from Dakar meet that criteria and suggest that these items are performing fairly well in that setting.

Upon examining all the item characteristic curves in Figure 1, the other items in Dakar and all items in the other samples are not performing to these same standards. Items 1 and 5 both

have nearly flat slopes (i.e. equal to zero) in all samples except for Dakar, suggesting that the item does a poor job of distinguishing between individuals with high and low latent HIV knowledge. This is due to the high numbers of individuals who answered these items correctly. Those items are therefore not discriminating between respondents of varying levels of HIV knowledge (flat slopes) and these items can be considered ineffective at measuring HIV knowledge.

Items 2, 3, and 4 in the other samples generally demonstrate a slope close to one (not ideal, but indicates some level of discrimination) and a difficulty falling somewhere within 1 or 2 standard deviations from the mean. These parameters indicate that these items are functioning, but functioning poorly.

The item information curves (IIC) for each country are displayed in the right column of Figure 1. The IICs indicate the amount of information that each item contributes to our understanding of an individual's latent HIV knowledge score. The y-axis indicates the amount of information, and the x-axis again indicates the value for theta (latent HIV knowledge). Again using item 4 (and to a lesser degree item 2) from Dakar as an example, we see a fairly tall bell-shaped curve which suggests that we get a lot of information for the individuals at the peak which is just to the left of the mean for theta, and decreasing amounts of information about individuals at the tails. Looking at other items and other samples, we see that items 1 and 5 largely provide us with no information about an individual's HIV knowledge. Items 2, 3, and 4 provide some information, but since they are mostly shallow curves, it suggests that they are not providing much information about HIV knowledge and therefore can be considered to be performing poorly.

After examining the individual items, we wanted to test if this scale performs the same way in different countries and different populations. This is an important question to ask about this scale considering its widespread use and the routine comparison of HIV knowledge scores across countries (31,47). We conducted a test of measurement invariance to examine if the model fit when constraining all the parameters to be equal was the same as model fit when allowing the parameters to be free.

When attempting to test for measurement invariance with all five samples, our constrained model failed to converge (Table III). Using further testing, we identified that the scale in São Paulo prevented the model from converging. We tested measurement invariance for the remaining four samples and found that the unconstrained model fit better than the constrained model (χ^2 Difference test = 202.13 df=12, $p<.001$). This finding suggests that the scale performs differently in these samples. We conducted two more tests to see if the scale performs differently between the youth samples and the high-risk men samples, separately. Again, São Paulo prevented the three country youth comparison (São Paulo, Kathmandu, and Dakar), so we only tested Kathmandu and Dakar. We found the scale performs differently among youth in Kathmandu and Dakar (χ^2 Difference test = 148.57 df=4, $p<.001$). When testing measurement invariance between high-risk men from Tema and Mbeya, however, we found model fit was not significantly different between the constrained and unconstrained models—an indication that we cannot reject the hypothesis that the scale performs similarly in these samples (χ^2 Difference test = 6.22, df=4, $p=0.1833$). Given this

scale's poor performance, no further analyses were conducted to evaluate this scale's internal consistency or external validity.

Discussion

In summary, five items commonly used to measure HIV knowledge performed poorly when used to measure HIV knowledge in samples of high-risk men and youth from five countries. While two items (Faithful and Condom) performed well for youth with low HIV knowledge in Dakar they did not provide much information in the other samples examined. Items 1 and 5 (Healthy and Inject) did not discriminate between respondents of varying levels of HIV knowledge in any sample and should not be used to measure HIV knowledge.

The scale as a whole did not perform well for any of the samples studied and the scale performed differently across the samples. We saw no clear patterns of scale performance based on HIV prevalence. The São Paulo sample was dissimilar enough from other samples that comparison was statistically impossible; we hypothesize that there may be a unique sexual culture in urban Brazil that differs from the other cities studied. Even though the scale appears to perform the same among high-risk men in Mbeya and Tema, the information about HIV knowledge provided by the scale is low in these samples.

To our knowledge there has been one previous attempt to assess the psychometric properties of HIV knowledge items using item response theory. Aarø and colleagues assessed 14 HIV knowledge questions for school students in Tanzania and South Africa (48). They concluded that most items were only able to discriminate at low levels of latent HIV knowledge. However, the items in the Aarø study performed better than the items in our study most likely because they pre-tested and modified the items to fit their study population. In contrast, our items come from a standard set of questions that are commonly used to compare HIV knowledge across populations and over time. Additionally, we provide evidence that these items are ineffective not just in sub-Saharan Africa, but in other regions as well. We conclude that current items used across settings are inadequate to measure current variability in HIV knowledge.

Measures of HIV knowledge focused on modes of transmission may have been more appropriate in the early stages of the HIV epidemic but over the long trajectory of the epidemic they have become less useful. We need to develop new and more difficult HIV knowledge items and evaluate them using psychometric methods. For example, new questions could be based on more recent findings about how HIV is transmitted and prevented. Questions in this regard could cover topics such as the acute infection stage, anal sex, male circumcision, multiple partners, and concurrent sexual partnerships. Questions could also be developed that map directly to current HIV prevention messaging.

Although a broadly applicable HIV knowledge measurement tool would be an optimal outcome, we also need to balance this goal with the reality that HIV risk contexts vary. HIV risk and prevention behaviors differ among geographic regions and populations. Questions about sharing needles and heroin cooking equipment ("indirect sharing"), for example, are not relevant to most African contexts, in which heterosexual sex is the primary mode of HIV

transmission. Such questions are, however, extremely important when dealing with injection drug users in the U.S., Europe or Asia.

Using both qualitative and quantitative methods will be crucial for developing new question items. In-depth interviews, focus groups, and cognitive interviewing can help identify question topics, wording, and meanings that are relevant to populations. Conducting statistical analyses such as item response theory on new survey items can provide information for how these items are functioning.

The evidence from the Aarø paper, together with our broader findings of inadequacy, suggests a real deficit in our ability to accurately measure HIV knowledge across global contexts and populations. Without the ability to accurately measure this construct, our HIV-related evaluations, programs and policies that use this construct will be biased. We need to develop and validate new, and more contextually relevant, measurement tools that reflect the contemporary HIV/AIDS context.

Conclusions

This analysis demonstrates that new HIV knowledge items need to be developed, tested using psychometric techniques such as item response theory, and then validated in populations targeted for HIV prevention efforts so that decisions made by HIV prevention researchers, practitioners, and policy makers are based on accurately measured constructs.

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Figure 1.
Item characteristic and item information curves by country

Table I.

HIV knowledge scale items and percentage correct by country.

Question	Percentage Correct				
	São Paulo	Kath-mandu	Dakar	Mbeya	Tema
<i>Can a person have HIV, even if they look healthy? (Healthy – 11)</i>	96.6	98.0	87.0	95.2	90.2
<i>Can using a condom protect against HIV? (Condom – 2)</i>	92.6	84.0	79.7	93.5	75.2
<i>Will abstaining from sexual intercourse protect against HIV? (Abstain – 3)</i>	37.8	52.7	71.9	85.5	60.7
<i>Does having one uninfected, faithful sex partner protect against HIV? (Faithful – 4)</i>	41.8	73.3	69.4	95.0	77.6
<i>Can a person get HIV by using drugs with a needle that was already used by someone else? (Inject – 5)</i>	98.9	97.5	87.2	96.9	95.3
<i>Mean scale score (standard deviation)</i>	3.7 (0.8)	4.1 (1.0)	4.0 (1.3)	4.7 (0.7)	4.0 (1.0)

* 112 individuals missing complete data (not all 5 items)

Table II.Item discriminations (*a*) and difficulty (*b*) estimate by country

Item	<i>São Paulo</i>		<i>Kathmandu</i>		<i>Dakar</i>		<i>Tema</i>		<i>Mbeya</i>	
	<i>a</i> (SE)	<i>b</i> (SE)	<i>a</i> (SE)	<i>b</i> (SE)	<i>a</i> (SE)	<i>b</i> (SE)	<i>a</i> (SE)	<i>b</i> (SE)	<i>a</i> (SE)	<i>b</i> (SE)
<i>Healthy</i>	−0.10 (0.14)	19.15 (26.90)	−0.18 (0.15)	11.90 (10.10)	0.69 (0.09)	−1.99 (0.20)	0.12 (0.09)	−10.62 (7.43)	0.35 (0.13)	−5.10 (1.73)
<i>Condom</i>	0.34 (0.11)	−4.52 (1.39)	1.22 (0.26)	−1.28 (0.13)	1.79 (0.22)	−0.95 (0.06)	0.84 (0.14)	−1.06 (0.13)	0.88 (0.22)	−2.29 (0.36)
<i>Abstain</i>	0.78 (0.38)	0.50 (0.16)	1.02 (0.17)	−0.09 (0.06)	1.13 (0.11)	−0.78 (0.07)	0.91 (0.16)	−0.40 (0.08)	0.96 (0.24)	−1.53 (0.23)
<i>Faithful</i>	0.56 (0.22)	0.42 (0.15)	0.67 (0.10)	−1.11 (0.14)	2.18 (0.34)	−0.56 (0.05)	0.94 (0.17)	−1.11 (0.13)	1.20 (0.38)	−2.14 (0.31)
<i>Inject</i>	−0.12 (0.23)	19.64 (38.08)	0.08 (0.11)	−23.88 (31.52)	0.66 (0.08)	−2.07 (0.21)	−0.03 (0.11)	58.66 (233.81)	0.32 (0.16)	−6.12 (2.79)

Table III.

Model results from measurement invariance tests

	Unconstrained χ^2	Constrained χ^2	χ^2 Difference test
<i>5 country</i>	158.86 df=25, p<.001	Did Not Converge	N/A
<i>4 country All but São Paulo</i>	149.27 df=20, p<.001	367.59 df=32, p<.001	202.13 df=12, p<.001
<i>2 country Tema and Mbeya</i>	13.93 df=10, p=0.176	19.64 df=14, p=0.1418	6.22 df=4, p=0.1833
<i>2 country Kathmandu and Dakar</i>	148.37 df=10, p<.001	318.06 df=14, p<.001	148.57 df=4, p<.001